# Indian Institute of Technology Indore

# Rules, Policies, Curriculum and Courses of Study for Post-Graduate and Ph.D. Programs

**November 2020**

[After incorporating decisions of 25th meeting of the Senate held on 17 October 2020]

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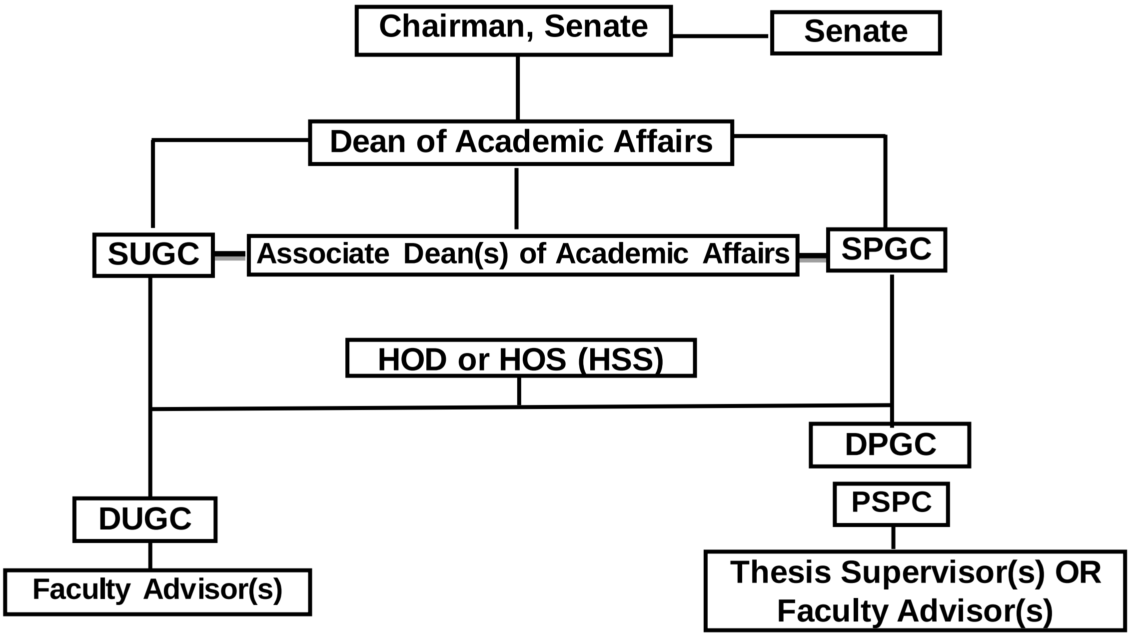
## Organization Structure for Academic Matters




## Committees for Academic Matters of the PG Students

**Department/Discipline Post-Graduate Committee (DPGC):** Each department/ discipline/inter-disciplinary research program has a DPGC to deal with all the academic matters of its PG and Ph.D. students. The committee members and its convener are appointed by the concerned Head. The Thesis supervisor(s) or Faculty advisor(s) of a PG/Ph.D. student report the academic matters related to that PG/Ph.D. student to the concerned DPGC. Its composition and scope of work are described below:

| Composition of DPGC | Scope of Work |
|---|---|
| **1. Members:** 3-4 faculty members representing all the major specializations of that discipline and PG/Ph.D. Student Representative nominated by the Students Gymkhana (for non-evaluation item only).<br>**2. Convener:** One of the members of DPGC appointed by the concerned Head.<br>3. **Appointing authority:** The concerned Head. | 1. To deal with issues related to **academic Programs, PG and Ph.D. curriculum and courses, academic performance, academic indiscipline, academic malpractices** of individual PG student and send its recommendations to the SPGC.<br>2. Assessment of the **academic Programs** and suggests appropriate **revisions or modifications or improvements** to Academic Senate through SPGC.<br>3. Revising the PG and Ph.D. curriculum.<br>4. Starting of new PG Programs and courses and recommending same to the SPGC.<br>5. Cases of **Early-termination** of the PG and Ph.D. students of the concerned Departments/Disciplines.<br>6. Any other issue related to PG and Ph.D. students. |

**Senate Post-Graduate Committee (SPGC):** This is an Institute level committee for dealing with the academic matters of the PG and Ph.D. students based on the recommendations of the concerned DPGC and submit its recommendations to the Senate. Its composition and scope of work are described below:

| Composition of SPGC | Scope of Work |
|---|---|
| **1. Members:**<br>(A) Conveners DPGC of all the disciplines, HSS and all the centers<br>(B) One PG and one Ph.D. student representative nominated by the Students Gymkhana(for non-evaluation item only).*<br>2. **Convener:** Nominated by the Senate<br>3. **Member Secretary:** DR/AR (Academics) *ex-officio* | 1. To discuss the issues recommended by the DPGCs covering the **academic programs, PG and Ph.D. curriculum and courses, academic indiscipline, academic malpractices** and send its recommendations to the Senate.<br>2. Based on the recommendations of the DPGC, and assessment of the **academic programs,** suggest appropriate **revisions or modifications or improvements** to Senate.<br>3. Discussing the revision of the PG and Ph.D. curriculum based upon the recommendations of the DPGC and recommending same to the Senate.<br>4. Discussion on the starting of new PG programs.<br>5. Discussion on starting of new PG and Ph.D. courses and recommending same to the Senate.<br>6. Cases of **Early-termination** of the PG and Ph.D. students keeping in view the recommendations of the concerned DPGC.<br>7. Any other academic issue related to the PG and Ph.D. students. |

**to be excused from those meetings or part of meeting in which certain academic performance issues of the students are to be discussed*

# Rules and Policies for PG and Ph.D. program

1. **Teaching Assistantship (TA) Work:** ALL the Full-time M.Tech. and Ph.D. students irrespective of their category of admission (i.e. **MHRD/ Institute TA, external agency Fellowship Awardees (FA) / Sponsored (SW)** have to do Teaching Assistantship (TA) duties assigned by the Institute or Competent Authority **to the extent of 8-12 hours of work per week**.

   Under the TA duties, a M.Tech./ Ph.D. student is supposed to assist the concerned faculty member (to be known as TA Supervisor) in the academic work related to conducting of practical classes, tutorial classes, preparing assignments/tutorials and their solutions, invigilation duties, etc. and the other academic work assigned by the concern TA Supervisor or the Competent authority.

   TA **must NOT** be assigned **confidential work** such as setting up question papers of different examinations and quizzes, final evaluation of answer sheets of different exams, and finalizing the grades, etc. Under no circumstances,

   TAs **cannot** be assigned the duties of taking lecture classes of any course.

   Monthly release of M.Tech./ Ph.D. scholarship/Fellowship requires submission of TA work report in the specified format duly signed by the TA Supervisor and Thesis supervisor or Faculty Advisor.

2. **Release of M.Tech., M.S. (Research) and Ph.D. Scholarship/ Fellowship:** Each M.Tech./ M.S. (Research)/ Ph.D. student must be present in the Institute at least during the working hours on all working days unless he/ she has been sanctioned for entitled leave. Each M.Tech./ M.S. (Research)/ Ph.D. student has to sign an attendance register daily during the specified time kept in the office of the concerned Discipline/ School/ institute.

3. The scholarship/ fellowship of the M.Tech./ M.S. (Research)/ Ph.D. students admitted under different category shall be processed for payment on the monthly basis by the respective Head, only after receiving a report from the concern TA supervisor and/ or thesis supervisor/ advisor duly signed by him/ her (as the case may be).

4. **Maximum Duration of Ph.D./ M.Tech./ M.S. (Research) Scholarship for TA category students:**
   a. **Maximum duration of Ph.D. scholarship will be FIVE years from date of joining the Ph.D. program or date of Ph.D. thesis submission, whichever is earlier.** Ph.D. student under Institute Teaching Assistantship category, on satisfactory annual progress for four years of his/ her Ph.D. program be eligible for the Ph.D. scholarship during the fifth year of Ph.D. program, based on his/ her request for extension of scholarship on a half-yearly basis, subject to rigorous evaluation at the end of four years and no case of violating any rules, regulations, academic ethics, and discipline policy of the Institute should be pending against a Ph.D. student. In all other cases, continuation of scholarship during the fifth year of Ph.D. program may be considered from the Research Project Fund/ RDF/ CPDA of concerned Thesis Supervisor.

In no circumstance will the Institute Teaching Assistantship be extended beyond five years.

In case of unsatisfactory performance, where a fellowship needs to be stopped temporarily or permanantly for any student, the Thesis Supervisor(s), PSPC members and DPGC-Convener have to recommend it to Head of department. Head should communicate the decision to Finance and Accounts Section with a copy to the Academic Office.

b. **Maximum duration of Scholarship for M.Tech.** student is **two years** or **date of viva whichever is earlier.**

c. The maximum duration excludes the time period for which a student does not get the scholarship from the Institute due to receipt of internship/ fellowship/ scholarship/ honorarium paid by external agency.

d. A Ph.D. student can leave the institute to take up an employment or Post-doc fellowship after submitting his/her Ph.D. thesis and the No Dues certificate. In such cases, the Ph.D. scholarship of the student, if he/she is getting it, will be stopped w.e.f. from the date of Ph.D. thesis submission or joining for employment of Post-doc, whichever is earlier.

e. The Ph.D. scholarship of last month will be released after Ph.D. viva and submission of No Dues Certificate by the Student.

f. For any such issues related to Ph.D./ M.Tech./ M.S., the student should move his/ her application through his/ her Thesis Supervisor(s), Convener of DPGC and the Head of his/ her discipline/ school.

g. Scholarship options for Female students during Maternity Leave (ML):

**Option 1:** No scholarship during ML and full scholarship beyond the maximum scholarship time period* for the duration of ML @ scholarship applicable during ML.
**Option 2:** 25% of the applicable scholarship rate during ML and 75% of the scholarship for the duration beyond the maximum scholarship time period* for the duration of ML @ scholarship applicable during ML.
**Option 3:** Full scholarship during ML and no scholarship beyond the maximum scholarship time period* (only for those female students who are only earning member for their dependents. Income proof of husband/ dependents must be enclosed with the application form).

In case a female student completes her Ph.D./ M.Tech./ M.S.(Research) program within the applicable maximum scholarship duration* even after availing ML then the scholarship not paid because of choosing option 1 and option 2 can be released after submission of her Ph.D./ M.Tech./ M.S.(Research) thesis.

* 5 years for Ph.D. and 2 years for M.Tech./ M.S.(Research) program from the date of joining the respective program or date of thesis submission whichever earlier.

5. **Ph.D. Course Credit Requirements:** The minimum and maximum number of courses and credits for the different categories will be as follows.

   In addition to the course requirements mentioned below, each Ph.D. student has to do a **compulsory** course **HS 641: English Communication Skills** having contact hours (L-T-P) of 2-0-2 to improve his/her English language communication skill **within its FIRST YEAR of joining the Ph.D. program**. This course will have grades as **Pass (PP) or No Pass (NP)** i.e. it will not affect the CPI of the student.

   **Category I:** Ph.D. students with **M.Tech./ M.E./ M.Phil. Or equivalent qualification** shall do 2-3 Ph.D. level courses of at least 3 credits each and 1 Ph.D. seminar course of at least 2 credits.

   Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

   **Category II:** Ph.D. students having **M.Sc./ M.A./ M.Com./ M.B.A./ B.Tech./ B.E. or equivalent qualification** admitted to a **Science or HSS discipline** shall do 5-7 courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each.

   Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*

   **Category III:** Ph.D. students having **B.Tech./ B.E./ M.Sc. or equivalent qualification** admitted to Ph.D. Program in an **Engineering discipline** shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each.

   Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 20 credits).*

6. **Duration of Ph.D. Coursework:** All the Ph.D. students are required to do course work, which shall normally be completed:
   a. Within **one semester** from the date of joining by the students having **M.Tech./ M.E./ M.Phil. or equivalent qualification**.
   b. Within the **first two semesters** from the date of joining by the students having **B.Tech./ B.E./ M.Sc./ M.A./ M.Com./ M.B.A. or equivalent qualification.**
   c. All the Ph.D. students MUST complete their course under normal circumstances **within ONE year** of joining the Ph.D. program.
   d. For any variation other than the requirements mentioned in (a)-(c), **permission from the Senate Post Graduate Committee (SPGC)** will be required which will consider the recommendations of the Discipline Post Graduate Committee (DPGC) while deciding on the matter.

7. **Minimum CPI requirement:** Each Ph.D. student must maintain a **minimum CPI of 6.0 at the end of each semester** for continuation in the program. Below this CPI, the Ph.D. student will be placed on **Academic Probation** (AP) which is **one time exercise** during the entire duration of the Program with maximum deduction of Scholarship up to 50%. **During Academic Probation**, the Ph.D. student must secure a CPI of 6.0 for continuation in the Ph.D. Program otherwise the student will be discontinued from the program.

An M.Sc./ M.Tech. student can graduate if he/she earns credits in all the prescribed courses of study (i.e. with CPI 4.0) but, an M.Tech. student should maintain a minimum CPI of 6.0 for continuation of Scholarship under TA category of admission. The faculty members of the concerned discipline/school should ensure that generally a PG student does not graduate with minimum CPI of 4.0.

Senate in its **14th meeting held on 20 February 2018** has decided that any **M.Sc. student** who secures CPI less than 3.0 at the end of any semester will be discontinued from his/ her M.Sc. program with an exception that Senate Chairman may consider the appeal of such student to continue in M.Sc. based upon genuineness of the appeal.

Senate in its **14th meeting held on 20 February 2018** has decided that any **M.Tech. and M.S. (Research)** student who fails to secure minimum CPI of 5.0 and 6.0 respectively at the end of any semester will be discontinued from M.Tech. and M.S. (Research) program with an exception that Senate Chairman may consider the appeal of such student under exceptional circumstances to continue in M.Tech. or M.S. (Research) program based upon genuineness of the appeal. ***Any M.Tech. student securing CPI in range of 5.0 to 6.0 to be placed on Academic Probation with 25% deduction in the M.Tech. scholarship. Full scholarship will be resumed once M.Tech. student secures CPI 6.0 or more.***

8. **Policy for Auditing a Course:**

a. If a student **formally registers** to audit a course through proper course registration and wants Audit grade (AU) to be printed on his/her gradesheets for that course, then the concerned student

(i) Must meet the class attendance criteria of that course as announced by the course coordinator **AND**

(ii) Must appear in all the components of the evaluation and secure a pass grade (i.e. non-FR) grade at the end of the semester. Otherwise audit of a course will be considered an **informal arrangement** between the concerned student and the concerned Course Coordinator for attending the course classes for the sake of enhancement of knowledge/information/skills and in such cases no grade will be shown in the grade sheet for such audited course. No re-exam will be conducted for audit courses.

b. The number of **formal or informal audit registered student** cannot be used to satisfy **the minimum student criteria to run a course**.

9. **Confirmation of Registration for Ph.D. Degree:** Ph.D. students shall be granted **Confirmation of Registration for the Ph.D. degree** from the first working day of the semester following the one in which they have successfully completed the required course work.

10. **Selection of Thesis Supervisor:** A M.Sc. and M.Tech. student has to formally select his/ her thesis supervisor(s) after completing the **required course-work**.

A Ph.D. student has to formally select his/her Thesis Supervisor(s) either within **ONE semester** of joining the Ph.D. Program or after completing the **required course-work.**

One thesis supervisor will be from the discipline and other supervisor(s) can be taken from within/outside the Discipline/Institute. **Maximum number of thesis supervisors** should NOT be more than **three** under normal circumstances.

Until a M.Sc., M.Tech. or Ph.D. student finally and formally selects his/ her thesis supervisor, the concerned ***Head*** will be the **Faculty Advisor** to the student. The faculty advisor will provide guidance and advice concerning academic, professional, and personal growth of the assigned students. The guidance to the students will enable them to complete their course of study in a smooth and satisfactory manner.

11. **Constitution of PG Student's Progress Committee (PSPC):** Progress of thesis work of each M.Sc., M.Tech. and Ph.D. student will be monitored through a committee called **PG Student's Progress Committee (PSPC)**.

    **Composition of PSPC:** The PSPC will consist of the thesis supervisor(s), one faculty within the discipline and other faculty/expert within/outside the discipline. One of the thesis supervisors will be the Convener of the PSPC. Visiting Faculty Members and Fellowship Holders can only be Co-Supervisor.

    The process of constituting the PSPC can be initiated by a PG/Ph.D. student once the Thesis Supervisor(s) is (are) finalized. The respective DPGC convener recommends the PSPC to HOD and subsequent recommendations are reviewed and approved by the SPGC convener and notified by the Academic Office.

    At a time, no Thesis Supervisor should guide more than 3 TA category Ph.D. students. The Thesis Supervisor of the Ph.D. student who has completed FIVE years and he/ she is yet to submit the Ph.D. Thesis, will not be allowed to take new Ph.D. students.

    **Procedure for Change of Thesis Supervisor(s):** For Change of thesis supervisor(s), the concerned student should write an application addressed to DOAA which should be routed through proper channel. The application should have written consent of the existing Thesis Supervisor(s) and new Thesis Supervisor(s) with the recommendation of DPGC Convener and Head of the concerned discipline/school/center, ADOAA(PG & PhD) for approval by DOAA.

    The form should be accompanied with PSPC constitution form and if required new PSPC members may also be suggested.

    In case, a new co-supervisor is not from IIT Indore then the duly filled “Form for selecting a co-supervisor from an external or sponsoring organization” on the letter head of his/her parent Organization/Institute/University must also be attached along with the application.

    Request for change of PSPC of any PhD student will not be considered once the student enters into the 4th year of his/her PhD program.

12. **Finalization of the PG/ Ph.D. thesis Topic:** Once the thesis topic of a M.Sc., M.Tech. and Ph.D. student is decided then it should be brought to DPGC for formal approval and institute-wide circulation to avoid the duplication of the thesis work.

13. **Monitoring the Progress of the PG/ Ph.D. Student:** The PSPC will monitor the progress of the thesis work of the M.Sc., M.Tech. and Ph.D. student through a **Comprehensive Evaluation of Research Progress (CERP).**

For the Ph.D. student, the **first CERP** is to be conducted within one year of joining the Ph.D. Program.

Based on the CERP, the PSPC will evaluate the progress of the work of the Ph.D. student in terms of satisfactory or unsatisfactory. The progress report duly recommended by the PSPC members must be submitted online to the Academic Office for further action latest by **30th April** for the Ph.D. students registered in the Ph.D. Program in the **Autumn Semester** and by **31st October for** the Ph.D. students registered in the Ph.D. Program in the **Spring Semester.**

In case the CERP report of a student is found **unsatisfactory** then he/ she will have to give another CERP before the PSPC within maximum THREE months from the corresponding CERP. If second time CERP is also unsatisfactory, then matter must be reported to the SPGC Convener for further action.

If required, the Thesis Supervisor(s) may arrange additional CERP between two **consecutives successful CERP**.

14. **Eligibility for Ph.D. Thesis Submission:** A Ph.D. student can submit his/ her Ph.D. thesis ONLY after minimum specified time for Ph.D. thesis submission AND meeting the minimum publication criteria.

**Minimum Publication Criteria:** He/she has **at least *three*** publications from his/ her Ph.D. thesis in the SCI or other equivalent indexed journals having good impact factor. The list of publications submitted along with report of Open Seminar and Ph.D. Synopsis should **clearly mention the publications from the Ph.D. thesis work** and other publications during Ph.D.

*The above-prescribed minimum publication criteria can be relaxed by the Senate Chairman based upon recommendation of the concerned Thesis Supervisor(s), Head and Dean, Academic Affairs on the merit of the application.*

15. **Minimum and Maximum Time for Ph.D. Thesis Submission: Minimum time period** for submission of Ph.D. thesis will be TWO years for **Category-I** and TWO and HALF years for **Category-II** and **Category-III** from the **Confirmation of Registration for the Ph.D. degree**.

**Maximum time period** for submitting the Ph.D. thesis for full-time Ph.D. program will be **FIVE years** from the date of admission to the Ph.D. program. Request for further extension beyond the maximum duration must be sought from the Senate Chairman through proper channel.

16. **Course codes and grades for M.Sc., M.Tech., M.S. (Research) and Ph.D. Seminar and Thesis:** The codes for the M.Sc./ M.Tech. seminar is XX 698 (XX 697 for M.S.) and for Ph.D. Seminar course is **XX 797** (for the autumn semester) and **XX 798** (for the spring semester). The course **code of the Ph.D. thesis** will be **XX 899 and** course **codes of the**

**M.Sc./ M.Tech. Research Projects** will be **XX 799 (3rd Sem) and XX 800 (4th Sem)** where XX is the code of the discipline (i.e. CS, EE, ME, HS, CH, MA, PH, BSE, MSE, etc.). Ph.D. thesis will be awarded **SS** as satisfactory and **US** as unsatisfactory, while the M.Sc. M.S. (Research) and M.Tech. thesis will be awarded letter grade.

17. **Grading of Ph.D. Thesis (XX 899) and consequences of unsatisfactory performance:** After successful completion of the required course work, a Ph.D. student will register for Ph.D. Thesis course (course code XX 899) every semester till completion of the Ph.D. program. It will be awarded Satisfactory (SS) or unsatisfactory (US) grade at the end of every semester by the concerned Ph.D. Thesis supervisor(s).

    ***Unsatisfactory performance in Ph.D. Thesis course in a semester may lead to temporarily stopping of Ph.D. scholarship until the student attains satisfactory grade in his/her Ph.D. Thesis course. If a Ph.D. student accumulates more than two US grades in XX 899 during his/her Ph.D. program, then that student may face early discontinuation from the Ph.D. program.***

18. **Policy for Class Attendance:** The weight-age for attendance is considered as 10 marks out of total 100 marks.

    Keeping marks for attendance is solely up to the discretion of the course coordinator. He/she may not keep marks for attendance, but if they keep marks for attendance, the below-mentioned proposed scheme must be implemented:

    a. Those students who have an attendance percentage of 80 and above (i.e., >=80%) would be awarded complete ten marks (i.e., 10/10).
    b. Students whose attendance percentages lie between 50 to 80 (50% - 80%) have their attendance score calculated as the ratio of their attendance percentage points and the threshold attendance percentage requirement, multiplied by 10. This hence guarantees a range of 6.25 to 10 marks attainable.
       For example, if the attendance threshold percentage is 80% and the student attends 60% of the classes, the student would be awarded a score of (60/80)*10=7.5 marks on 10.
    c. For students with border line attendance (for example: 49% or 79%), it is solely up to the course coordinator to consider the student for 50% minimum attendance or the threshold attendance of 80%.
    d. Students whose attendance percentages lie below 50 (i.e., <50%) would not be allowed to appear for the end-semester exams, would get an XX grade and would have to repeat the course. However, this decision of awarding XX grade is solely up to the discretion of the course coordinator.
    e. If any student misses classes for institute events like FLUXUS or to represent IIT Indore (in BAJA, ROBOCON etc.) or due to medical reasons, the students ought to be granted attendance for the missed classes as per the discretion of the course coordinator (on production of supporting documents or notification by the Academic Office/DOSA/Student Gymkhana as per the underlying reason).

**20. Policy for the Components of Evaluation**

a. As per the Institute policy, mid semester examination (MSE) and end semester examination (ESE) are the **essential components of the evaluation** with a

**minimum weightage** of 20% and 40% and **maximum weightage** of 40% and 60% respectively.

b. Other components of evaluation such as quizzes, term paper, term project, home assignments, viva, etc. can constitute maximum weightage up to 40% ONLY.

c. MSE and ESE are to be conducted as per the scheduled exam time table and as per the notified seating plan.

d. The question papers for the MSE and ESE (even for open-book and take-home type) are to be submitted in the Academic Office within one working day in advance for distribution to all the invigilators for a particular MSE or ESE as per the seating plan.

e. **Only home assignments during the entire semester without MSE and ESE are NOT allowed to evaluate the students registered in a particular course. This is against the institute norms, dilutes the academic standards of the Institute and highly unfair to the students. The faculty members must desist from such practices.**

f. Any deviation from this policy without prior approval will be considered very seriously.

## 21. Policy for Open-Book and Take-Home Exam

a. The concerned faculty has to declare well in advance in the class about the **Open-book or Take-home exams** to the students. The faculty should also declare as to what will be allowed in the Open-book exams i.e. lecture notes, handouts, data handbook, data sheets, etc. The question paper must contain the detailed instructions for the **Open-Book Exam** so that there is no confusion to the invigilators.

b. The **Open-book exam** will be of same duration as per the institute norms for the MSE or ESE or quiz. For any deviation from this, approval from DOAA is to be taken.

c. Both Open-book and Take-home exams are to be conducted on the **scheduled day as per the exam time table** using the IIT Indore answer sheets only.

d. The **question papers** for both types of exams should be of such standards that they demand the necessity of having Open-book or take-home exam.

e. The question paper should be submitted to the Academic Office which distributes them to different invigilators according to the seating plan for the exam.

f. Other Details for the **Take-home exam**.

(i) The Take-home exam generally should be of **maximum 24 hours duration** only. For any duration more than this, prior approval from DOAA needs to be taken.

(ii) T**o maintain the fairness of take-home exams and t**o **avoid mass copying**, the questions should be **open-ended type** which cannot be solved by a group of students. To achieve this objective, the faculty is required to make **different sets of question papers equal in number to the number of the students registered in his/her course**. The concerned faculty should also inform the Academic Office as to which student is to be given which set of question paper so that students do not interchange the question paper after taking it to home.

(iii) Students should be asked to collect the Question paper from the Academic Office during the specified time only.

(iv) The answer sheets must be submitted to the Academic Office within the stipulated time along with the question paper. The concerned faculty will collect the answer sheet from the Academic Office as done in case of regular exams.

g. Any deviation from this policy without prior approval will be considered very seriously.

**22. Policy regarding Rescheduling of Mid Semester Exam (MSE) and End Semester Exam (ESE) and other Components of Evaluation:** Following policy is followed to deal with the request of re-scheduling the MSE, ESE and other components of evaluation scheduled as per the Academic Calendar:

a. Since, the schedules of MSE and ESE for both Autumn and Spring semester is known in 6-8 months in advance, therefore, the **students should NOT participate and/or organize any event/competition which clashes with dates of MSE and ESE**.

b. Requests of the students to reschedule MSE and ESE will NOT be considered for any **unapproved participation/event**s which clashes with the dates of MSE and ESE.

c. Faculty members will not entertain direct requests of the students to reschedule MSE, ESE and other exams for their unapproved participation/event.

d. Request for rescheduling the exams for **approved events/ participation** duly recommended by Students Gymkhana and DOSA must be sent to the Convener, Time Table Committee well in advance before the exam schedule is notified.

e. The MSE and ESE will **be pre-poned** and not **post-poned** in following extreme cases when there is clashes with the declared dates of MSE and ESE:

a. Interviews for IIMs admission

b. Medical emergency of the student for self

c. Approved participation in those Events/ Competitions which are recommended by the Students Gymkhana and DOSA. Deviation from this shall be treated on the merit of the case.

f. The concerned Faculty member / Course Coordinator should submit the question papers for such pre-poned exams to the Academic Office for conducting such exams.

g. The student will have to return the question papers along with the answer sheet for such pre-poned exams.

h. In a rare case if any exam however cannot be re-scheduled and a student still misses then he/she will be treated absent and awarded ZERO marks for such missed exams. (NB: ***It is compulsory to appear in ESE of a course. A student absent in the ESE of a course, is to be awarded the FR grade irrespective his/her performance in-semester components of evaluation***)

i. For better planning of the Academic Calendar (AC), the Student Gymkhana must inform the Academic Office about the reputed important Competitions and Events in which students are likely to participate at the time of preparation of the Academic Calendar. The Academic Office will try to take care of the events/participation as informed by the Students Gymkhana while preparing AC.

23. **System of evaluation and award of grades:** At the end of every semester, a student is awarded a grade based on his/her performance in examination, in every course registered by him/her. These grades are described by the letter grade and have numerical equivalent called the grade points as given below:

| Letter grade | Grade point | Remark |
|---|---|---|
| AP | 10 | Awarded to the students with exceptional performance in the course |
| AA | 10 | |
| AB | 9 | |
| BB | 8 | |
| BC | 7 | |
| CC | 6 | |

| | | |
|---|---|---|
| CD | 5 | |
| DD | 4 | |
| FR | 0 | Credit not earned<br>• For compulsory course: Repeats the course<br>• For an elective course: Repeat or replace the course |
| XX | 0 | |
| PP | - | Pass (for non-credit course) |
| NP | - | Not Pass (for non-credit course) |
| AU | - | Pass (for audit course) |
| SS | - | Satisfactory (for Ph.D. thesis) |
| US | - | Unsatisfactory (for Ph.D. thesis) |

a. Scale of marks to award the above mentioned grades will be decided by the concerned Course Coordinator. However, grades will be authenticated by School Post Graduate Committee (SPGC) before releasing the grades. Course coordinator(s) should not reveal the grades to students before authorization by SPGC. They may show the Answer Sheets and marks to the students.
b. For AP grade upper cap is 2% with class strength of 25 or above i.e. for a class strength of 25 to 50, 1 student can be awarded AP grade.
c. Upper cap for AA grade is 15% (including 2% of AP grade), it can be rounded-off to higher integer number in case of fractional number, i.e. 6.1 can be made 7.
d. Highest grade that can be awarded to a student repeating a course [on account of earning FR or XX grade in that course in previous semester(s)] is BB.
e. Minimum grade for earning credits in a course is DD.

## 24. Rules and Regulations for 5 Year B.Tech. + M.Tech. program

**A. Eligibility:**

i. Only those B.Tech. students of IIT Indore are eligible to apply for B.Tech. + M.Tech. program who have completed all the prescribed courses of their B.Tech. program till the $6^{th}$ Semester and secured a minimum CPI of 7.00 at the end of $6^{th}$ Semester without earning any FR/ XX grade in any of the courses registered by him/her till $6^{th}$ semester.
ii. There should not have been any disciplinary cases and/or penalty imposed or contemplated against the student. Student should not have been punished for any type of misconduct/ misbehavior/ indiscipline/ irregularities, and use of unfair means.

**B. Other Conditions:**

i. Those students who have been admitted for the dual degree program are not eligible for the campus placement activities in their $4^{th}$ year.
ii. A student admitted to this 5-Year B.Tech. + M.Tech. program **will not have any exit option.** He/she will get the degree at the end of $5^{th}$ year by fulfilling all the prescribed requirements of this program.
iii. The admitted students will be exempted from Internship, B.Tech. Project (BTP), English Communication Skills course (HS 641). However, they have to fulfill their minimum requirements in their M.Tech. Electives, PG Seminar course and M.Tech. Research Project work.
iv. The **last date of application** generally will be $31^{st}$ March and list of selected candidates will be declared by $2^{nd}$ week of May.

**C. Intake:** to be as decided by the discipline for each of its M.Tech. Program. This will be in addition to the seats sanctioned for the regular M.Tech. program.

**D. Selection Criterion and Shortlisting:** To be decided by the concerned discipline.

**E. Scholarship:** As per the MHRD norms from their 9th semester onwards provided the student has CPI ≥ 7.0 at the end of 8th Semester. Or else, after qualifying the GATE exam. If a student fails to fulfill either of these conditions, then the student will not be eligible for any MHRD scholarship.

**F: Fee:** Fee structure of M.Tech. program will be applicable from the 7th semester onwards.

**25. Award of M.Sc./ M.Tech. degree to the internally converted students of dual degree Program (M.Sc. + Ph.D. and M.Tech. + Ph.D. )**

The internally converted students of dual degree Program will be awarded the M.Tech./ M.Sc. degree with the wordings as follows:

"Indian Institute of Technology Indore upon recommendation of the Senate hereby confers the degree of M.Tech./ M.Sc. in recognition of completion of the prescribed requirements for the said degree (and partial fulfillment towards the M.Tech./ M.Sc. and Ph.D. dual degree program)."

For such students, the research component of their Master's project work may be included as part of their Ph.D. thesis, when they continue research on the same area and topic as their Master's thesis.

**26. A. Medal for graduating students of the Masters' Program:** There are two Institute Silver Medals for PG program. One will be awarded to the best performing M.Tech. student and other to the best performing M.Sc. student among all the graduating students, using following approved procedure:

- Each discipline will nominate top two candidates of its Master's program based on his/her CPI in coursework, CPI in thesis, overall CPI, research output for consideration of award to Silver medal. This should be immediately done after final viva of the PG thesis are completed but before 15th July.
- An evaluation committee consisting of Heads (or a faculty member nominated by the concerned Head) of those discipline which have PG program and an external expert from a reputed Institute/ Industry would be constituted by Dean, Academic Affairs.
- The nominated PG students will submit a short summary of their thesis work highlighting major innovation/research contribution and will also make presentation of their thesis work before the evaluation committee.
- The evaluation committee based on its evaluation would submit its recommendations for the best performer in the Master's program to Chairman, Senate through Dean, Academic Affairs for approval.

**B. Buti Foundation Gold Medal:** For a female student securing the highest CPI among graduating students of all the two-year PG programs.

**27. Rules for Institute Staff (IS) or Sponsored (SW) or Defense Forces (DF) categories doing PG and Ph.D. programs:**

Candidates from **Institute Staff (IS) category** or **Sponsored (SW) or Defense Forces (DF) category** can enroll for PG and Ph.D. programs of the Institute as **part-time** candidates subject to following rules and regulations which can be amended from time to time as per the requirement:

a. An IS category applicant must be a **permanent Institute employee** since last two years at the time of application. While, the **Sponsored category** applicant should have minimum two-year work experience in a **reputed Industrial/Research Organization**. Candidates under DF category should be serving officer in the Defense Forces of India.
b. The **part-time candidate** will not be entitled for payment of any fellowship/stipend during the entire academic program.

c. The IS category applicant is required to submit a “No-Objection Certificate (NOC)” from the Head of the concerned department/section while, SW and DF category applicant should submit the NOC from the Competent Authority of his/her parent organization along with his/her application in the prescribed form. ***Officials sponsored by Central Government, State Government and PSU are exempted from submission of sponsorship letter*** but ***have to submit NOC and other required documents.***

d. (A) The **NOC of the IS category** applicants should clearly state that:

- The candidate is allowed to pursue the academic program on **part-time** basis.
- The admission to the academic program will not affect his/her discharging of the assigned duties from the Institute.

(B)The **NOC of SW and DF category** applicant should clearly state that:

- The sponsoring organization shall fully relieve him/her of his/her duties in the organization during the **time period of required course work** (for **Part-Time**) / **entire duration** (for **Full-Time**) of the academic Program.

e. The **Part-time Sponsored** category students will have to do the required course work on full-time residential basis.

f. The SW and DF **category** candidate may be permitted to have **one thesis/ reporting supervisor** from his/her parent organization after consent from the Principle Thesis Supervisor (i.e. a faculty from IIT Indore). The Principal Supervisor will be solely responsible for ensuring the fulfillment of all the academic requirements as per the Institute Rules and Regulations. The supervisor of SW and DF category candidate must have the qualifications and experience as follows:

- With Ph.D. qualification should have a minimum of 5 years post-Ph.D. experience in a reputed Industrial/Research/Defense Organization; OR

- With M.Tech./ME/MPhil or equivalent qualification should have minimum **10 years post-PG qualification experience** in a reputed Industrial/Research/Defense Organization; OR

- With B.E./ B.Tech./ M.C.A./ M.B.A./ M.Sc./ M.Com./ M.A. or equivalent qualification should have minimum **15 years post-qualification** experience in a reputed Industrial/ Research/ Defense Organization.

g. The eligibility and process of application, admission process, registration fee, registration process, academic rules and regulations and other academic procedures will be same as applicable to full-time category students.

h. IIT Indore will have exclusive copyright on the Ph.D./ PG thesis of the Sponsored category students while Patents and innovations will be governed by the IPR policy of IIT Indore.

i. The Institute reserves the right to cancel/ renew the admission to PG/ Ph.D. program of Institute Staff (IS) and Sponsored (SW) candidate in case of change of employment.

**Details of the other specific conditions for Part-time Ph.D. and PG Programs:**

| | Ph.D. Program (part-time) | PG Program (part-time) |
|---|---|---|
| **Minimum duration of required course work** | Same as full-time candidates as mentioned in the Institute Rules and Procedures for and PG and Ph.D. programs. | |
| **Maximum duration of the required course work** | i) TWO semesters with M.Tech./ M.E./ M.Phil. or equivalent qualification from the date of joining the program.<br>ii) THREE semesters with M.Sc./ M.A./ M.Com./ M.B.A./ B.Tech./ B.E. or equivalent qualification from the date of joining the program. | FOUR semesters from the date of joining the program. |
| **Minimum time required for thesis submission** | **SIX months** more as compared to the **full-time** candidates i.e. **30 months** for M.Tech./ M.E./ M.Phil. or equivalent qualification and **36 months** for B.Tech./ B.E./ M.Sc./ M.A./ M.Com./ M.B.A. or equivalent qualification from the *date of confirmation in the Ph.D. program*. (i.e. from the first working day of the next semester in which the student successfully completes his/ her required course work). | Three years from date of joining the program. |
| **Maximum duration of the program** | 7 Years from date of joining the program. | 4 Years from date of joining the program. |
| **Expectations from IS category candidates** | The Institute expects at least two year continuous service from the date of completion of the Ph.D. program. | The Institute expects at least one year continuous service from the date of completion of the PG program. |

The forms required for Institute Staff (IS), Sponsored (SW) and Defense Forces (DF) College Teacher (CT) and QIP category students for doing PG and Ph.D. program at IIT Indore are available at https://academic.iiti.ac.in/phdforms.php.

## 28. Rules for Ph.D. Program under College Teacher (CT) category:

**Eligibility requirements (ER)**

a. The College/Institute/University from which the faculty member is sponsored should be **amongst top 100 NIRF ranked College or Institute or University in respective category** in the immediate preceding year.
b. The applicant must be **Permanent Employee of the sponsoring College/ Institute/ University**. The Sponsoring Organization must mention in the No Objection-cum-Sponsoring-Experience Certificate (attached below) that it will continue to pay remuneration to the candidate for the entire duration of his/ her Ph.D. program on Full-time basis.
c. The applicant should have **at least one publication** in SCI indexed journal, proceedings of peer reviewed ranked international conferences/ chapter in a book published by reputed international or national publishers or should a patent or should have developed state-of-the-art patentable and/ or transferable technology.

d. Candidate will be admitted as **Full Time Ph.D. candidate initially for 3 years** i.e. the Sponsoring Organization will certify in the No Objection-cum-Sponsoring-Experience Certificate that the candidate will be relieved from all the duties and responsibilities from the Institute to enable him to complete the Ph.D. program on Full-time basis within 3 years duration. If extension for more duration is required, then the candidate should submit application through his/her Sponsoring Organization to the competent authority of IIT Indore for consideration.

**Minimum Educational Qualification (MEQ):**
As per the Ph.D. advertisement of the concerned Discipline/ School/ Center in which is she/ he interested to apply.

### Other Rules and Regulations

a. Candidates admitted under this category will be required to pay registration fee on semester basis as applicable to Full-time Ph.D. student of IIT Indore with following exemptions:
   i. Group Insurance Premium per annum (per semester for Ph.D. students) and Medical Fee, if the candidate is not availing medical facilities of the Institute.
   ii. Mess Security Deposit and Dining charges, if the candidate is not availing dinning facility of the Institute.
   iii. Hostel Security Deposit and Accommodation Charges, if the candidate is not availing hostel facility of the Institute
b. All the rules and regulations of Ph.D. program of IITI will be applicable to CT category students.
c. Course-work, selection of Ph.D. thesis supervisor(s) and constitution of PG Student Progress Committee (PSPC) to be done as per applicable rules and regulations of IITI.
d. Comprehensive Evaluation of Research Progress (CERP) will be conducted as per the policy of the institute for Full-time Ph.D. student. In case the candidate is allowed to convert as Part-time Ph.D. student then CERP will be conducted in every 6 months before last date of Ph.D. thesis (i.e. XX 899) grade submission in that respective semester.
e. Maximum duration for completion of Ph.D. program will be five years as applicable to Full-Time Ph.D. student of IIT Indore.
f. No Objection-cum-Sponsoring-Experience Certificate from the Sponsoring University/ College/ Institution for Ph.D. Applicant under College Teacher Category (CT) must be submitted on letterhead of the Institute (format of form is available at https://academic.iiti.ac.in/phdforms.php)

**29. Policy for temporary withdrawal of students from Academic Program on grounds misconduct and violation of institute rules:** Any student found guilty for misconduct and violation of institute rules then he/ she will be withdrawn temporarily up to two semesters from his/ her Academic Program on recommendation of the Disciplinary Action Committee.

If such offence is very serious or an offence is repeated frequently then the concerned student will be withdrawn completely from the academic program based on recommendation of the Disciplinary Action Committee.

# Procedure for Submission of Ph.D. thesis

**<u>1. ELIGIBILITY FOR Ph.D. THESIS SUBMISSION:</u>** A Ph.D. student can submit his/ her Ph.D. thesis ONLY after meeting the requirements mentioned in (1A) **AND** 1(B),

**(1A) Minimum Publication Criteria:** He/she has **at least *three*** publications from his/ her Ph.D. thesis in the SCI or other equivalent indexed journals having good impact factor. The list of publications submitted along with report of Open Seminar and Ph.D. Synopsis should **clearly mention the publications from the Ph.D. thesis work** and other publications during Ph.D.

*The above-prescribed minimum publication criteria can be relaxed by the Senate Chairman based upon recommendation of the concerned thesis supervisor(s), Head and Dean, Academic Affairs on the merit of the application.*

**AND**

**<u>(1B) MEETS THE MINIMUM TIME REQUIREMENT CRITERIA:</u>** **Minimum time period** for submission of Ph.D. thesis from the date of **Confirmation of Registration to the Ph.D. degree (i.e.** from the **first working day of the semester** following the one in which they have successfully completed the **required course work**) is

(a) TWO years under **Category-I** (Ph.D. students with **M.Tech./ M.Phil. Or equivalent qualification**),

(b) TWO and HALF years under **Category-II (**Ph.D. students having **M.Sc./ M.A./ M.Com./ M.B.A. or equivalent qualification** admitted to a **Science or HSS discipline)** and **Category-III** (**B.Tech./ M.Sc. or equivalent qualification** admitted to Ph.D. Program in an **Engineering discipline**)

**2. OPEN SEMINAR:** Before submitting the Ph.D. thesis, an **OPEN SEMINAR** is to be given by the concerned Ph.D. student about his/ her Ph.D. thesis work and in the presence of the Ph.D. Student's Progress Committee (PSPC). This seminar will be OPEN to the entire IIT Indore Community and notice of this will be sent by the Thesis Supervisor(s) one week in advance. ***Before the OPEN SEMINAR, the Ph.D. student will send the draft of synopsis of his/her Ph.D. thesis to ALL the PSPC members.***

The PSPC may suggest the Ph.D. student to incorporate all those feasible comments/suggestions received during the OPEN SEMINAR which can improve the quality of the Ph.D. Thesis. The report of the successful Open Seminar must be submitted by the Thesis Supervisor(s) in the **prescribed form** (**Form-PTS 1**) well in advance before the student proceeds to submit his/ her Ph.D. Synopsis and the Ph.D. Thesis.

**3. SUBMISSION OF Ph.D. SYNOPSIS and THESIS:** After conduct of **SUCCESSFUL OPEN SEMINAR**, the Ph.D. student through his/her thesis supervisor(s) has to submit the following:

(a) One copy of **synopsis** of his/ her **Ph.D. thesis (both in softcopy and hard copy)** within **maximum 15 days** from the date of the Open Seminar along with the **required Certificates** (**Form-PTS 2**). The synopsis should be a **concise summary** (including the figures, tables, few references, and list of publications) of the Ph.D. thesis. It should not contain more than **8-12 pages** of A4 size with the text typed in **12 pt. Times New Roman font having 1.5 spacin**g.

The **primary objective** of the synopsis is to enable the reader to judge whether, prima facie there exists a case for accepting the proposed Ph.D. thesis for the award of the Ph.D. degree. The synopsis should therefore, clearly list the contributions resulting from the investigations carried out by the candidate, which has led to the advancement of knowledge in the field of investigation.

In order to fully appreciate the candidate's contribution, it is necessary to put it in a proper context. Therefore, it is **recommended that the synopsis** should contain a brief account of the existing knowledge and the inadequacy or gaps in this knowledge that led the candidate to the formulation of the problem of his/ her investigation. A few references, needed in this respect should be included but their number should normally, not exceed ten. List of publications (including published, accepted, submitted in the refereed journals and conferences) or Patents (granted or applied) from the Ph.D. thesis work should be included.

In case the Ph.D. student gets employment and wants to submit the synopsis and Ph.D. thesis from outside the institute after successful open seminar then the request can be made in the prescrbied format (**form-PTS 2a**)

(b) Required number (= 2 + number of thesis supervisor(s)) of ***soft or spiral bound*** copies of the **Ph.D. thesis** along with the *required form* (**Form-PTS 4**) within **maximum ONE month** from the date of the Open Seminar along with its editable softcopy in the CD/ DVD and by e-mail. The Ph.D. thesis must be written in the prescribed format as mentioned below:

| | |
|---|---|
| **Printing Format:** | BOTH SIDE PRINTING |
| **Paper:** | Executive Bond |
| **Font:** | Times New Roman |
| **Line Spacing:** | 1.5 |

| **Program** | **Color of cover page** | **Font color on cover** |
|---|---|---|
| *Ph.D.* | *Maroon* | *Golden* |
| *BTP* | *Navy Blue* | *Golden* |
| *M.Tech.* | *Pistachio Green* | *Black* |
| *M.Sc.* | *Sky Blue* | *Black* |
| *M.Phil.* | *Light Gray* | *Black* |
| M.S. | Aqua Blue | Black |

**Ph.D. Thesis**
**B.T.P. Report**
**M.Tech Thesis**
**M.Sc. Thesis**
**M.Phil. Thesis**
**M.S. Thesis**

4. **Ph.D. THESIS EXAMINERS:** The Ph.D. thesis supervisor(s) will be the Thesis Examiner(s) also. In addition to this the Ph.D. thesis supervisor(s) will suggest details of FOUR *examiners within India* and FOUR *examiners from outside India* in the *prescribed format* (**Form-PTS 3**) for evaluating the Ph.D. thesis. The proposed Ph.D. thesis examiners should have Ph.D. qualification and should be

(a) Professor in an Institute/ University of international/ national repute, OR
(b) Professor emeritus of international/ national repute but active in his/her research field, OR
(c) Scientist-F or above in a recognized research organization, OR
(d) An individual having minimum 10 years of post-Ph.D. industrial experience.

***Same external examiner should not be proposed at least for a period of TWO years, after having examined thesis of a Ph.D. student under the same Thesis Supervisor.***

From the list of suggested examiners, the Chairman, Senate@ in consultation with the Dean, Academic Affairs* will give order of preference to these examiners. The **Ph.D. synopsis** will be sent to the Ph.D. thesis examiners in the order of preference for getting their consent to evaluate the Ph.D. thesis within SEVEN days of receipt of such request. If NO consent or reply is received within SEVEN days from the first examiner, then the Ph.D. synopsis will be sent to the next examiner and so on.

From the list of suggested examiners, if NO examiner agrees to evaluate the Ph.D. thesis then the concerned Ph.D. thesis supervisor(s) will be asked to suggest new examiners.

** (a) If Dean, Academic Affairs (DOAA) is the Ph.D. thesis supervisor, then Director may consult Dean R & D (DORD).*
*(b) If both DOAA and DORD are the Ph.D. thesis supervisors, then Director may consult DOFA.*
*@ If the Director is the Ph.D. thesis supervisor then DOFA in consultation with DOAA may select the Ph.D. thesis examiners.*

The names of the selected examiners will be kept confidential till the Ph.D. Oral Examination is conducted successfully.

**5. EVALUATION OF THE Ph.D. THESIS BY THE EXAMINERS:** The Ph.D. thesis examination board will consist of the Thesis Supervisor(s) and the thesis examiners selected as mentioned in (4). The softcopy and hardcopy of the Ph.D. thesis will be sent to ALL the examiners.

The examiners will be requested to send the evaluation report of the Ph.D. thesis **within TWO months** from the receipt of the Ph.D. thesis in the prescribed format (**Form-PTS 5**).

If the evaluation report is **not** received within a period of two months, then a reminder will be sent to the examiner(s) for sending the evaluation report within **next two weeks**. In exceptional cases, the examiner(s) can be given **maximum one month additional time** for the Ph.D. thesis evaluation i.e. maximum within three months the evaluation report should be received.

*In unfortunate case of death of an examiner, a new examiner will be selected and the process of evaluation of the Ph.D. thesis will be started afresh.*

The Ph.D. examiner will be asked to recommend ONLY one of the following four options along with the detailed report/feedback justifying his/her recommendation.

**(A)** The thesis in its present form is satisfactory for the award of the Ph.D. Degree.
**(B)** The thesis is recommended for the award of the Ph.D. degree subject to the clarification of the queries/ comments before the Ph.D. Oral Examination Board. If the Ph.D. Oral Examination Board deems it appropriate, the same may be incorporated in the thesis based on the discussions during the viva-voice examination. The revised thesis need not be sent to the examiner.
**(C)** The thesis needs to be revised as per suggestions enclosed and the thesis be sent for re-evaluation.
**(D)** The thesis be rejected.

| Recommendation of the Thesis Examiners including the Thesis Supervisor(s) | Action to be taken |
|---|---|
| 1. A and/or B | (A) Oral Examination can be conducted and the required action to be taken if any recommendation is of 'B' category. |
| 2. Any one examiner recommending option 'C' | (A) The thesis is to be REVISED as per the suggestions of the examiner who has recommended 'C' option. The Revised thesis to be resubmitted and will be sent 'ONLY' to that examiner.<br>(B) The Oral examination to be conducted only when, there is a change in the recommendation. |
| 3. Examiner(s) recommending option 'D' | (A) The thesis is to be REWORKED and REVISED in consultation with the Thesis Supervisor(s) incorporating the comments/feedback of the Examiner(s) who has/have given 'D' category recommendation in such a way that it improves the overall quality of the Ph.D. work.<br>(B) The Thesis is to be resubmitted and will be sent to different Examiner(s) for the evaluation. |
| 4. The Thesis supervisor(s) recommending option 'D' | (A) In the rarest of the rare, the request of the Ph.D. student for changing the supervisor may be considered.<br>(B) The Ph.D. thesis is to be reworked as per the guidance of the new Thesis supervisor.<br>(C) The OPEN seminar is to be given again and after the successful OPEN Seminar, the thesis is to be submitted as new thesis.<br>(D) The procedure of the thesis evaluation is to be followed considering it as new thesis. |
| (i) In case of both external examiners classifying the Ph.D. thesis as "C" or lower (i.e., "D"), the Open Seminar would be required to be given again and Ph.D. thesis to be resubmitted.<br><br>(ii) In such cases where one examiner classifies the Ph.D. thesis as 'C' category, then the PSPC must evaluate the revisions and recommend or not for submission of the revised version of the Ph.D. thesis. The revised Ph.D. thesis must be submitted along with the recommendation of the concerned PSPC, DPGC Convener and the Head. | |

**6. ORAL EXAMINATION OF THE Ph.D. THESIS and the ORAL EXAMINATION BOARD (OEB):**

The Ph.D. oral Examination Board will consist of the following:

a. Chairman, nominated by the Chairman, Senate from the four names suggested by the thesis supervisor(s).
b. Thesis supervisor(s)
c. Thesis Examiner (within India) as External Examiner
d. Other PSPC members
e. Convener, DPGC (*ex-officio*)
f. Head of the Discipline (*ex-officio*)

The date and time of the oral examination will be decided by the Chairman (OEB) in mutual consultation with thesis supervisor(s) and other members of OEB as well as depending upon the availability of the Thesis Examiner (within India). It will be open to the IIT Indore community. A notice for same must be circulated by the Chairman (OEB) to all the students and faculty in the institute at least one week in advance.

As per the approval of the Senate Ph.D. viva can be conducted beyond regular working hours or beyond weekdays with prior permission and subject to ensuring proper advance information/ publicity and ensuring considerable attendance of the audience other than members of Oral Examination Board in the viva. Attendance of the audience to be recorded and to be submitted along with the report of Ph.D. viva.

**Guidelines for OEB chairman for conducting Ph.D. viva:**

1. Thesis supervisor(s) will suggest four names at the level of Associate Professor and above for consideration of OEB Chairperson.
2. Deans and HoDs should not be suggested for OEB Chairperson.
3. Chairperson of the OEB will contact the external examiner for fixing the date and time of the PhD viva. The schedule must be finalized in such a way that it is convenient to all the members of OEB and enable them attend the PhD viva in person.
4. OEB Chairperson should ensure that all reports of the examiners, rebuttal /corrections, and the revised thesis are shared with the OEB members before the PhD viva.
5. OEB Chairperson should ensure that all the members of OEB, including the ex-officio, are given equal importance and chance to ask questions in a PhD Viva.
6. OEB chairperson should ensure that all the members of OEB sign the PhD viva report and it is submitted to the Academic Office on the day of PhD viva itself.

The ***report of the Oral Examination*** must be submitted to the Academic Office in the prescribed format (**form PTS 6**).

After the successful Oral Examination or Ph.D. Viva, the student has to submit the ***soft copies*** of the Ph.D. thesis incorporating all the corrections of the Ph.D. Oral Examination Board along with the required form (**form PTS 7**) for the same. The students will be required to submit a soft copy of thesis in PDF format, with signature of the concerned members of the OEB on the certificate, to the Central Library and Department Library. If required a Hard Copy of the thesis can be submitted to the concerned Thesis Supervisor. The central library and the department library should maintain the database accessible to the institute community.

**7. HONORARIUM to the Ph.D. THESIS EXAMINERS:** Following honorarium will be paid to the Ph.D. thesis examiners. The Head of Discipline or DPGC Convener must ensure that the payment of honorarium to Thesis examiner is made at the earliest and preferably on the day of Ph.D. Oral Examination itself. Advance may be drawn for, on the spot payment.

| | **Examiner (with India)** | **Examiner (outside India)** |
|---|---|---|
| Evaluation of the Ph.D. Thesis | INR 8,000/- | US $ 200 |
| Conducting the Ph.D. Oral examination | INR 4,000/- + Travelling expenses from the workplace to IIT Indore and local hospitality | --- |

## Procedure for Submission and Evaluation of M.Tech./ M.Sc. Thesis

Last date for submitting **softbound copies** of M.Tech./ M.Sc. thesis in the prescribed format will be **30th June along** with form **PGTS-1**. The Oral Examination Board (OEB) for M.Tech./ M.Sc. thesis will consist of

1. Head or a faculty member nominated by him (Chairman)
2. The DPGC Convener
3. Members of the PSPC of the Student (which includes thesis supervisor(s), one expert from the discipline and one expert from other discipline)

The last date of conducting the **Oral Examination/ Thesis Defense** of the M.Tech./ M.Sc. thesis and report of Oral Examination along grade awarded in the PG thesis must be submitted latest by the **last date as per the Academic Calendar** in the prescribed form **PGTS-2**. The notice for M.Tech./ M.Sc. thesis oral examination should be circulated at least **5 days in advance** to the entire IIT Indore community.

The last date of submitting the **soft copies** of M.Tech./ M.Sc. thesis after incorporating all the changes suggested by OEB along with the **No dues Certificate** (NDC) will be **30 June** along with **form PGTS-3.** After submission of hardbound copies of the M.Tech./ M.Sc. thesis and NDC**, the provisional degree certificate can be issued to an M.Tech./ M.Sc. student.** The date of M.Tech./ M.Sc. thesis oral examination will be considered as date of completion of the program. The students will be required to submit a soft copy of thesis in PDF format, with signature of the concerned members of the OEB on the certificate, to the Central Library and Department Library. If required a Hard Copy of the thesis can be submitted to the concerned Thesis Supervisor. The central library and the department library should maintain the database accessible to the institute community.

*(In case there is a holiday/ vacation on the above-mentioned dates then it should be replaced by the next working day)*

# Procedure for Submission and Evaluation of MS (Research) Thesis

**1. ELIGIBILITY FOR MS (RESEARCH) THESIS SUBMISSION**: Students of MS (Research) can submit his/ her thesis ONLY after meeting the requirements mentioned below:
a. Successful completion of course work and research work.
b. Student must have one journal publication in SCI index from his/ her MS (Research) thesis for completion of the degree.
***"In view of situation of COVID-19, Senate resolved in its 23rd meeting held on 5 June 2020 to exemption from the minimum criteria of publication for MS (Research) Batch-2018. This is only for AY 2019-20, 2020-Spring Semester."***

**2. SUBMISSION OF SYNOPSIS AND SOFTBOUND COPY OF THESIS:** Student will submit softcopy of synopsis and softbound copy of thesis to the Academic Office along with prescribed format (Form-MSRTS-1) latest by 30 June.

**3. LIST OF SUGGESTED EXAMINERS FOR MS (RESEARCH) THESIS:** The MS (Research) Thesis Supervisor(s) will be one of the Thesis Examiner(s), also in addition to that concerned Thesis supervisor(s) will suggest four External Examiners (within India) in the prescribed format (MSRTS-2) for evaluating the MS (Research) thesis. The proposed MS (Research) thesis examiners should have Ph.D. qualification and should be:

(a*) Associate Professor/ Professor in an Institute/ University of international/ national repute, OR*
*(b) Professor emeritus of international/ national repute but active in his/her research field, OR*
*(c) Scientist-F or above in a recognized research organization, OR*
*(d) An individual having minimum 10 years of post-Ph.D. industrial experience.*

***Same external examiner should not be proposed at least for a period of TWO years, after having examined thesis of a MS (Research) student under the same Thesis Supervisor.***

From the list of suggested examiners, the Chairman, Senate@ in consultation with the Dean, Academic Affairs* will give order of preference to these examiners. The MS (Research) synopsis will be sent to the external examiners in the order of preference for getting their consent to evaluate the MS (Research) thesis within SEVEN days of receipt of such request. If NO consent or reply is received within SEVEN days from the first examiner, then the MS (Research) synopsis will be sent to the next examiner and so on.

From the list of suggested examiners, if NO examiner agrees to evaluate the MS (Research) thesis then the concerned MS (Research) thesis supervisor(s) will be asked to suggest new examiners.

**(a) If Dean, Academic Affairs (DOAA) is the MS (Research) thesis supervisor, then Director may consult Dean R & D (DORD).*
*(b) If both DOAA and DORD are the MS (Research) thesis supervisors, then Director may consult DOFA.*
*@ If the Director is the MS (Research) thesis supervisor then DOFA in consultation with DOAA may select the thesis examiners.*

The names of the selected examiners will be kept confidential till the MS (Research) Oral Examination is conducted successfully.

**4. EVALUATION OF THE MS (RESEARCH) THESIS BY THE EXAMINERS:** The MS (Research) thesis will be evaluated by Thesis Supervisor(s) and the External Examiner selected as mentioned in above. The softcopy and hardcopy of the MS (Research) thesis will be sent to ALL the examiners.

The examiners will be requested to send the evaluation report of the MS (Research) thesis within one month from the receipt of the MS (Research) thesis in the prescribed format
(Form-MSRTS-3).

If the evaluation report is not received within a period of one month, then a reminder will be sent to the examiner(s) for sending the evaluation report within next one week. In exceptional cases, the examiner(s) can be given maximum one-month additional time for the MS (Research) thesis evaluation i.e. maximum within two months the evaluation report should be received.

In case report not received from existing an examiner, a new examiner will be selected and the process of evaluation of the MS (Research) thesis will be started afresh.

The MS (Research) examiner will be asked to recommend ONLY one of the following four options along with the detailed report/feedback justifying his/her recommendation.

**(A)** The thesis in its present form is satisfactory for the award of the MS (Research) Degree.
**(B)** The thesis is recommended for the award of the MS (Research) degree subject to the clarification of the queries/ comments before the MS (Research) Oral Examination Board. If the MS (Research) Oral Examination Board deems it appropriate, the same may be incorporated in the thesis based on the discussions during the viva-voice examination. The revised thesis need not be sent to the examiner.
**(C)** The thesis needs to be revised as per suggestions enclosed and the thesis be sent for reevaluation.
**(D)** The thesis be rejected.

| **Recommendation of the Thesis Examiners including the Thesis Supervisor(s)** | **Action to be taken** |
|---|---|
| 1. A and/or B | (A) Oral Examination can be conducted and the required action to be taken if any recommendation is of 'B' category. |
| 2. Any one examiner recommending option 'C' | (A) The thesis is to be REVISED as per the suggestions of the examiner who has recommended 'C' option. The Revised thesis to be resubmitted with recommendations of Thesis Supervisor(s), PSPC members, DPGC Conveners and Head. It will be sent ‘ONLY’ to that examiner. (B) The Oral examination to be conducted only when, there is a change in the recommendation. |
| 3.Examiner(s) recommending option 'D' | (A) The thesis is to be REWORKED and REVISED in consultation with the Thesis Supervisor(s) incorporating the comments/feedback of the Examiner(s) who has/have given 'D' category recommendation in such a way that it improves the overall quality of the MS (Research) work. (B) The Thesis is to be resubmitted and will be sent to different Examiner(s) for the evaluation. The Revised thesis to be resubmitted |

| | |
|---|---|
| | with recommendations of Thesis Supervisor(s), PSPC members, DPGC Conveners and Head. |
| 4. The Thesis supervisor(s) recommending option 'D' | (A) In the rarest of the rare, the request of the MS (Research) student for changing the supervisor may be considered. (B) The MS (Research) thesis is to be reworked as per the guidance of the new Thesis Supervisor. |

**5. EVALUATION OF THE MS (RESEARCH) THESIS BY THE EXAMINERS:** The Oral Examination Board (OEB) for MS (Research) thesis will consist of

1. Chairman, nominated by the Chairman, Senate from the names suggested by the thesis supervisor(s).
2. External Examiner
3. Thesis Supervisor
4. PSPC members
5. Head or a faculty member nominated by him

The date and time of the oral examination will be decided by the OEB Chairman depending upon the availability of the other members of the OEB. **Only External Examiner may attend the viva online**. It will be open to the IIT Indore community. A notice for same must be circulated by the OEB Chairman to all the students and faculty members in the institute at least one week in advance. The report of the Oral Examination must be submitted to the Academic Office in the prescribed format (Form-MSRTS-4).

The last date of submitting the final copy of MS (Research) thesis after incorporating all the changes suggested by OEB along with the No dues Certificate (NDC) with prescribed format (MSRTS-5) will be one week.

After submission of final copy of the MS (Research) thesis and (NDC), the provisional certificate can be issued to MS (Research) student. The date of MS (Research) thesis oral examination will be considered as date of completion of the program. The students will be required to submit a soft copy of thesis in PDF format, with signature of the concerned members of the OEB on the certificate, to the Central Library and Department Library. If required a Hard Copy of the thesis can be submitted to the concerned Thesis Supervisor. The central library and the department library should maintain the database accessible to the institute community.

**HONORARIUM TO THE MS (RESEARCH) THESIS EXTERNAL EXAMINERS:** Following honorarium will be paid to the MS (Research) thesis examiners.

| | **Examiner (with India) Examiner** |
|---|---|
| Evaluation of MS (Research) thesis and conduct of Oral Examination | INR 5,000/- |

# Course Structure
# of
# Ph.D. Program in
# Humanities and Social Sciences
# and Syllabi of Courses

## Course Structure for Ph.D. Program in Philosophy

**(A) Semester-I (Autumn / Spring)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | HS xxx | Elective-I | x-x-x-3 |
| 2 | HS xxx | Elective-II | x-x-x-3 |
| 3. | HS xxx | Elective-III | x-x-x-3 |
| 4 | HS 797 * / HS 798* | Ph.D. Seminar Course | 0-2-0-2 |

**(B) Semester-II (Spring / Autumn)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | HS xxx | Elective-IV | x-x-x-3 |
| 2 | HS xxx | Elective-V | x-x-x-3 |
| 3 | HS xxx | Elective-VI | x-x-x-3 |
| 4 | HS 798 * / HS 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Philosophy course for the Elective-I to VI** *(in addition these courses students can take courses from the other disciplines also)*

| S.No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | HS 600 | Data Analysis and Technical Writing | |
| 2. | HS 602 | Foundations of Knowledge | 2-1-0-3 |
| 3. | HS 603 | Epistemology | 2-1-0-3 |
| 4. | HS 605 | Social and Political Philosophy | 2-1-0-3 |
| 5. | HS 606 | Moral Philosophy | 2-1-0-3 |
| 6. | HS 607 | Foundation of Social Sciences | 2-1-0-3 |
| 7. | HS 608 | Nations & Nationalism | 2-1-0-3 |
| 8. | HS 611 | Philosophy of Natural Sciences | 2-1-0-3 |
| 9. | HS 612 / HS 412 | Contemporary Indian Thought | 2-1-0-3 |
| 10. | HS 615 | Humanities and Technology | 2-1-0-3 |

Note:

1. A Ph.D. student having **M.Sc./ B.Tech./ B.E. or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*
2. A Ph.D. student having **M.Tech./ M.E./ M.Phil.** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

   * Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

| | |
|---|---|
| Course Code | **HS 600** |
| Course Title | **Data Analysis and Technical Writing** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the concerned discipline/School | Humanities and Social Sciences (HSS) |
| Pre–requisite, if any (for the students) | None |
| Objectives of the course | • To introduce the students the data preparation and analytical methods: quantitative and qualitative research<br>• Technical writing component will include: academic publishing (plagiarism, copyright etc.), writing conference abstracts, proposals, presentations, different styles and different types of manuscripts, different ways of approaching thesis/dissertation writing |
| Course Syllabus | **Quantitative Analysis**: Data preparation: research design, experimental designs, sampling design, measurement techniques, methods of data collection, descriptive statistics<br>Probability and Sampling Distributions: discrete probability distributions (binomial and Poisson), continuous probability distributions (normal), conditional probability, covariance and variance, sampling distribution of Mean and Proportions, other distributions (Chi Square, student's t and F distribution)<br>Inferential statistics: Null hypothesis and alternative hypothesis, hypothesis testing for single population and two populations<br><br>**Qualitative Research**: Anthropological and sociological approaches, timeline, life history, participatory and non-participatory approaches, measurement of human development, poverty, inequality.<br><br>**Technical Writing:** Abstracts for conferences, Project Writing, Thesis Writing, Citation styles and use, Articles/essay manuscript writing, Plagiarism, Reference software (Endnote, Zotero and their uses). |
| Suggested Books | 1. L. Margaret, 2011, *Applied Statistics for Economists*. Routledge Publications. ISBN 978-0-415-77798-8<br>2. Freedman, D., Pisani, R and Purves, R. 2007. *Statistics*. 4th edition, WW Norton & Company, Inc., ISBN 978-0-393-92972-0<br>3. Fleming, M.C. and Nellis, J.G. 2000. *Principles of Applied Statistics*. 2nd Edition. Thomson. ISBN 1-86152-586-9<br>4. MLA , APA and other citation styles. 2007*MLA Handbook* Seventh Edition.<br>5. Davis, Clyde Parker and Detmar Straub, 2008*Writing the Doctoral Dissertation: A systematic Approach,* Gordon Barrons Educational Series, ISBN-13: 978-0764147876<br>6. Wayne C Booth and Gregory Colomb. 2008. *The Craft of Research* Wayne University of Chicago Press ISBN: 978-0226065663<br>7. Gerard Genette and Jane Lewis 1983. Narrative Discourse: An Essay in Method. Cornell University Press. |

<table>
<tr><td>1.</td><td>Course Code</td><td colspan="2">HS 602</td></tr>
<tr><td>2.</td><td>Title of the Course</td><td colspan="2">Foundations of Knowledge</td></tr>
<tr><td>3.</td><td>Credit Structure</td><td colspan="2">L-T- P-Credits<br>2-1-0-3</td></tr>
<tr><td>4.</td><td>Name of the Concerned Discipline</td><td colspan="2">Philosophy</td></tr>
<tr><td>5.</td><td>Pre–requisite, if any</td><td colspan="2">None</td></tr>
<tr><td>6.</td><td>Objectives of the course</td><td colspan="2"></td></tr>
<tr><td rowspan="4">7.</td><td rowspan="4">Course Syllabus</td><td>Epistemology</td><td>Belief-Knowledge-Truth Relationship<br>Knowledge & Justification</td></tr>
<tr><td>Analysis</td><td>Reason vs. Unreason<br>Objectivity vs. Subjectivity<br>The Relativity Problem</td></tr>
<tr><td>Paradigms.</td><td>Philosophy, Science and Society<br>Evolutionary Epistemology vs. Social Epistemology</td></tr>
<tr><td>Culture</td><td>Human Diversity: Need for Epistemology</td></tr>
<tr><td>8.</td><td>Suggested Books</td><td colspan="2">1. Appiah, Kwame Anthony, Thinking it Through: A Introduction to Contemporary Philosophy (New York: OUP, 2003).<br>2. Boghassian, Paul A., The Importance of Subjectivity: Selected Essays in Metaphysics and Ethics (Oxford: Clarenden Press, 2006).<br>3. Cherry, Mark J. (Ed), The Death of Metaphysics; The Death of Culture: Epistemology, Metaphysics, and Culture (Dordrecht: Springer, 2006).<br>4. Edgar, Andrew and Peter Sidgwick, Cultural Theory: Key Thinkers (London: Routledge, 2002).<br>5. Goldman, Alvin I., Knowledge in a Social World (New York: OUP, 1995).<br>6. Kazen, Jean, Philosophy and the Good Life (Oxford: Blackwell Publishing, 1989).<br>7. MacIntyre, Alasdair, The Tasks of Philosophy: Selected Essays, Vol I (Cambridge: CUP, 2006).<br>8. Psillos, Stathis and Martin Curd, The Routledge Companion to the Philosophy of Science (London: Routledge, 2008).<br>9. Recanati, Francois, Perspectical Thought: A Plea for (Moderate) Relativism (Oxford: OUP, 2007).<br>10. Rorty, Richard, Philosophy as cultural Politics: Philosophical Papers, Vol 4 (Cambridge: CUP, 2007).</td></tr>
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| | | |
|---|---|---|
| 1. | Course Code | **HS 603** |
| 2. | Title of the Course | **Epistemology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Philosophy |
| 5. | Pre–requisite, if any | NIL |
| 6. | Objectives of the course | |
| 7. | Course Syllabus | 1. Epistemology: Knowledge as Justified True Belief or Something *Else?*<br>2. Value Problem for Knowledge: Analysis and Structure of Knowledge<br>3. Philosophy: Use, Abuse and Redundancy of Truth<br>4. Philosophy and Naturalism<br>5. Moral Knowledge - Epistemic or Something *Else? Analytical vs. Continental Approaches* |
| 8. | Background Readings | 1. Audi, Robert, *Belief, Justification and Knowledge* (California: Wordsworth Publishing company, 1988).<br>2. Campbell, Richard & Bruce Hunter, *Moral Epistemology Naturalized* (Calgary: University of Calgary Press, 2000). [Canadian Journal of Philosophy Special Supplement Vol 26 (2000)]<br>3. Gadamer, Hans-Georg, *A Century of Philosophy: A Conversation with Riccardo Dattorir*<br>4. Haught, John F., *Is Nature Enough? Meaning and Truth in the Age of Science* (Cambridge: Cambridge University Press, 2006).<br>5. Lihoreau, Franck, *Knowledge and Questions* (New York: Rodopi, 2008).<br>6. Maddy, Penelope, *Second Philosophy: A Naturalistic Method* (Oxford: Oxford University Press<br>7. Nagel, Thomas, *The Last Word* (New York: Oxford University Press, 1997).<br>8. Prichard, Duncan, Alan Millar & Adrain Haddock, *The Nature and Value of Knowledge: Three Investigations* (Oxford: Oxford University Press, 2010).<br>9. Thomas, Lawrence, “Moral Equality and Natural Inferiority”, *Social Theory and Practice* (2005).<br>10. Williams., Bernard, *Truth and Truthfulness: An Essay in Genealogy* (Princeton: Princeton University Press, 2002).<br>11. Williams., Bernard, *Philosophy as a Humanistic Discipline*, Ed. By A. W. Moore (Princeton: Princeton University Press, 2008). |

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|---|---|---|
| 1. | Course Code | **HS 605** |
| 2. | Title of the Course | **Social and Political Philosophy** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Philosophy |
| 5. | Pre–requisite, if any | None |
| 6. | Objectives of the course | |
| 7. | Course Syllabus | The concept of Modernity and its philosophical underpinnings, Nationalism and its moral basis, Democracy and its forms, Secularism and its critiques, Socialism and its alternatives. |
| 8. | Suggested Books | 1. Part I in *Hegel* by Charles Taylor, Cambridge University Press, 1975<br>2. *The Morality of Nationalism* by Robert McKim and Jeff McMahan, Oxford University Press, 1997<br>3. *The Ethics of Nationalism* by Margaret Moore, Oxford University Press, 2001<br>4. *Secularism and its Critics* by Rajeev Bhargava, Oxford University Press, 1998<br>5. *Political Philosophy* edited by Anthony Quinton. Oxford University Press, 1967<br>6. 'Why Socialism' *in Ideas and Opinions* by Albert Einstein. Rupa and Co. Calcutta 1992<br>7. Selected Chapters in *Open Society and its Enemies* Volume II by Karl Popper, Princeton University Press, 1971<br>8. *The Burden of Democracy* by Pratap Bhanu Mehta, Penguin India, 2003<br>9. *Rethinking Democracy* by Rajini Kothari, Zed books, 2007 |

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|---|---|---|
| 1. | Course Code | **HS 606** |
| 2. | Title of the Course | **Moral Philosophy** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Philosophy |
| 5. | Pre–requisite, if any | None |
| 6. | Objectives of the course | |
| 7. | Course Syllabus | The Rationality of the Emotions, Objective Moral Reasons, Moral reasons in Context, Respect for persons, Obligation, Happiness, Moral Responsibility, Facts and Values, Egoism and Altruism, Utilitarianism and its rivals. |
| 8. | Suggested Books | 1. *Ethics: Key Concepts in Philosophy* by Dwight Furrow, Continuum, 2008<br>2. *The Moral Philosophers: An Introduction to Ethics* by Richard Norman, 1998<br>3. *Moral Epistemology* by Aaron Zimmerman, Routledge, 2010<br>4. *Being Good: A Short Introduction to Ethics* by Simon Blackburn, Oxford University Press, 2001<br>5. *The Elements of Moral Philosophy* by James Rachels, McGraw-Hill Publishing, 2009<br>6. *Ethics: History, Theory, & Contemporary Issues* edited by Steven Cahn & Peter Markie, Oxford University Press, 2005<br>7. *Ethical Theory: An Anthology* edited by Russ Shafer-Landau, Blackwell, 2007 |

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|---|---|---|
| 1 | Course Code | **HS 607** |
| 2 | Title of the Course | **Foundations of Social Sciences** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Philosophy |
| 5 | Pre–requisite, if any | For Research Scholars |
| 6 | Objectives of the course | |
| 7 | Course Syllabus | Philosophy of Social Sciences: *The Location of the Social*<br>The Natural and the Social Order<br>*Law and Explanation in Social Sciences*<br>Explanation and Understanding<br>The Interpretative Science: Uncertainty Problem<br>Making the Social World |
| 8 | Suggested Books | 1. Elster, Jon, *Explaining Social Behaviour: More Nuts and Bolts for Social Sciences*<br>2. Gordon, Scoot, *The History and Philosophy of Social Science* (London: Routledge, 1991).<br>3. Habermas, Jurgen, *On the Logic of Social Sciences* (Harvard: MIT Press, 1988).<br>4. Kincaid, Harold, *Philosophical Foundations of Social Sciences: Analysing Controversies in Social Research* (Cambridge: Cambridge University Press, 1996).<br>5. Manicas, Peter T., *A Realist Philosophy of Social Science: Explanation and Understanding* (Ambridge: Cambridge University Press, 2006).<br>6. Mantzavinos, Ed., *Philosophy of the Social Sciences: Philosophical Theory and Scientific Practice* (Cambridge: Cambridge University Press, 2009).<br>7. Martin, Michael & Lee C. McIntyre, Ed., *Readings in the Philosophy of Social Sciences* (Massachusetts: MIT Press, 1994).<br>8. Searle, John, *Making the Social World: The Structure of Human Civilization* (London: OUP, 2010).<br>9. Turner, Stephen & Paul A. Roth, *The Blackwell Guide to the Philosophy of Social Sciences* (Oxford: Blackwell Publishing, 2003). |

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|---|---|---|
| 1 | Course Code | **HS 608** |
| 2 | Title of the Course | **Nations and Nationalism** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Philosophy |
| 5 | Pre–requisite, if any | None |
| 6 | Objectives of the course | |
| 7 | Course Syllabus | Modernity and Nationalism, Moral Psychology of Nationalism, Co-national Partiality, Nationalism and Liberalism, Self-Determination, Citizenship. |
| 8 | Suggested Books | 1. Anderson, Benedict. 1991. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. New York: Verso.<br>2. Balakrishnan, Gopal. 1996. *Mapping the Nation.* New York: Verso.<br>3. Chatterjee, Partha. 1999. *Nationalist Thought and the Colonial World: A Derivative Discourse?* in *The Partha Chatterjee Omnibus*. New Delhi: Oxford University Press.<br>4. Couture, J., K. Nielsen and M. Seymour (eds.). 1998. *Rethinking Nationalism*, *Canadian Journal of Philosophy*, Supplement Volume 22.<br>5. Gans, Chaim. 2003. *The Limits of Nationalism*. Cambridge: Cambridge University Press<br>6. Gellner, Ernest. 1983. *Nations and Nationalism*. Oxford: Blackwell.<br>7. Gilbert, P. 1998. *The Philosophy of Nationalism*. Boulder, Co.: West View Press.<br>8. Hutchinson, John and Anthony D. Smith (eds.). 1994. *Nationalism.* Oxford: Oxford University Press.<br>9. McKim, Robert and Jeff McMahan (eds.). 1997. *The Morality of Nationalism.* New York: Oxford University Press.<br>10. Moore, Margaret. 2001. *The Ethics of Nationalism*. Oxford: Oxford University Press |

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|---|---|---|
| 1 | Course Code | **HS 611** |
| 2 | Title of the Course | **Philosophy of Natural Sciences** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Philosophy |
| 5 | Pre–requisite, if any | None |
| 6 | Objectives of the course | |
| 7 | Course Syllabus | The Sciences of Philosophy and Philosophy of sciences, Sciences and Nature (Scientific Knowledge), Science and Progress of Knowledge, Explanation and Understanding (Physical Sciences and Biological Sciences), Inductive and Deductive Science, Philosophy and Science: Convergence and Difference. |
| 8 | Suggested Books | Books related to Philosophical Foundations of Science, Philosophy of Biology and critical approaches to Philosophy and Science will be referred in this course. |

| | | |
|---|---|---|
| 1 | Course Code | **HS 612 / HS 412** |
| 2 | Title of the Course | **Contemporary Indian Thought** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Philosophy |
| 5 | Pre–requisite, if any | None |
| 6 | Objectives of the course | |
| 7 | Course Syllabus | Rabindranath Tagore, Swami Vivekananda, M.K. Gandhi, V.D. Savarkar, Sri Aurobindo, Krishnachandra Bhattacharyya, B.R. Ambedkar and Jawaharlal Nehru.<br><br>(The course deals with key ideas of some of the contemporary Indian thinkers. The attempt will be to focus on important debates in contemporary Indian Philosophy) |
| 8 | Suggested Books | 1. Bhattacharya, Sabyasachi. *The Mahatma and the Poet: letters and debates between Gandhi and Tagore, 1915-1941*. 1997. New Delhi: National Book Trust.<br>2. Lal, B.K. *Contemporary Indian Philosophy.* 2010. Delhi: Motilal Banarasi Das.<br>3. Raghurama Raju, A. *Debates in Indian Philosophy: Classical, Colonial and Contemporary*. 2007. New Delhi: Oxford University Press.<br>4. Raju, P.T. *Structural Depths of Indian Thought.*1985. New Delhi: South Asian Publishers.<br>5. Moolchand. *Nationalism and Internationalism of Gandhi, Nehru and Tagore.*1989. New Delhi: M.M. Publishers.<br>6. Naravane, Vishwanath S. 1964. *Modern Indian Thought.* Bombay: Asia Publishing House.<br>7. Nagaraj D.R. “Self-purification versus Self–respect” in Raghurama Raju. A (Ed) *Debating Gandhi.* 2006.New Delhi: Oxford University Press.<br>8. Nehru, Jawaharlal. *The Discovery of India.*1994. New York: Oxford University Press, Centenary Edition.<br>9. Sharma, Chandradhar *A Critical Survey of Indian Philosophy.* 2000. Delhi: Motilal Banarasi Das. |

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|---|---|
| Course Code | **HS 615** |
| Course Title | **Humanities and Technology** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the concerned Discipline/School | Humanities and Social Sciences (HSS) |
| Pre-requisite, if any | None |
| Objectives of the course | • To be conversant with various concepts and methods to understand the intersection of Humanities and Technology<br>• Develop the critical thinking skills necessary to evaluate digital scholarship<br>• Collaborate on research in a field that has traditionally privileged individual scholarship<br>• Writing skills through an engagement with writing as a continuing process |
| Course Syllabus | **Digital Humanities**: Authority and Authorship, Knowledge legitimization, expertise and credentialing, institutional histories, nexus of knowledge and power, selecting DH projects, Data mining, Using Gephi or Node XL for beginners<br>**Experimental Method in Cognitive and Behavioral Studies:** Introduction to Experimentation: Experimentation and Scientific Method, Basics of Experimentation. Technological Support and Laboratory Experiment: Experimentation System Development, Computer Assisted Experimentation. Ethical Issues: Privacy and Confidentiality, Legal Liability, Data Sharing.<br>**Intellectual Property Rights**: Copyrights, Copyrights in Digital World, Copyleft, Open Source, Trademarks (Passing Off), Geographical Indications, IPRs and Traditional Knowledge related issues e.g. Biopiracy |
| Suggested books | *1.* Susan Scriebman, Ray Siemens and John Unsworth *Ed A companion to Digital Humanities* Oxford: Blackwell 2004.<br>*2.* David Berry *Understanding Digital Humanities* Palgrave Macmilan, 2012.<br>*3.* Ed Jim Ridolfo and William-Hart Davidson. *Rhetoric and the Digital Humanities* University of Chicago Press, 2013.<br>*4.* Anne Burdick, Johanna Drucker et al. *Digital Humanities* MIT Press, 2013<br>*5.* Mathew God Ed *Introduction to Digital Humanities*, MIT Press, 2008<br>*6.* David W. Martin. (2008). Doing Psychology Experiments. Wadsworth. ISBN 10: 0495115770 / ISBN 13: 9780495115779<br>*7.* Eugene Zechmeister, Jeanne Zechmeister, John Shaughnessy (2009). Essentials of Research Methods In Psychology. McGraw Hill Education (India) Private Limited. ISBN 10: 0070700451<br>8. Allan J. Kimmel (2009). Ethical Issues in Behavioral Research: Basic and Applied Perspectives. John Wiley & Sons. ISBN: 978-1-4051-3439-2<br>9. Elizabeth A. Buchanan (2003). Readings in Virtual Research Ethics: Issues and Controversies. Information Science Publishing. ISBN 13: 9781591401520<br>10. M. Kimberly MacLin and Robert L. Solso (2007). Experimental Psychology: A Case Approach. Pearson. ISBN-13: 978-0205410286<br>11. Orlans Gluck (1997). Ethical Issues in the Use of Animals in Research. Psychology Press. ISBN13: 9780805898606<br>12. Intellectual Property Rights: Patents, Copyrights, Trademarks and Allied Rights by Cornish, LLewelyn and Aplin<br>13. Case studies of Facebook, Darjeeling Tea, Ell Nilly etc. |

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|---|---|
| | 14. Stiglitz, J.E. 1999. "Knowledge as a Global Public Good." In *Global Public Goods: International Cooperation in the 21st Century*, ed. I. Kaul, I. Grunberg, and M.A. Stern. New York: Oxford University Press. |

## Course Structure for Ph.D. Program in English

### (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title (L-T-P-Credits) | L-T-P-Credits |
|---|---|---|---|
| 1 | HS xxx | Elective-I | x-x-x-3 |
| 2 | HS xxx | Elective-II | x-x-x-3 |
| 3. | HS xxx | Elective-III | x-x-x-3 |
| 4 | HS 797 * / HS 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title (L-T-P-Credits) | L-T-P-Credits |
|---|---|---|---|
| 1 | HS xxx | Elective-IV | x-x-x-3 |
| 2 | HS xxx | Elective-V | x-x-x-3 |
| 3 | HS xxx | Elective-VI | x-x-x-3 |
| 4 | HS 798 * / HS 797* | Ph.D. Seminar Course | 0-2-0-2 |

**English course for the Elective-I to VI** *(in addition these courses students can take courses from the other disciplines also)*

| S. No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | HS 600 | Data Analysis and Technical Writing | 2-1-0-3 |
| 2. | HS 642/ HS 442 | Language and Mind | 2-1-0-3 |
| 3. | HS 643 / IHS 443 | Contemporary Short Fiction | 2-1-0-3 |
| 4. | HS 741 | Black Literary Cultures and the Slave Tradition | 2-1-0-3 |
| 5. | HS 742 | Twentieth Century and the European Novel | 2-1-0-3 |
| 6. | HS 743 | Indian English Fiction | 2-1-0-3 |
| 7. | HS 744 | South Asian Diaspora Literature | 2-1-0-3 |
| 8. | HS 745 | Post-Colonial Theory and Criticism | 2-1-0-3 |
| 9. | HS 746 | Translation Studies | 2-1-0-3 |
| 10. | HS 747 | Advanced Literary Theory | 2-1-0-3 |

Note:

1. A Ph.D. student having **M.Sc./ B.Tech./ B.E. or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*

2. A Ph.D. student having **M.Tech./ M.E./ M.Phil.** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

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| 1. | Course Code | **HS 641** |
| 2. | Title of the Course | **English Communication Skills** |
| 3. | Contact Hours | L-T-P<br>2-0-2- [Grades: Pass (PP) or No Pass (NP)] |
| 4. | Name of the Concerned Discipline/School | Humanities and Social Sciences (HSS) |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Communication Fundamentals:** Stages of Communication, Channels of Communication, Technical Communication Skills, Barriers to Effective Communication<br>**Listening Comprehension:** Types of Listening, Listening with a Purpose, Barriers to Listening, Improving Listening comprehension, Listening and Note Taking<br>**Speaking:** The Speech Process, Conversation (Telephonic) and Oral Skills, Body Language, Phonetics and Spoken English, Speaking Techniques in a Global Village<br>**Group Discussion:** Importance of Group Discussion Skills, Characteristics of Successful Group Discussion, Group Discussion Strategies, Techniques for Individual Contribution, Group Interaction Strategies, Group Discussion in Action (video recording)<br>**Presentation Skills:** Planning the Presentation, Preparing the Presentation, Improving Delivery, Checklist for Effective Presentation (oral)<br>**Study Skills:** Reading Comprehension, Note Making Summarising and Paraphrasing, Referencing<br>**Grammar Review:** Parts of Speech, Use of Articles, Prepositions, Modals, Tenses, Active and Passive, For M.S., Direct and Indirect Speeches, Conditional Sentences, Question Tags, Common Errors<br>**Writing Strategies:** Writing Effective Sentences, Sentence Coherence, Paragraph and Essay Writing Report Writing, Proposals and Articles<br>**The Craft of Business Letter Writing:** Essentials of Effective Correspondence, The Lay-out of a Business Letter, Formats for Typing: Block and Indented Styles, Salutation, Subject, Body and Closures, Resumes and Cover Letters<br>**Development of Vocabulary and Soft Skills** |
| 7. | Suggested books | 1. M. Raman and S. Sharma, **Technical Communication: English Skills for Engineers**, Oxford University Press, 2011<br>2. K. Mohan and M. Banerji, **Developing Communication Skills**, McMillan Co., 1990.<br>3. **Oxford Advanced Learner's Dictionary**, Oxford University Press, 2010(8th edition) (with CD).<br>4. M. Swan, **Practical English Usage**, Oxford University Press, 1996.<br>5. Reid & Martin |

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| **Course code** | **HS 642/ HS 442** |
| **Title of the course** | **Language and Mind** |
| Credit Structure | L - T - P – Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Humanities & Social Sciences |
| Pre-requisite, if any | NA |
| Scope of the course | The course aims to build interest of students in the field of language and mind. Language is considered to be the most accessible output of the working of the mind and raises some very important questions for a phenomenon unique to human beings. The course addresses some fundamental questions including how language is represented in our minds, how children acquire language so quickly and effortlessly, the connection between language and thought among others. |
| Course Syllabus | **Nature of Language:** Language as an object of scientific study, essential components of Language, Standard and non-standard languages, basic universal features in phonological, morphological and syntactic systems of language.<br>**Biological Foundations:** Is Language unique to humans? Animals learning language, Nature versus Nurture Debate for Language, Language Acquisition Device, Poverty of Stimulus, Principles and Parameters, Critical Period Hypothesis, Case Studies of Feral Children and language savants, Linguistic Relativism.<br>**Language in the Brain:** Language in the human brain, contra-lateralization, and language centres in the brain, aphasia and its types, specific language impairment, brain plasticity, fundamental differences between first and second language acquisition, sign language. |
| Suggested Books | 1. J. F. Kess, ***Psycholinguistics: Psychology, Linguistics, and the Study of Natural Language***, John Benjamins Publishing, Amsterdam, The Netherlands, 1992, 9789027235848<br>2. N. ChoM.S.ky, ***Lectures on Government and Binding,*** Mouton De Gruyter, Holland, 1981, 9783110141313<br>3. S. D. Krashen, **Second Language acquisition and Second Language Learning,** Pergamon Press Inc, Oxford, 1981, 0080253385<br>4. J. Aitchison, ***The Articulate Mammal: An Introduction to Psycholinguistics***, Routledge, New York, 2008, 0415420164 |

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| 1. | Course Code | **HS 643/ IHS 443** |
| 2. | Title of the Course | **Contemporary Short Fiction** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | English/HSS |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | This course aims to familiarize students with the genre of the short story, a form of writing that has been around ever since human beings began to write the stories. Students will learn to understand the features of the short story and read selected short works written in the $20^{th}$ century from different cultures across the world. Translations of stories in different languages will allow students to recognize the various modes of crafting and narrating short stories across the world. Examples of novellas or the 'long' short story will also be discussed. |
| 7. | Course Syllabus | Discussion of short stories, history of the short story, introduction to prominent short story authors from different cultures and their writings, identify and describe the different features of the genre, story and plot structure, critical writing in the genre, comparison of structure and form with other genres of literature. |
| 8. | Suggested Books | 1. D. Halpern (edited), **The Art of the Story: An International Anthology of Contemporary Short Stories**, Penguin 2000.<br>2. N. Chimamanda Ngozi and J. Lahiri (Edited), **The Global Anthology of Short Stories**, New Internationalist Publishing, May 2009.<br>(Selected 10-12 stories from both these collections)<br>**Background Readings:**<br>1. M H Abrams **Glossary of Literary terms,** Wadsworth Publishing, 2011.<br>2. Selected electronic articles that I will provide links to or copies from time to time. |

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| 1. | Course Code | **HS 741** |
| 2. | Title of the Course | **Black Literary Cultures and the Slave Tradition** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | The Course will focus on selected writings and excerpts from the above authors. The attempt will be to study some of these works and writers in tandem so as to trace the evolution of Black Intellectual thought and its ideational influence on Black Narratives |
| 7. | Course Syllabus | Phillis Wheatley, **Iola Leroy,** Frances E.W. Harper, **Our Nig,** Harriet E. Wilson, Martin Delany,<br>**Narrative of the Life of Frederick Douglass,** Frederick Douglass<br>**The Souls of Black Folk,** W E B Du Bois, Langston Hughes, Zora Neale Hurston, James Baldwin, Richard Wright, Ralph Ellison, Harold Cruse, Angela Davis, CLR James, V.Y. Mudimbe, Achille Mbembe, Leopold Senghor, Franz Fanon, Cornel West, Samuel R Delany, Octavia Butler, Randall Keenan, Colson Whitehead, |
| 8. | Suggested Books | 1. An Introduction to Africana Philosophy, Lewis Gordon<br>2. African American Perspectives and Philosophical Traditions, John P. Pittman<br>3. Blacks and Social Justice, Bernard R. Boxill.<br>4. The Signifying Monkey, Henry Louis Gates.<br>5. The Practice of Diaspora: Literature, Translation and the Rise of Black Internationalism, Brent Hayes Edwards<br>6. Playing in the Dark: Whiteness and the Literary Imagination, Toni Morrison.<br>7. African American Literary Theory: A Reader, Winston Napier |

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| 1. | Course Code | **HS 742** |
| 2. | Title of the Course | **Twentieth Century and the European Novel** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | An attempt will be made to position the genre as a mode of response to a period of volatility and turbulence on the European continent. The course could include selections from other genres and alternative media in order to examine concepts such as nation, state and citizenship and the way in which these concepts pan out in literary narrative. |
| 7. | Course Syllabus | Marcel Proust – *Swan in Love*<br>Thomas Mann – *Dr. Faustus*<br>Franz Kafka – *The Trial*<br>Albert Camus – *The Outsider*<br>Joseph Roth- *The Radetsky March*<br>Italo Calvino- *If on a winter's night a traveler* |
| 8. | Suggested Books | 1. Mikhail Bakhtin, *Dialogic Imagination*<br>2. Milan Kundera, *The Art of the Novel*<br>3. Roland Barthes, **A Barthes Reader, ed. by Susan Sontag**<br>4. André Brink, **The Novel: Language and Narrative from Cervantes to Calvino**<br>5. Georg Lukács, **The Theory of the Novel**<br>6. Jenny Mander, **Remapping the Rise of the European Novel**<br>7. Christopher Nash, **World-games: the tradition of anti-realist revolt**<br>8. Vladimir Nabokov, *Lectures on Literature*<br>9. Jacques Derrida*, Spectres of Marx*<br>10. Giorgio Agamben*, State of Exception*<br>11. Alain Badiou*, Being and Event*<br>12. Sigmund Freud, *Civilization and its Discontents* |

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| 1. | Course Code | **HS 743** |
| 2. | Title of the Course | **Indian English Fiction** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | The course will make an attempt at examining the varied ways in which the notion of India has been explored by the various practitioners of Indian English fiction. Through an analysis of some of the representative Indian fiction in English and close reading of some relevant excerpts from the texts, some of the issues which may be discussed in some detail in the class are: "anxiety of Indianness", "the role of target audience in the author's depiction of India", "India as a nation state", "postcolonial India", "urban-rural divide in India", "portrayal of marginalized India on the basis of caste, class, religion, gender, region", "stereotypes and realities in depicting India", "India of Indian English Fiction versus India of Regional Language Literatures", "Indian identity", "notions of 'local', 'global', 'glocal'",etc. The list of texts mentioned are only indicative and other relevant texts could be included to explore these issues further or to bring in new perspectives. The background readings will be helpful in familiarizing the students with some of the issues at hand and their complexities. |
| 7. | Course Syllabus | Rao, Raja. *Kanthapura;* Narayan, R. K. *Malgudi Days;* Anand, Mulk Raj. *Untouchable;* Singh, Khushwant. *A Train to Pakistan;* Desani, G. V. *All About H. Hatter;* Rushdie, Salman. *Midnight's Children;* Tharoor, Shashi. *The Great Indian Novel;* Mathur, Anurag. *The Inscrutable Americans;* Das, Manoj. *Cyclones;* Roy, Arundhati. *God of Small Things;* Lahiri, Jhumpa. *Interpreter of Maladies;* Swarup, Vikas. *Q & A;* Deb, Siddhartha. *Surface;* Adiga, Aravind. *The White Tiger;*<br>Raj, M. C. *Raachi* |
| 8. | Suggested Books | 1. Mukherjee, Meenakshi. *The Perishable Empire: Essays on Indian Writing in English*<br>2. Mukherjee, Meenakshi. *The Twice Born Fiction*<br>3. Vijay Kumar, T, Mukherjee, Meenakshi, Harish Trivedi, et al, eds. *Focus India: Postcolonial Narratives of the Nation*<br>4. Mukherjee, Meenakshi. *Realism and Reality: The Novel and Society in India*.<br>5. Mukherjee, Meenakshi, Vijayasree, C. *Nation in Imagination*<br>6. Khair, Tabish. *Babu Fictions: Alienation in Contemporary Indian English Novels*<br>7. Naik, M. K., Narayan, Shymala, A. *Indian English Fiction: A Critical Study*<br>8. Bates, Crispin. *Beyond Representation: Colonial and Postcolonial Constructions of Indian Identity* |

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| 1. | Course Code | **HS 744** |
| 2. | Title of the Course | **South Asian Diaspora Literature** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | The concept of Diaspora as a state of deterritorialization is perhaps a common theme that runs across the various implications of the term extending but not confined to ideas of exile, displacement and migration, forced or otherwise. While recognizing that there is always a hint or trace of the roots / home that defines the cultural and historical identity of the exile / migrant the course will seek to build a healthy wariness of essentializing threads of race or ethnicity that limit discussions to those that revolve around nationhood. |
| 7. | Course Syllabus | Paranjape, Makarand. *In Diaspora: Theories, Histories, Texts*. New Delhi: Indialog Publications, 2001; Bose, Neilesh, Ed. *Beyond Bollywood and Broadway: Plays from the South Asian Diaspora*. Bloomington: Indiana University Press, 2009 (selected plays); Baldwin, Shauna Singh. *We Are Not in Pakistan*. New Delhi: Rupa, 2009; Refiq, Fauzia, Ed. *Aurat Durbar: Writings by Women of South Asian Origin.* Toronto: Second Story Press, 1995; Diane McGifford, Ed. *Geography of Voice: Canadian Literature of the South Asian Diaspora*. Toronto: TSAR, 1992; Ghosh, Amitav. *The Shadow Lines*. London: BlooM.S.buy, 1988;<br>Kureishi, Hanif. *The Buddha of Suburbia*. New York: Viking, 1990; Mathur, Anurag. *The Inscrutable Americans*. Kolkata: Rupa & Co, 1991. |
| 8. | Suggested Books | 1. Mishra, Vijay. *The Literature of the Indian Diaspora: Theorizing the Diasporic Imaginary*. New York: Routledge, 2007.<br>2. Nasta, Susheila. *Home Truths: Fictions of the South Asian Diaspora in Britain*. London: Palgrave Mcmillan, 2001.<br>3. Pirbhai, Mariam. *Mythologies of Migration, Vocabularies of Indenture: Novels of the South Asian Diaspora in Africa, the Caribbean, and Asia-Pacific.* Toronto: University of Toronto Press, 2009.<br>4. Rushdie, Salman. *Imaginary Homelands: Essays and Criticism, 1981-1991.* London: Granta Books, 1991. |

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| 1. | Course Code | **HS 745** |
| 2. | Title of the Course | **Postcolonial Theory and Criticism** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the Course | The course will build on introductory concepts in the field of post-colonialism using them to see if a move can be made away from the advocacy of the conventional empire model. The readings of texts such as *The travels of Dean Mohammed*, *A Passage to India*, *Oroonoko*, *Mansfield Park*, *Wide Sargasso Sea*, *Heart of Darkness* and the stories of Tagore among others will strive to establish a premise for the study of postcolonial texts based on more intimate spaces such as folkways, societal ritual, language and religion, eventually helping the reader to think in terms of "imagined communities" rather than ones that are historically generated. |
| 7. | Course Syllabus | 1. Ashcroft, Bill, Gareth Griffiths, and Helen Tiffin. *The Empire Writes Back: Theory and Practice in Post-colonial Literatures.* New York: Routledge, 1989.<br>2. *The Post-Colonial Studies Reader*. New York: Routledge, 1995.<br>3. Loomba, Ania. *Colonialism/ Postcolonialism*. New York: Routledge, 1998.<br>4. Bhabha, Homi K. *The Location of Culture*. New York: Routledge, 1994.<br>5. *Nation and Narration*. New York: Routledge, 1990.<br>6. Said, Edward W. *Culture and Imperialism*. New York: Knopf, 1994.<br>7. *Orientalism*. New York: Pantheon, 1978.<br>8. Spivak, Gayatri Chakravorty. *In Other Worlds: Essays in Cultural Politics*. New York: Routledge, 1987.<br>9. Trivedi, Harish, and Meenakshi Mukherjee, eds. *Interrogating Post-Colonialism: Theory, Text and Context*. Shimla: IIAS, 1996. |
| 8. | Suggested Books | 1. Fanon, Frantz. *Black Skin, White Masks*. Tr. Constance Farrington. New York: Grove Press, 1994.<br>2. *The Wretched of the Earth*. Tr. Richard Philcox. New York: Grove Press, 2005.<br>3. Williams, Patrick, and Laura Chrisman, eds. *Colonial Discourse and Post-colonial Theory: A Reader*. New York: Columbia University Press, 1994.<br>4. Chrisman, Laura and Benita Parry. *Postcolonial Theory and Criticism.* New York: D. S. Brewer, 2000. |

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| 1. | Course Code | **HS 746** |
| 2. | Title of the Course | **Translation Studies** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | The course will involve a study of primary texts that have been self-translated by authors such as Manoj Das, Girish Karnad, O.V. Vijayan and Rabindranath Tagore. The background readings will be helpful in familiarizing the students with some of the issues at hand and their complexities. |
| 7. | Course Syllabus | Amos, F. R. R. *Early Theories of Translation*. New York: Octagon, 1973.<br>Anderman, G. *Europe on Stage: Translation and Theatre*. London: Oberon Books, 2005.<br>Bassnett, S. Translation Studies. London: Routledge, 1980.<br>Bassnett, S. and Lefevere, A. *Constructing Cultures: Essays on Literary Translation*. Clevedon: Multilingual matters, 1998.<br>Bassnett, S. and Trivedi, H, eds. *Postcolonial Translation: Theory and Practice*. London: Routledge, 1999.<br>Chaudhuri, S. *Translation and Understanding*. Delhi: Oxford University Press, 1999.<br>Cheyfitz, E. *The Poetics of Imperialism: Translation and Colonization from The Tempest to Tarzan*. London: Oxford University Press, 1991.<br>Kothari, R. *Translating India*. Manchester: St Jerome, 2003.<br>Lefevere, A. *Translation, Rewriting and the Manipulation of Literary Fame*. London: Routledge, 1992.<br>Toury, G. *In Search of a Theory of Translation*. Tel Aviv: Porter Institute, 1980. |
| 8. | Suggested Books | 1. Bly, R. *The Eight Stages of Translation*. Boston: Rowan Tree, 1983.<br>2. Cronin, M. *Translation and Globalization*. London, Routledge, 2003.<br>3. Katan, D. *Translating Cultures*. Manchester: St. Jerome, 2004.<br>4. Kreiswirth, M. and Cheetham, M. A., eds. *Theory Between the Disciplines: Authority / Vision / Politics*. Ann Arbor: The University of Michigan Press, 1990. |

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|---|---|---|
| 1. | Course Code | **HS 747** |
| 2. | Title | **Advanced Literary Theory** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Discipline | English |
| 5. | Pre–requisite, if any | NIL |
| 6. | Scope of the course | This course aims to familiarize research students with the fundamentals of theoretical vocabulary and understand the works of important theorists in the discipline. The course uses the Norton Anthology of Theory and Criticism as the overarching text to select the particular theorists and works to be covered based on the research interests of the students of a particular semester. The other seminal texts are selected keeping in mind some of the relevant questions of criticism in the discipline. Postcolonial Studies, Politics of language, translations are some of the areas covered in depth. Faculty teaching the course can add other works relevant to the broad area of literary theory for any particular semester. This can change based on individual faculty and student research areas. The aim of the course is to discuss the role of theory in literary discourse and its importance in critically examining the contexts of literary works that may lead to new ways of reading and understanding different works. The course offers an in-depth understanding of theoretical terminology that enables students to develop a sense of the strengths and weaknesses of the well-known schools of theory. Most importantly, the course aims to train them to recognize the parameters from which the terminology emerges and develop the ability to analyze incisively and offer new ways of (re)configuring meta narratives. |
| 7. | Course Syllabus | Formalism, Reader-response theory, Rhetoric, Dialecticism, Structuralism, Post-structuralism, Post-colonialism, Translation Theories, Deconstruction, Feminist and Gender studies, Race Theory, Cultural Studies will be some of the major schools of theory covered. |
| 8. | Suggested Books | 1. Charu Gupta, Ed. *Gendering Colonial India: Reforms, Print, Caste and Communalism*. Orient Blackswan, New Delhi.<br>*2.* David Damrosch. *What is World Literature?* Princeton University Press, NJ 2003<br>3. Eagleton, Terry. *Literary Theory: An Introduction.* University of Minnesota Press, 2008.<br>4. Foucault, Michel. *Discipline and Punish: The Birth of the Prison,* translated by Allen Sanders, 1971.<br>5. GJV Prasad and Makarand Paranjpe Ed **Indian English and Vernacular India: Contests and Contexts**. New Delhi: Pearson Longman, 2010.<br>6. Jeffrey T Nealon and Susan Giroux, *The Theory Toolbox: Critical Concepts for the New Humanities,* Rowman and Littlefield, Lanham, MD 2003.<br>7. Loomba, Ania and Esty, Jed Edited. *Postcolonial Studies and Beyond* Duke University Press, New York, 2005.<br>8. Paranjpe, Makarand Ed. **Nativism: Essays in Literary Criticism***. New Delhi: Sahitya Akademi, 1997* |

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| | | 9. **Another Canon: Indian Texts and Traditions in English**. London: Anthem Books, 2009; Paperback ed, New Delhi: Anthem Press, 2010.<br>10. Spivak, Gayatri. *A Critique of Postcolonial Reason: Toward a History of the Vanishing Present,* Harvard University Press, 1999.<br>11. *The Aesthetics of Education in the Age of Globalization,* Harvard University Press, 2012.<br>12. Satya Mohanty. *Literary Theory and the Claims of History: Postmodernism, Objectivity and Multicultural Politics*. Cornell University Press, 1997.<br>13. Trivedi, Harish and Susan Bassnett: *Postcolonial translation Studies*.<br>14. Vincent Leitch, Barabara Johnson, John McGowan et al edited *Norton's Anthology of Theory and Criticism.* W.W. Norton, 2010.<br>**Primary Works of Literature (just a sample, can be changed by the Course Instructor)**<br>1. Amitav Ghosh. *In an Antique Land* Permanent Black, Ravi Dayal Press 2009.<br>- *The Glass Palace.* Random House February 2002; *Sea of Poppies.* 2010<br>2. Mahashweta Devi. (translated by Gayatri Spivak) *Imaginary Maps.* Routledge, New York 2002.<br>3. Mahashweta Devi (translated by Suman Gangopadhyay): *Mother of 1084*<br>4. Lalithambika Antherjanam (Translated by Gita Krishnankutty): *Cast me Out if you Will.*<br>5. Shakespeare, William. *The Tempest.* Norton Critical Edition, Ed Sherman, William. |

## Course Structure for Ph.D. Program in Economics

### (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | HS 601 | Research Methods in Social Sciences | 2-1-0-3 |
| 2 | HS 623 | Advanced Microeconomics-I | 2-1-0-3 |
| 3. | ZZ xxx | Elective-I | x-x-x-3 |
| 4 | HS 797 * / HS 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | HS 624/ HS 424 | Econometrics-I | 2-1-0-3 |
| 2 | HS xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III + | x-x-x-3 |
| 4 | HS 798 * / HS 797* | Ph.D. Seminar Course | 0-2-0-2 |

Economic courses for Electives-I, II, and III
(In addition to these courses, students can also take courses from other disciplines)

| S.No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | HS 600 | Data Analysis and Technical Writing | 2-1-0-3 |
| 2. | HS 618 / HS 418 | Sustainability Studies | 2-1-0-3 |
| 3. | HS 622 / IHS 422 | Development Economics | 2-1-0-3 |
| 4. | HS 626 | Environmental and Natural Resource Economics | 2-1-0-3 |
| 5. | HS 628 | Institutional Economics | 2-1-0-3 |
| 6. | HS 630 | Intellectual Property Rights | 2-0-0-2 |
| 7. | HS 724 | Econometrics-II | 2-1-0-3 |

+ Additional elective course to be taken by the students with MA/ M.Sc. /B.Tech./BE qualification only.

* Ph.D. Seminar course can be taken either in Autumn (HS 797) or in Spring Semester (HS 798) or both as suggested by the Faculty Advisor/Thesis Supervisor.

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|---|---|---|
| 1. | Course Code | **HS 601** |
| 2. | Title of the Course | **Research Methods in Social Sciences** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | None |
| | Scope of the Course | |
| 6. | Course Syllabus | Foundations- language, philosophy, conceptualization and evaluation of research;<br>Sampling-probability and non-probability sampling; Measurement- construct validity and reliability; Survey research- types of surveys and interviews; Scaling- Thurston, Likert and Guttman scaling;<br>Qualitative Measures- data, approaches and validity, Design- Experimental and quasi-experimental,<br>Analysis- data preparation, descriptive statistics, hypothesis testing, multivariate analysis (inferential statistics),<br>Report Writing. |
| 7. | Suggested Books | 1. W.T. Trochim, **Research Methods: The Concise Knowledge Base,** Atomic Dog Publisher, 2004. (ISBN: 1592601464)<br>2. C.R. Kothari, **Research Methodology: Methods and Techniques** ($2^{nd}$ edition), New Age International, 2009.<br>3. R.V. Hogg, A. Craig, and McKean. **Introduction to Mathematical Statistics** ($6^{th}$ Edition), Prentice Hall, 2004 (ISBN 130085073) |

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|---|---|---|
| 1. | **Course Code** | **HS 618 / HS 418** |
| 2. | **Title of the Course** | **Sustainability Studies** |
| 3. | Credit Structure | L-T-P-Credits<br>3-0-0-3 |
| 4. | Name of the Concerned Discipline | Humanities and Social Sciences |
| 5. | Pre–requisite, if any | None |
| 6. | Course Objective | The course introduces and details the concepts in sustainability from the social sciences and basic sciences perspectives. It will include definitions, theories, historical developments, applications and case study references. The course will also include a module on Eco-criticism in literature, theoretical discourses and examples from contemporary literature. |
| 7. | Course Syllabus | Introduction to sustainability, Climate change, biosphere, physical resources: water, pollution, and minerals, resource economics<br><br>Systems Dynamics, models in natural sciences<br><br>Sustainable energy systems, Problem solving: metrics, and tools; Agro-food systems, renewable resources: water fish and forests, Non-renewable resources: oil<br><br>Sustainable infrastructure<br><br>Eco-criticism including eco-feminism and deconstruction of rhetoric of environment studies. Definition of eco-critical theory and practice, observing the more recent influence of interdisciplinary, ecological perspectives in criticism and theory (the emergence of 'eco-criticism') and considering their implications for the interpretation of literature and the creation of writing, environmental foundations of the global economy, Narratives of development in postcolonial writing |
| 8. | Suggested Text Books | 1. Theis and Tomkin (Ed.) 2011. Sustainability: Comprehensive. Foundation University of Illinois Open Source Text Book Initiative. ID: 1741effd-9cda-4b2b-a91e-003e6f587263@43.5<br>2. Bert J.M. de Vries2012 Sustainability Science Cambridge University Press, ISBN 9780521184700<br>3. Mulligan, M. 2015. An Introduction to Sustainability: Environmental, Social and Personal Perspectives. Routledge Publications ISBN 9780415706438<br>4. Newton A.C. and Cantarello E. 2014 An Introduction to the Green Economy: Science Systems and Sustainability. Routledge Publications. ISBN 978 0415 711609<br>5. Ed. CheryllGlotfelty and Harold Fromm. 1996. *The Ecocriticism Reader.* University of Georgia Press<br>6. AmitavGhosh 2010. *The Glass Palace* Harper Collins<br>7. Mahashweta Devi. 2008. *Imaginary Maps.* Routledge<br>8. Westling, Louise. "Literature and Ecology" (75-90). *Teaching Ecocriticism and Green Cultural Studies.* Ed. by Greg Garrard.<br>9. Timothy Clark, *The Cambridge Introduction to Literature and the Environment* |

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|---|---|---|
| 1. | Course Code | **HS 622 / IHS 422** |
| 2. | Title of the Course | **Development Economics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Economics/HSS |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course offers a broader understanding of economic transformation of developing countries. It discusses issues in per capita income, economic growth, inequality, poverty, population. It also aims at analyzing land, labour and insurance sector. At the macro level the course will orient students about political economy of international trade, monetary policy and international relations from developing country perspective. |
| 7. | Course Syllabus | Trends in international development; Basic features of underdeveloped countries/ LDCs; Development indices, Growth and development theories, Dual economy models, Domestic resources and foreign resources and economic development, Industrialization, protection and trade policies, Strategy towards foreign capital external finances; Strategy towards imports /export balance of payments; Balanced / unbalanced growth approach; Sectoral strategy; population, poverty, employment, migration, Some recent contributions to development theory; Trade and development, The global strategy: new international economic order (NIEO); The policy of structural adjustment, environment and development. |
| 8. | Suggested Books | 1. S. Ghatak, **Introduction to Development Economics,** Routledge Publication. 2003. 4th edition.<br>2. D. Ray. **Development Economics,** Princeton University Press. 1998.<br>3. G. Meier, and J. Stiglitz, **Frontiers of Development Economics,** Oxford University Press, 2001.<br>**Reference Readings:**<br>1. A. Sen, **Development as Freedom,** Oxford University Press, 1999.<br>2. P. Draper, P. Alves, R. Sally (editors), **The political Economy of Trade Reform in Emerging Markets: Crisis or Opportunity?"** Edward Elgar Publishing, 2009.<br>3. R. Capello, and Nijkamp, **Handbook of Regional Growth and Development Theories,** Edward Elgar Publishing, 2009.<br>4. O. Galor, **Inequality and Economic Development: The Modern Perspective,** Edward Elgar Publishing, 2009.<br>5. D. WilliaM.S., **International Development and Global Politics: History, Theory and Practice,** Routledge Publication, 2011.<br>6. Y. Hayami, and Godo, **Development Economics: From the Poverty to the Wealth of Nations,** Oxford University Press, 2005. |

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|---|---|---|
| 1. | Course Code | **HS 623** |
| 2. | Title of the Course | **Advanced Microeconomics-I** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | Some UG/PG level course on Microeconomics |
| 6. | Scope of the Course | The course aims at providing students with the recent advancements in the theory of Microeconomics and take up the concepts covered at undergraduate level at higher level. |
| 7. | Course Syllabus | Preference and Choice; Classical Demand Theory; Production; Choice Under Uncertainty<br>Game Theory<br>Market Equilibrium and Market Failure: Competitive Markets, Externalities and Public Goods, Market Power, Asymmetric Information<br>Theory of Welfare, General equilibrium theory. |
| 8. | Suggested Books | 1. H.R. Varian, Microeconomic Analysis (3rd edition), W.W. Norton and Company. 1992.<br>2. A. Mas-Colell, M.D. Whinston, and J.R. Green, Microeconomic Theory, 2006.<br>3. Reading Material in form of research articles to be provided to the students. |

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|---|---|---|
| 1. | Course Code | **HS 624/ HS 424** |
| 2. | Title of the Course | **Econometrics-I** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | Research Methods in Social Sciences; Basic Statistics |
| 6. | Scope of the Course | This aim of the course is to cover basic econometrics with focus on regression modeling and the problems encountered in dealing with cross-section and time series data. |
| 7. | Course Syllabus | Methodology of econometrics; Regression analysis; Assumptions of the classical linear regression Models; Two variable regression analyses;<br>Multiple regression analyses;<br>Heteroscedasticity; Autocorrelation and Multicollinearity;<br>Dummy variable regression models;<br>Model Selection;<br>Time Series Econometrics (introduction);<br>Panel data regression models (introduction). |
| 8. | Suggested Books | 1. D.N. Gujarati, Basic Econometrics, The McGraw-Hill Companies. 2005.<br>2. G.S. Maddala, Introduction to Econometrics, (3rd edition) Wiley, 2001.<br>3. J.M. Wooldridge, Introductory Econometrics: A Modern Approach, South Western, 2009. |

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|---|---|---|
| 1. | Course Code | **HS 626** |
| 2. | Title of the Course | **Environmental and Natural Resource Economics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Environmental Challenges- Role of economics,<br>Valuing the environment- concepts and methods,<br>Property rights, externalities and environmental problems, sustainable development,<br>Allocation of resources- depletable and renewable- energy, minerals, water, land;<br>Environmental pollution- air, water;<br>Environmental justice, Sustainability of development. |
| 8. | Suggested Books | 1. T. Tietenberg, and L. Lewis, Environmental and Natural Resource Economics (International Edition) Pearson Education, 2008 (ISBN 9780321560469).<br>2. J. Conrad, Resource Economics, Cambridge University Press, 1999.<br>3. Hanley, N., Shogren, J., and B. White, Environemntal Economics in Theory and Practice (2nd edition), Palgrave MacmIllan: UK, 2007.<br>4. Pearce, D., Turner, K., and I. Bateman, Environmental Economics: An Elementary Introduction, Pearson Education Ltd.: England, 1994.<br>5. Birnie, P., Boyle, A., and C. Redgwell, International Law and the Environment (3rd edition), Oxford University Press: Oxford, New York, 2009. |

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| 1. | Course Code | **HS 628** |
| 2. | Title of the Course | **Institutional Economics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | Microeconomics, History of Economic Thought |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Introduction:** Institutions and Organizations, Structure of Institutions (formal and informal), Old and New Institutional Economics;<br>**Transaction costs:** types and cost measurement;<br>**Theory of property rights:** Externalities, Internalization of externalities, Coase Theorem, Common property, Collective action;<br>**Contracts:** legal and economic approach, Asymmetric information, adverse selection, Asset plasticity and moral hazard;<br>Institutional theory of firm, market, regulation;<br>Institutional Change. |
| 8. | Suggested Books | 1. Eggertson, T. *Economic Behaviour and Institutions.* Cambridge: Cambridge University Press, 1990.<br>2. North D. *Institutions, Institutional Change and Economic Performance.* Cambridge: Cambridge University Press, 1990.<br>3. Furubotn, E, and R. Richter. *Institutions and Economic Theory.* The University of Michigan Press, 1997.<br>4. Claude, M. and M.M. Shirley (Eds.) Handbook of New Institutional Economics, US: Springer, 2008. |

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|---|---|---|
| 1. | Course Code | **HS 630** |
| 2. | Title of the Course | **Intellectual Property Rights** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-0-2 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The course aims at providing the basic understanding of intellectual property rights, the rationale behind making provision for these rights and the recent concerns in the field. |
| 7. | Course Syllabus | History and concept of Property; Introduction to intellectual property rights (IPRs); Patent, Industrial design; Copyrights, Trademarks, Geographical Indications; Trade Secrets; International aspect of IPRs; Developments at the International level regarding IPRs; The debate: Copyright vs Copy left; Research ethics |
| 8. | Suggested Books | 1. Cornish, W.R. and L. David. 2010. 7th Edition. Intellectual Property: Patents, Copyrights, Trademarks and Allied Rights. Sweet and Maxwell.<br>2. Narayan, P. 2002. Intellectual Property, Law in India, 3rd Ed. New Delhi, Delhi Law House.<br>3. Ganguli, P. 2001. Intellectual Property Rights: Unleashing the Knowledge Economy. Tata McGraw Hills (Reference)<br>4. Watal, J. 2001. Intellectual Property Rights in the WTO and Developing Countries. New Delhi: Oxford University Press |

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|---|---|---|
| 1. | Course Code | **HS 724** |
| 2. | Title of the Course | **Econometrics-II** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Economics |
| 5. | Pre–requisite, if any | **Econometrics I** |
| 6. | Scope of the Course | The aim of the course is to cover econometric modeling for panel data as well as time series. It will also focus on simultaneous equation modeling and models dealing with discrete data. |
| 7. | Course Syllabus | Classical linear regression model; Specification Analysis and Model Selection; Heteroscedasticity; Serial Correlation; Models for Panel Data; Systems of Regression Equations; Simultaneous-equation models; Models with lagged variables; Time-series models; Models for discreet choice. |
| 8. | Suggested Books | 1. Greene, W. H. 2005. *Econometric Analysis*. 5th ed. New Delhi: Pearson Education.<br>2. Baltagi, B.H. 2005. Econometric Analysis of Panel Data. 3rd ed. West Sussex: John Wiley & Sons.<br>3. J.M. Wooldridge, 2001. Econometric Analysis of Cross Section and Panel Data, MIT Press.<br>4. W. Enders, 2004. Applied Econometric Times Series (2nd Edition), Wiley. |

## Course Structure for Ph.D. Program in Psychology

### (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3. | ZZ xxx | Elective-III | x-x-x-3 |
| 4 | HS 797 * / HS 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title () | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI | x-x-x-3 |
| 4 | HS 798 * / HS 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Psychology courses for Electives-I to VI** *(in addition to these courses, students can also take courses from other disciplines, in consultation with the thesis supervisor/faculty advisor and the concerned course coordinator.)*

| S.No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | HS 600 | Data Analysis and Technical Writing | 2-1-0-3 |
| 2. | HS 671 | Human Factors and Higher Cognitive Processes | 2-0-2-3 |

Note:

1. A Ph.D. student having **M.Sc./ B.Tech./ BE or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*
2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

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|---|---|---|
| 1. | Course Code | **HS 671** |
| 2 | Title of the Course | **Human Factors and Higher Cognitive Processes** |
| 3. | Credit Structure | L-T-P-Credit<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline/ School | Psychology/Humanities & Social Sciences |
| 5. | Pre-requisite, if any (for the students) | Basic Understanding of Psychology |
| 6. | Course Objective | The aim of the course is to familiarise students with a wide range of theories and research investigating human factors. As an advanced course, the course normally covers all the areas specified in the syllabus, but students wishing to concentrate especially on particular topic areas may do so by agreement with the instructor as a part of project/practicum portion. The course has been developed to be as interesting and challenging as possible. The following are the objectives of the course:<br>1. To develop understanding of the breadth of different approaches to human factors practices.<br>2. To gain awareness of the principles and perspectives of human factors through the study of theories, concepts, and research.<br>3. To develop the ability to apply human factors research to real-world issues.<br>4. To understand how to critically appraise concepts, theories, and empirical evidence.<br>5. To be familiar with a range of research methods. |
| 7. | Course Syllabus | **Understanding Human Factors:** Introduction and Background to Human Factors, Defining Design, System Thinking, and Sociotechnical System.<br>**Human System Interaction: Affective and Cognitive Processes in System Development, Design, and Evaluation:** User & Interactive Systems, User Cognition, Emotion, HCI, Complex Systems, Human Error, Human Performance, Human Centered Engineering, Usability & Human-Centered Systems Design.<br>**Cognitive Ergonomics:** Visual Cognition & Attention, Eye Movement, Visual Perception, and Computer Vision Syndrome.<br>**Ergonomics Standards:** Displays, The EC directives, Technical standards.<br>**Strategic Practices:** Social & Cultural Contexts, Design thinking, Business Design, Social Innovation, Democratic |

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|---|---|---|
| | | Design, Transformation.<br>**Research Practitioner:**<br>• Research Methods, Usability Evaluation, Reporting, Recent Developments.<br>• Professional Issues: ISE, HFES; EACE, FEES, IEA, EAEFS, SEAES, SEANES, BCPE; Accreditation; Training & Employment. |
| 8. | Suggested Books | **Textbooks:**<br>1. C. D. Wickens, J. G. Hollands. **Engineering Psychology and Human Performance** (3rd Ed.), Prentice Hall, 1999.<br>2. C. D. Wickens, J. L. Lee, Y. D., & Gordon-Bekcer, S. **An Introduction to Human Factors Engineering** (2nd Ed.). Upper Saddle River, NJ: Prentice Hall. 2004.<br>**Reference Readings:**<br>1. M. S. Sanders & E. J. McCormick. **Human factors in Engineering and Design** (7th Ed.). New York: McGraw-Hill. 1993.<br>2. Pamela McCauley Bush. **Ergonomics Foundational Principles, Applications, and Technologies**. 2011.<br>3. Norman, D. A. **The design of everyday things**. New York: Basic Books. 2002.<br>4. Casey, S. M. **Set Phasers on Stun**. Santa Barbara, CA: Aegean. 1998.<br>5. Stanton, N., Hedge, A., Brookhuis, K., & Salas, E. (Eds.). **Handbook of human factors and ergonomics methods**. 2004. |

## Course Structure for Ph.D. Program in Sociology

### (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3. | ZZ xxx | Elective-III | x-x-x-3 |
| 4 | HS 797 * / HS 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI | x-x-x-3 |
| 4 | HS 798 * / HS 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Sociology courses for Electives-I to VI** *(in addition to these courses, students can also take courses from other disciplines, in consultation with the thesis supervisor/faculty advisor and the concerned course coordinator.)*

| S. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | HS 600 | Data Analysis and Technical Writing | 2-1-0-3 |
| 2. | HS 616 | Advanced Sociological Theory | 2-1-0-3 |
| 3. | HS 680 | Sociology of Religion | 2-1-0-3 |

Note:

1. A Ph.D. student having **M.Sc./ B.Tech./ BE or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*
2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

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|---|---|---|
| 1 | **Course Code** | **HS 616** |
| 2 | **Course Title** | **Advanced Sociological Theory** |
| 3 | Credit structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Humanities and Social Sciences |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To provide an overview of the major thinkers and their works in the area of contemporary sociological theory with a special emphasis on the epistemology and ontology of social research;<br><br>The focus will be on the practice of sociological research and study of developmental problems of modern society by dismantling barriers between theoretical and empirical sociology. |
| 7. | Course Syllabus | **The structure of sociological theory**<br>Subject matter and objectives;<br>Talcott Parsons and his Grand Theory<br>Robert Merton: Middle-range theory<br><br>**Conflict theory and the critique of society**<br>Marx and Weber: Power, position and Legitimacy<br>Simmel and the Chicago School: The web of conflict<br><br>**The Frankfurt School and Critical Theory**<br>Adorno and Horkheimer, Enlightenment as Mass Deception.<br>Walter Benjamin- The work of Art in the Age of Mechanical Reproduction. (Illuminations)<br><br>**Phenomenology and the Social World**<br>Edmund Husserl and Alfred Schutz<br>Harold Garfinkel and 'Ethnomethodology'<br>Dorothy Smith: Feminist Standpoint theory |
| 8. | Suggested Books | Text Books:<br>Wallace, R.A., Wolf, A. 2006. *Contemporary sociological theory:*<br>*expanding the classical tradition.* Prentice Hall, NJ.<br>Calhoun, C., Gerteis, J., Moody, J., Pfaff, S., Virk, I. (eds.). 2012.<br>*Contemporary sociological theory.* Wiley-Blackwell, Oxford.<br>Gordon, S. 1991. *The history and philosophy of social science.*<br>Routledge, London.<br>Sayer, A. 1992. *Method in social science: a realist approach.*<br>Routledge, London.<br>Adorno, T., Horkheimer, M. 1944. *Dialectic of Enlightenment*.<br>Continuum, NY.<br>Schutz, A. 1972. *The Phenomenology of the Social World.*<br>Northwestern University Press. Illinois. |

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| **Course Code** | **HS 680** |
| **Title of the Course** | **Sociology of Religion** |
| Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| Name of the Concerned Department | Humanities & Social Sciences |
| Pre-requisite, if any | None |
| Course Objective | This course on religion equips students with essential theoretical and empirical insights to understand religion comprehensively from diverse sociological viewpoints. It attempts to examine religion scientifically in the light of prominent and compelling scholarly works in the field of sociology of religion. Given the standard and focus of this course, it is primarily meant for Post Graduate students, preferably Ph.D. students, in the school of humanities and social sciences. |
| Course Syllabus | **Society and Religion: Theoretical Foundations**<br>The evolution of the sociology of religion, Sacred & Profane, Totemism, Protestantic Ethic and the Spirit of Capitalism, Religion and Ideology, Religion and rationality, The Sacred Canopy, Elementary Forms of Religious Life.<br>1. Religion as Social Action (Max Weber), Political Economy of Religion (Karl Marx), Sociology of Religious Experience (Emile Durkheim), Religion as Cultural System (Clifford Geertz), Holy terrors – thinking about religion after 9/11.<br>**The Secularization Debate:**<br>Sacred and Secular: Religions and Politics, Secularization Theory, Public Religions in the Modern World, Religion and Comparative Politics, Politics of Religion, Secularization as declining religious authority, Secularization, R.I.P.<br>**Religious Particulars Vs Universals Debate**:<br>Construction of religion as Anthropological category, Anthropological conceptions of religion, Genealogies of religion: Discipline and reasons of power in world religions, The culture of disbelief.<br>**Religion, Fundamentalism & Violence**:<br>Clash of civilizations, Global rise of religious violence, Fundamentalist language and politics, Three model of religious violence, Taming the Gods in Democracy. |
| Suggested Books | 1. J. Casanova, ***Public Religions in the Modern World***, Chicago, University of Chicago Press, 1994, ISBN-10: 0226095355.<br>2. E. Durkheim, ***The Elementary Forms of The Religious Life,*** Oxford: Oxford University Press, 2008, ISBN-10**:** 0029079373.<br>3. M. Weber, ***The Protestant Ethic and the Spirit of Capitalism***, London, Routledge, 2001, ISBN-10: 0199747253.<br>4. P. Berger, ***The Sacred Canopy: Elements of a Sociological Theory of Religion,*** Garden City, Anchor, 1990, ISBN-10: 0385073054.<br>5. T. Asad. ***Genealogies of Religion: Discipline and Reasons of Power in Christianity and Islam***, Baltimore, The Johns |

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| | Hopkins University, ISBN-10: 0801846323.<br>6. G. Clifford. ***The Interpretation of Cultures: Selected Essays***, Basic Books, ISBN-10: 0465087302.<br>7. P. Norris & R. Inglehart, ***Sacred and Secular: Religions and Politics Worldwide***, Cambridge, Cambridge University Press, 2004<br>8. Juergensmeyer, Mark, **Terror in the mind of God: The global rise of religious violence,** Berkeley, University of California Press, 2003. (Vol. 13) |

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|---|---|---|
| 1. | Course Code | **HS 797 (Autumn Semester)**<br>**HS 798 (Spring Semester)** |
| 2. | Title of the Course | Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | HSS |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various relevant journals. |

# Course Structure
# of
# PG and Ph.D. Program in
# Computer Science and Engineering
# and Syllabi of Courses

**Course Structure of M.S. (Research) Program in Computer Science and Engineering with an option to convert to M.S. (Research) + Ph.D. dual degree program (From AY 2018-19)**

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Computer Science and Engineering or Information Technology. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS and valid score of GRE.
**(b) Indian Students:** Valid GATE qualification in Computer Science and Information Technology (CS).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis with maximum extension of one semester.

**Evaluation of Research Work and Thesis:** Students are expected to identify their Thesis Supervisor(s) within one month of joining the program so that PG Student Progress Committee (PSPC) can be formed and student can start research work from beginning of the program. Progress of the M.S. thesis will be monitored by PSPC through CERP to be conducted at the end of every semester with preferably Mid Semester evaluation also. Final evaluation of M.S. thesis will be done by at-least one External Examiner. Student must have one journal publication in SCI index from his/ her M.S. thesis for completion of the degree. Final evaluation of MS thesis will be done by at-least one Professor or equivalent level External Examiner from outside the Institute but within India. Student must have one journal publication in SCI index from his/ her MS thesis for completion of the degree.

**1st Year: Semester-I**

| Course code | Course Name | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| CS 611/ CS 411 | Advanced Algorithms | 2-0-2 | 3 |
| CS XXX | Elective-I | X-X-X | 3 |
| ZZ XXX | Elective-II | X-X-X | 3 |
| CS 697 | PG Seminar course | 0-2-0 | 2 |
| CS 791 | M.S. Thesis (Stage-1) | 0-0-14 | 7 |
| | | **Total minimum credits earned during the semester** | 18 |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | Non-credit course (with PP/NP grade) |

**1st Year: Semester-II**

| Course code | Course Name (L-T-P-Credits) | Contact hours (L-T-P) | Credits |
|---|---|---|---|

| | | | |
|---|---|---|---|
| CS 792 | M.S. Thesis (Stage-2) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | 18 |

**2nd Year: Semester-III**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| CS 793 | M.S. Thesis (Stage-3) | 0-0-36 | 18 |

**2nd Year: Semester-IV**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| CS 794 | M.S. Thesis (Stage-4) | 0-0-36 | 18 |
| **Total minimum credits to be earned during the program** | | | **72** |

**CSE courses for Electives- I and II @**

| S. No. | Course Code | Course Title | Contact hours (L-T-P-C) |
|---|---|---|---|
| 1. | CS 603 | Machine Learning | 2-0-2-3 |
| 2. | CS 606/ CS 406 | Data Mining and Data Warehousing | 2-0-2-3 |
| 3. | CS 609/ CS 409 | Advanced Topics in Database Management Systems | 2-1-0-3 |
| 4. | CS 612/ CS 412 | Pattern Recognition | 2-0-2-3 |
| 5. | CS 614/ CS 414 | Cloud Computing and Applications | 2-1-0-3 |
| 6. | CS 616/ CS 416 | Service Oriented Systems | 2-1-0-3 |
| 7. | CS 617/ CS 417 | Cryptography and Network Security | 2-0-2-3 |
| 8. | CS 618/ CS 418 | Systems and Usable Security | 2-1-0-3 |
| 9. | CS 619/ CS 419/ ICS 419 | Computer Vision | 2-1-0-3 |
| 10. | CS 620/ CS 420 | Embedded Systems | 2-1-0-3 |
| 11. | CS 622/ CS 422 | Numerical Simulation | 2-1-0-3 |
| 12. | CS 701 | Selected Topics in Advanced Algorithms | 2-1-0-3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**Regarding Conversion to M.S. (Research) and Ph.D. dual degree program**

1. Request for conversion from M.S. (Research) to M.S. (Research)+Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated M.S. (Research) students at the end of the **third semester of their program.**

2**.** If the student opts for the Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.S. (Research) Degree can be earned at the end of the final semester of the normal M.S. Program by getting the M.S. (Research) Thesis will be examined in the standard manner as per the requirements for the award of an M.S. (Research) degree.

3. The enhancement in the scholarship from M.S. (Research) to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.S. (Research) degree are fulfilled, whichever is later.

**Course Structure for Ph.D. Program in Computer Science and Engineering**
**(from AY 2010-11 to AY 2012-13)**

**(A) Semester-I (autumn / spring)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | CS 701 | Selected Topics in Advanced Algorithms | 2-1-0--3 |
| 2 | ZZ xxx | Elective-I | x-x-x-3 |
| 3 | ZZ xxx | Elective-II + | x-x-x-3 |
| 4 | CS 797* / CS 798* | Ph.D. Seminar Course | 0-2-0-2 |

**(B) Semester-II (spring / autumn)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective - III + | x-x-x-3 |
| 2 | ZZ xxx | Elective - IV + | x-x-x-3 |
| 3 | CS 798* / CS 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Computer Science & Engineering courses for Elective**

| S.No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1 | CS 606 / CS 406 | Data Mining and Data Warehousing | 2-0-2-3 |
| 2 | CS 609 / CS 409 | Advanced Topics in Database Management Systems | 2-1-0-3 |
| 3 | CS 614 / CS 414 | Cloud Computing and Applications | 2-1-0-3 |
| 4 | CS 616 / CS 416 | Service Oriented Systems | 2-1-0-3 |
| 5 | CS 617 / CS 417 | Cryptography and Network Security | 2-1-0-3 |
| 6 | CS 618 / CS 418 | Systems and Usable Security | 2-1-0-3 |
| 7 | CS 619 / CS 419 | Computer Vision | 2-1-0-3 |

For rest elective courses, the student should choose any PG-level course from other disciplines/schools in consultation with the thesis supervisor/faculty advisor and the concerned course coordinator.

Note:
+ Additional elective course is to be taken by the students with B.Tech./BE/M.Sc. qualification only.
* Depending upon the semester of admission (CS 797 for Autumn Semester and CS 798 for the Spring Semester).
Core courses are compulsory.

## Course Structure for Ph.D. Program in Computer Science and Engineering (w.e.f. AY 2013-14)

### (A) Semester-I (autumn / spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III | x-x-x-3 |
| 4 | CS 797* / CS 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (spring / autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective – IV | x-x-x-3 |
| 2 | ZZ xxx | Elective - V | x-x-x-3 |
| 3 | ZZ xxx | Elective - VI | x-x-x-3 |
| 4 | CS 798* / CS 797* | Ph.D. Seminar Course | 0-2-0-2 |

**NOTE**

1. A Ph.D. student having **M.Tech./ M.E./ M.Phil.** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.
2. A Ph.D. student having **B.Tech./ B.E./ M.Sc. or equivalent qualification** admitted to Ph.D. Program in an **Engineering discipline** shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 20 credits).*

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

**CSE courses for Electives-I to VI** *(in addition to these courses students can also take courses from other disciplines)*

| S. No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | CS 601 / CS 401 | Soft Computing | 2-0-2-3 |
| 2. | CS 603/ CS 403 | Machine Learning | 2-0-2-3 |
| 3. | CS 606 / CS 406 | Data Mining and Data Warehousing | 2-0-2-3 |
| 4. | CS 609 / CS 409 | Advanced Topics in Database Management Systems | 2-1-0-3 |
| 5. | CS 614 / CS 414 | Cloud Computing and Applications | 2-1-0-3 |
| 6. | CS 616 / CS 416 | Service Oriented Systems | 2-1-0-3 |

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|---|---|---|---|
| 7. | CS 617 / CS 417 | Cryptography and Network Security | 2-1-0-3 |
| 8. | CS 618 / CS 418 | Systems and Usable Security | 2-1-0-3 |
| 9. | CS 619 / CS 419 / ICS 419 | Computer Vision | 2-1-0-3 |
| 10. | CS 620 / CS 420 | Embedded Systems | 2-1-0-3 |
| 11. | CS 622 / CS 422 | Numerical Simulation | 2-1-0-3 |
| 12. | CS 701 | Selected Topics in Advanced Algorithms | 2-1-0-3 |

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|---|---|---|
| 1. | Course Code | **CS 601 / CS 401** [from AY 2014-15 onwards] |
| 2. | Title of the Course | **Soft Computing** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline/Discipline | Computer Science and Engineering |
| 5. | Pre–requisite, if any | Discrete Mathematical Structures, Design and Analysis of Of Algorithms, Computational Intelligence |
| 6. | Scope of the Course | After having basic knowledge of artificial intelligence related to neural, fuzzy and evolutionary approaches, advancements in different areas are to be covered with working in a specific domain. This is by taking a case study to come up with the implementation and results. |
| 7. | Course Syllabus | **Review on Mathematical and theoretical methods on soft computing**: neural networks. RBF structures. Self- organizing networks and methods. Fuzzy logic. Support vector machines and kernel methods. Evolutionary algorithms.<br>**Hybrid Intelligent Systems:** Neuro-fuzzy Systems. Neuro-Genetic systems, Evolving neural systems. Neuro-swarm. Hybridization with novel computing paradigM.S.: Quantum computing, DNA computing, membrane computing. Neural dynamic logic and other methods, etc.<br>**Learning and adaptation for novel:** Adaptive systems. Imitation learning. Reconfigurable systems. Supervised, unsupervised, Semi-supervised, reinforcement and statistical of Algorithms. Stability and convergence analysis.<br>**Applications:** Image and signal processing. Ambient intelligence. process control, and manufacturing. Biometry and bioinformatics. Data mining. Internet modeling, communication and networking. Intelligent systems in education. Human–robot interaction. Time series analysis and prediction etc. |
| 8. | Suggested Books | **Book:**<br>1. Jang, Roger and Mizutani, “Neuro-Fuzzy and Softcomputing: A Computational Approach to learning and Machine Intelligence”, Pearson.<br>2. R. John and Ralph Birkenhead, SoftComputing Techniques and Applications (Advances in Intelligent and Softcomputing), 2000, Springer-Verlag.<br>3. F.O. Karray, C. W. De Silva, SoftComputing and Intelligent System Design: Theory, Tools and Applications, Addison Wesley; 1st Ed. 2004.<br>**Other References:**<br>1. IEEE Transactions on Fuzzy Systems<br>2. ACM Transactions on Knowledge Discovery from Data (TKDD)<br>3. The journal of pattern recognition society, ELSEVIER<br>4. The journal of Neurocomputing, ELSEVIER<br>5. IEEE Transactions on Evolutionary Computation<br>6. IEEE Transactions on Neural Networks Learning Of Algorithms |

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| | | 7. Other web resources will be posted on the course website from time to time. |

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|---|---|
| **Course code** | **CS 603/ CS 403** |
| **Title of the course** | **Machine Learning** |
| Credit Structure | L - T - P - Credits<br>2-0-2-3 |
| Name of the Concerned Discipline | Computer Science & Engineering |
| Pre-requisite, if any | Artificial Intelligence/Computational Intelligence |
| Scope of the course | This course provides a broad introduction to machine learning, datamining, and statistical pattern recognition. Topics include: (i) Supervised learning (parametric/non-parametric algorithms, support vector machines, kernels, neural networks). (ii) Unsupervised learning (clustering, dimensionality reduction, recommender systems, deep learning). (iii) Best practices in machine learning (bias/variance theory_ innovation process in machine learning and AI). The course will also draw from numerous case studies and applications, so that candidate's also learn how to apply learning algorithms to build different intelligent systems. |
| Course Syllabus | Introduction, Machine Learning and AI, Motivations for Studying ML, Supervised and Unsupervised learning, Linear prediction, Maximum likelihood Regularizers, basis functions and cross-validation, Optimisation, Linear and Logistic Regression, Gaussian Discriminant Analysis, Support Vector Machines, Decision Trees, Neural networks architectures and its advances, Ensemble Methods, Clustering, Naive Bayes, Bayesian Statistics, K-Means, Gaussian Mixture Models, Learning Theory, Model Selection. |
| Suggested Books | 1. C. M. Bishop, ***Pattern Recognition and Machine Learning,*** Springer, Heidelberg, 2006, 978-0-387-31073-2<br><br>2. T. Mitchell, ***Machine Learning***, McGraw Hill, 1997 (new chapters on line, 2006), New York, 1997, 978—0071154673<br><br>3. Duda, Hart and Stork, ***Pattern Classification*** *(2nd ed.),* Wiley Interscience, US, 2000, 978-8126511167 |

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|---|---|
| Course Code | **CS 606/ CS 406** |
| Title of the Course | **Data Mining and Data Warehousing** |
| Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| Name of the Concerned Discipline | Computer Science & Engineering |
| Pre-Requisite, if any | CS 301 (Data Base & Information Systems) |
| Scope of the Course | |
| Course Syllabus | **Data Warehouse and OLAP Technology:** Data warehousing Definition, usage and trends, Data marts, Metadata, Multidimensional data model, Data cubes, Schemas for Multidimensional Database: stars, snowflakes and fact constellations, Data warehouse architecture, OLTP and OLAP, types of OLAP servers: ROLAP, MOLAP, 3- Tier data warehouse architecture, Data warehouse implementation, computation of data cubes, indexing OLAP data, processing OLAP queries.<br>**Data Mining:** Data mining definition & task, data preprocessing, data mining functionalities: Characterization and Discrimination, Mining frequent patterns, Frequent itemset mining methods, associations, and Correlations, Classification and Predictions, Cluster Analysis, Outlier Analysis, Evolution Analysis<br>**Mining complex data objects:** Spatial databases, Multimedia databases, Time series and Sequence data, mining Text Databases and mining Word Wide Web, Applications and Trends in Data Mining |
| Suggested Books | 1. Jiawei Han and Micheline Kamber, **Data Mining: Concepts and Techniques**, Elsevier Publication, 2nd Edition.<br>2. Margaret H. Dunham, **Data Mining: Introductory and Advanced Topics**, Pearson Education 2004. |

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|---|---|
| Course Code | **CS 609 / CS 409** |
| Title of the Course | **Advanced Topics in Database Management Systems** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Discipline of Computer Science & Engineering |
| Pre-Requisite, if any | Data Structures and Of Algorithms and Database and Information Systems |
| Scope of the course | |
| Course Syllabus | **Advanced Data Models:** Enhanced Relational System, Object-Oriented Data Model, Spatial and Temporal Databases, Multimedia Databases.<br>**Query Processing and Optimization:** Query Interpretation and Equivalence Expressions, Cost Estimate in Query Optimization, Semantic Query Optimization.<br>**Transaction Processing and Concurrency Control:** Properties of Transactions, Schedules and Serializability of Schedules, Transaction Failures and Recoverability, High Performance Transaction Systems.<br>**Distributed Databases:** Design of Distributed Databases, Distributed Query Processing, Deadlock Handling, Concurrency Control and Recovery.<br>**Database Security and Authorization:** Database Security Issues, Security and Integrity Violations, Multilevel Security, Discretionary and Mandatory Access Control, Statistical Database Security. |
| Suggested Books | 1. R. Elmasri and S. Navathe, **Fundamentals of Database Systems** (3rd Ed), Benjamin Cummings, 2002.<br>2. H. F. Korth and A. Silberschatz, **Database System Concepts** (3rd Ed.), McGraw Hill Inc., 2003<br>3. C. Zaniolo, S. Ceri, C. Faloutsos, Richard T. Snodgrass, V.S. Subrahmanian, R. Zicari, **Advanced Database Systems**, Morgan Kauffmann, 2002 |

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| Course Code | **CS 411/ CS 611** |
| Title of the Course | **Advanced of Algorithms** |
| Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| Name of the Concerned Discipline | Discipline of Computer Science & Engineering |
| Pre-Requisite, if any | Data Structures and Of Algorithms and Design and Analysis of Algorithms |
| Scope of the course | |
| Course Syllabus | **Advanced Solutions to Basic Data Structuring ProbleM.S.:** Binomial heaps and Fibonacci heaps, Red-Black tree, Splay tree, van Emde Boas Priority Queues, Dynamic Data Structures for Graph Connectivity/Reachability.<br>**Bit Tricks Techniques:** Word-level Parallelism, Trans dichotomous Model, O(n) and O(log n) Integer Sorting.<br>**String Algorithms:** Rabin-Karp Fingerprinting Algorithm, Suffix Trees.<br>**Maximum Flows:** Augmenting Paths and Push-Relabel Methods, Minimum Cost Flows, Bipartite Matching.<br>**Linear Programming:** Formulation of ProbleM.S. as Linear Programs, Duality, Simplex, Interior Point, and Ellipsoid Algorithms.<br>**Online Algorithms:** Ski Rental, River Search Problem, Paging, The k-Server Problem, List Ordering and Move-to-Front.<br>**Approximation Algorithms:** One Way of Coping with NP-Hardness, Greedy Approximation Algorithms, Dynamic Programming and Weakly Polynomial-Time Algorithms, Linear Programming Relaxations, Randomized Rounding, Vertex Cover, Wiring and TSP.<br>**Fixed-Parameter Algorithms:** Parameterized Complexity, Kernelization, Vertex Cover, Connections to Approximation.<br>**Parallel Algorithms:** PRAM. Pointer Jumping and Parallel Prefix. Tree Contraction. Divide and Conquer. Randomized Symmetry Breaking. Maximal Independent Set.<br>**External-Memory Algorithms:** Accounting for the Cost of Accessing Data from Slow Memory. Sorting. B-trees. Buffer Trees. Cache-oblivious Algorithms for Matrix Multiplication and Binary Search.<br>**Computational Geometry:** Convex Hull. Line-segment Intersection. Sweep Lines. Voronoi DiagraM.S.. Range Trees. Seidel's Low-dimensional LP Algorithm. |
| Suggested Books | 1. T. Cormen, C. Leiserson, R. Rivest, and C. Stein. **Introduction to Algorithms**. (3rd Ed). MIT Press, McGraw-Hill, 2010.<br>2. R. Motwani and P. Raghavan, **Randomized Algorithms**, Cambridge University Press, 1995.<br>3. V. V. Vazirani, **Approximation Algorithms**, Springer. 2001. |

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| | 4. Ravindra K. Ahuja, Thomas L. Magnanti, and James B. Orlin, **Network Flows: Theory, Algorithms, and Applications**, Prentice Hall, 1993. |

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|---|---|
| Course Code | **CS 412/ CS 612** |
| Title of the Course | **Pattern Recognition** |
| Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| Name of the Concerned Discipline | Computer Science & Engineering |
| Pre-Requisite, if any | Basics of probability theory, Programming |
| Scope of the course | This course aims to cover the basic concepts for analyzing patterns and their preprocessing techniques. It also aims to give exposure to various learning algorithms and their applications to various real life applications. |
| Course Syllabus | **Basics of pattern recognition:** Definitions, data sets for pattern recognition, representations of patterns and classes, metric and non-metric proximity measures, feature extraction, statistical and syntactic pattern recognition<br>**Bayesian decision theory:** Classifiers, discriminant functions, decision surfaces, normal density and discriminant functions, discrete features<br>**Parameter estimation methods:** Maximum-likelihood estimation, expectation-maximization method, Bayesian estimation, Gaussian mixture models<br>**Non-parametric techniques:** Density estimation using Parzen-window method, K-nearest neighbor method, nearest neighbor classifier<br>**Dimension reduction methods:** Lineardiscriminant analysis (LDA), principal component analysis (PCA)<br>**Linear discriminant function based classifiers:** Perceptron, support vector machines (SVM)<br>**Non-metric methods for pattern classification:** Non-numeric data or nominal data decision trees<br>**Unsupervised learning and clustering:** Criterion functions for clustering, algorithms for clustering: K-means, Hierarchical and other methods, Cluster validation<br>**Applications:** Biometrics recognition, handwriting recognition, document recognition, multimedia data retrieval, speech recognition, data mining, web searching, network traffic analysis etc. |
| Suggested Books | • R. O. Duda, P. E. Hart and D. G. Stork, **Pattern Classification**, John Wiley, 2001<br>• S. Theodoridis and K. Koutroumbas, **Pattern Recognition**, 4th Ed., Academic Press, 2009<br>• C. M. Bishop, **Pattern Recognition and Machine Learning**, Springer, 2006 |

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|---|---|
| Course Code | **CS 614/ CS 414** |
| Title of the Course | **Cloud Computing and Applications** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science & Engineering |
| Pre-Requisite, if any | UG level courses on Operating Systems, Computer Architecture and Computer Networks |
| Scope of the Course | To study the technology behind the cloud computing methodology. The course would include many cloud computing service models namely *IaaS*, *SaaS*, and *PaaS* and cloud computing deployment models such as public Cloud, private Cloud and hybrid Cloud. Further, with the exponential growth in Cloud computing services, there is a need to understand the various issues that affect the different stakeholders of Cloud computing. The success story of the cloud computing not only depends on the underlying technology but also on the economics of the Cloud computing resource market. Hence, in this course, we would also cover the concept of Service Level Agreement (SLA), SLA matching techniques, cloud resources management, resource provisioning and sharing, pricing strategies, monitoring risk, trust, and Quality of Service (QoS) etc. |
| Course Syllabus | **History of Cloud Computing:** ParadigM.S. in Computing, Parallel Computing, Distributed Computing, Grid Computing, Service Computing; Service Oriented Architecture (SOA), Web Services<br>**Cloud Computing:** Definition, Characteristics, Architecture, Components, Service Models, Deployment Models, Virtualization: Server, Storage, Network, Desktop; Hypervisor, Virtual Machine, Multi-tenancy, Opportunities and Risks<br>**Service Level Agreement (SLA):** Definition, Types of SLA, SLA Life Cycle, Issues Related to Cloud SLA, SLA Frameworks: WS-Agreement, WSLA, WSOL, Slang, Bilateral Protocol; Translation of SLAs into Monitoring Specifications, Dynamic Creation of Monitoring Infrastructures, Penalty Management, Runtime Prediction<br>**Cloud Security:** Cloud Security Fundamentals, Vulnerability Assessment, Security and Privacy in Cloud, Cloud Computing Security Architecture: Identity Management and Access Control, Autonomic Security; VM Specific Security Techniques<br>**Cloud Application Programming Models:** Cloud File Systems: GFS and HDFS, BigTable, Hbase and Dynamo; Map Reduce Programming Model, Hadoop: Hadoop Fundamentals, Hama and other Hadoop Related Services<br>**Cloud Application Development PlatforM.S.:** Xen Hypervisor, Amazon Web Service, Windows Azure, Google App Engine, Eucalyptus, Open Stack, Open Nebula |

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| Suggested Books | 1. A. T. Velte, **Cloud Computing - A Practical Approach**, McGraw Hills<br>2. P. Wieder and J.M. Butler, **Service Level Agreements for Cloud Computing**, Springer<br>3. C. Buan, **Cloud Computing - Web Based Dynamic IT Services**, Springer<br>4. Tanenbaum and V. Steen, **Distributed Systems: Principles and ParadigM.S.**, Pearson<br>5. David E.Y. Sarna, **Implementing and Developing Cloud Computing Applications**, CRC Press<br>6. R. Krutz and R. D. Vines, **Cloud Security**, Wiley-India<br>7. T. White, **Hadoop: The Definitive Guide**, O'Reilly Media |

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|---|---|
| Course Code | **CS 616 / CS 416** |
| Title of the Course | **Service Oriented Systems** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science and Engineering |
| Pre–requisite, if any | UG Level course on Software Engineering and Computer Networks |
| Scope of the course | To understand the technical as well as management aspects of service-oriented systems. Emphasis would be on the most common realization of service-oriented systems i.e. web-services |
| Course Syllabus | • **Introduction:** service explosion in the world, independent services, 'servitization' of products<br>• **Service-oriented systems:** understanding the 'register, find, bind' triangle, loose coupling, Software-as-a-Service, Governance issues Practical realization of service-oriented systems via web services, basics of xml and its use in web-service implementation, http protocol, utility of web-services<br>• **Basic web services stack:** understanding the SOAP protocol, WSDL, UDDI registry. Implementation of web services using the basic web services stack<br>• **Representational State Transfer (REST) web services:** implementation of RESTful web services, REST constraints, comparison of this approach of web-service implementation with that of the basic web-service stack, advantages and limitation of RESTful web services<br>• **Service composition:** understanding of the concepts of service orchestration and service choreography, static versus dynamic service composition, assessment of quality in service compositions, appropriate service selection for compositions, role of the customer in service composition |
| Suggested Books | 1. J. Snell, D. Tidwell, P. Kulchenko. **Programming Web Services with SOAP,** O'Reilly<br>2. L. Richardson, S. Ruby, D. H. Hansson. **Restful Web Services,** O'Reilly<br>3. B. A. Christudas, M. Barai, V. Cacello. **Service-Oriented Architecture with Java,** Packt Publishing. |

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|---|---|
| Course Code | **CS 617 / CS 417** |
| Title of the Course | **Cryptography and Network Security** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline/Discipline | Computer Science and Engineering |
| Pre–requisite, if any | Discrete Mathematical Structures, Design and Analysis of Algorithms, Computer Networks |
| Scope of the Course | To understand the basic concepts of cryptography, get familiarized with encryption and authentication protocols and look at system level security. We will study block ciphers, stream ciphers, hash functions and public key cryptography and security mechanisM.S. in networks and Internet. In the process we will learn some number theory and algebra. |
| Course Syllabus | **Introduction:** What is cryptography, classical ciphers, cryptanalysis.<br>**Shannon's theory:** Concept of perfect secrecy, entropy<br>**Symmetric-key Cryptography:** Pseudorandomness, Stream ciphers, Block ciphers, Data Encryption Standards, Advanced Encryption Standards, Modes of operation<br>**Hash-functions:** Data Integrity, Merkle-Damgard construction, Message Authentication Codes<br>**Number Theory:** Euclidean Algorithm, Chinese Remainder Theorem, Primality Testing algorithms, Factoring algorithms<br>**Public-key Cryptography:** RSA, Discrete log problem, Diffie-Hellman key exchange protocol, Signatures schemes Public key Infrastructure, Digital certificates<br>**Network Security:** Network security at application, Security issues in electronic mail, IP Security, Web security, transport layer security and Secure Socket Layer, intrusion detection, malicious software, viruses, worM.S. and related threats, firewalls, trusted systems. |
| Suggested Books | **Suggested Textbook:**<br>1. D. R. Stinson: **Cryptography theory and practices**, 3rd Edition, CRC Press, (2006)<br>2. W. Stalling: **Cryptography and Network security Principles and Practices**, 4th or 5th Edition PHI, 2006/2010<br>**Other References:**<br>1. A. Menezes, P. Oorschot, S. Vanstone: **Handbook of Applied Cryptography** (individual chapters are freely available online at http://www.cacr.math.uwaterloo.ca/hac/<br>2. J. Katz and Y. Lindell: **Introduction to Modern Cryptography**, Chapman & Hall/CRC 2008<br>3. S. Singh: The Code Book. (A good popular introduction to the subject)<br>4. Other web resources will be posted on the course website from time to time. |

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|---|---|
| Course Code | **CS 618 / CS 418** |
| Title of the Course | **Systems and Usable Security** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science and Engineering |
| Pre–requisite, if any | UG Level Courses on Operating Systems and Computer Networks |
| Scope of the course | To understand the principles of systems security from an applied viewpoint and obtain hands-on experience on security threats and counter-measures. To study operating systems security, advanced topics on network security, access control and digital rights management, web security and usable security. After the completion of the course, the student will have sound understanding of practical aspects of security and will be able to analyze and design the secure systems. |
| Course Syllabus | **Introduction:** Computer Security Concepts, threats, Attacks, and Assets<br>**Malicious Software:** Types of Malicious Software (Malware), Infected Content–Viruses, Vulnerability Exploit–WorM.S., Social Engineering–SPAM E-mail, Trojans, System Corruption, Zombie, Bots, Information Theft–Keyloggers, Phishing, Spyware, Stealthing–Backdoors, Rootkits.<br>**Operating System Security:** System Security Planning, Application Security, Linux/Unix Security, Windows Security, Virtualization Security<br>**Access Control:** Access Control Principles, Subjects, Objects, and Access Rights, UNIX File Access Control, Role-Based Access Control, Attribute based Access Control.<br>**Database Security:** The Need for Database Security, Database Management Systems, Database Access Control, Statistical Databases, Private Information Retrieval, Cloud Security.<br>Digital Rights Management: Multicast security, copyright protection, Digital Finger printing.<br>**Web Security:** Secure E-mail and S/MIME, Domain Keys Identified Mail, Secure Sockets Layer (SSL) and Transport Layer Security (TLS), HTTPS, Ipv4 and Ipv6 Security, Internet Authentication Applications, Kerberos, X.509, Public-Key Infrastructure, Federated Identity Management.<br>**Wireless Security:** Wireless Security Overview, IEEE 802.11 Wireless LAN Overview, IEEE 802.11i Wireless LAN Security.<br>**Usable Security:** Introduction to privacy, trust and semantic security, Visualizing privacy, Web browser security and privacy, Authentication and text passwords, biometrics and graphical passwords. |
| Suggested Books | 1. W. Stallings and L. Brown, **Computer Security: Principles and Practice** (2nd Edition), Prentice Hall, 2011. |

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| | 2. A. Menezes, P. Oorschot, S. Vanstone: **Handbook of Applied Cryptography (**individual chapters are freely available online at http://www.cacr.math.uwaterloo.ca/hac/)<br>**Other References:**<br>3. Goodrich and Tamassia, *Introduction to Computer Security,* Addison-Wesley, 2010.<br>4. Kaufman, Perlman and Speciner, *Network Security: Private Communications in a Public World***, (2nd edition),** Prentice Hall, 2003. |

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| Course Code | **CS 619/ CS 419/ ICS 419** |
| Title of the Course | **Computer Vision** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science and Engineering |
| Pre–requisite, if any | |
| Scope of the course | Objective of this course is to understand and create artificial vision systems which can reliably extract information from images. Study of vision probleM.S. require the basic understanding of image formation, image representation, ways of analyzing the images and patterns present in them. This course aims at providing the knowledge at all these fronts. |
| Course Syllabus | **Digital Image Processing:** Fundamentals, Types of Image Processing, Image Acquisition Methods, Human Perception of Color and Images, Transformations: Orthogonal, Euclidean, Affine, Projective etc.<br>**Low-level Image Processing:** Image Enhancement in Spatial Domain – Histogram Processing, Contrast Stretching, Log Transformation, Gamma Correction, Smoothing and Sharpening; Logical and Arithmetic Operations, Morphological Image Processing, Image Enhancement in Frequency Domain, Fourier Transform, Convolution and Filtering, Image Restoration.<br>**Image Feature Extraction:** Edge detection – Canny, Sobel, Prewitt, LOG, DOG, Line detector: Hough Transform; Corner detectors – Harris and Hessian Affine; Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis – Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT.<br>**Image Segmentation:** Edge Based Approaches to Segmentation, Region Growing, Texture Segmentation, Object Detection and Segmentation: Graph-cuts, Active Contours, Mean-Shift.<br>**Object Recognition:** Structural Approaches, Model-based Approaches, Appearance and Shape-based Approaches, Probabilistic ParadigM.S..<br>**Pattern Analysis:** Clustering: K-Means; Gaussian Mixture Model (GMM); Classification – Discriminant Function, Supervised, Semi-supervised, Unsupervised; Classifiers: Bayes, KNN, ANN models; Dimensionality Reduction: PCA, LDA, ICA; Non-parametric methods.<br>**Motion Analysis:** Background Subtraction and Modeling, Optical Flow, KLT, Spatio-Temporal Analysis.<br>**Applications and Performance Measures:** CBIR, CBVR, Activity Recognition, Biometrics, Document processing, Super-resolution, Augmented Reality, Security and Surveillance, Performance Evaluation Measures. |
| Suggested Books | **Text Books**<br>1. Computer Vision: A Modern Approach, D. A. Forsyth and J. Ponce, Pearson Education, 2003. (693 pages), ISBN: 9780130851987.<br>2. Computer Vision: Algorithms and Applications, Richard Szeliski, Springer-Verlag, 2011. (832 pages), ISBN: 978-1848829343.<br>**Reference Books**<br>1. Digital Image Processing, Rafael C. Gonzalez and Richard E. Woods, Pearson Education, 2008. (976 pages), ISBN: 9788131726952.<br>2. Pattern Classification, R.O. Duda, P.E. Hart and D.G. Stork, Wiley- |

| | |
|---|---|
| | Interscience, 2000. (654 pages), ISBN: 978-0471056690.<br>3. Multiple View Geometry in Computer Vision, Richard Hartley and Andrew Zisserman, Cambridge University Press, 2004. (668 pages), ISBN: 978-0521540513.<br>4. Introduction to Statistical Pattern Recognition, Keinosuke Fukunaga, Academic Press, 1990. (592 pages), ISBN: 978-0122698514. |

| | |
|---|---|
| Course Code | **CS 620/ CS 420** |
| Title of the Course | **Embedded Systems** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science and Engineering |
| Pre–requisite, if any | Programming knowledge, Computer Architecture, Operating Systems. CSE students take these subjects in their I, II and III years. |
| Scope of the course | Embedded systems are becoming more and more ubiquitous and pervasive in our day to day life. Their applications range from domestic household appliances, health-care, defense, transportation, space technology, gaming, infotainment, mobiles, energy generation, etc.<br>Research reports1 reveal that 99% of the microprocessors/software produced annually end up in embedded systems/applications. The course will focus on software issues in embedded systems. It will include demonstrations and getting acquainted with 8/16/32-bit micro-controller and its development environment (starter kits, appropriate compilers and flashers), interrupt programming, resource management, and peripheral interfacing & drivers. The practical part will involve demos and getting started kind of exercises to show the tangible side of taught concepts. |
| Course Syllabus | 1. Introduction to embedded systems: Embedded vs. General purpose computer Systems; Abstract Model; computer-plant interaction and real-time reactive behaviour of embedded control systems.<br>2. Sequential and continuous control systems;<br>3. Basic modeling and implementation techniques for sequential and continuous control systems - state machines, function blocks and function block diagraM.S., which is followed by advanced modelling techniques for complex systems, such as hierarchical and concurrent state machines and hybrid models;<br>4. Real-time operating systems (RTOS), Real-time kernels, Deploying applications on RTOS/Kernels. |
| Suggested Books | 1. David E. Simon, **Embedded Systems Primer**, Addison-Wesley, 1999, 020161569X / 9780201615692.<br>2. Tammy Noergaard, **Embedded Systems Architecture: A Comprehensive Guide for Engineers and Programrs**, 2005, Newnes, ISBN-10: 0750677929, ISBN-13: 978-0750677929 / 9780123821966 |

| | |
|---|---|
| Course Code | **CS 622/ CS 422** |
| Title of the Course | **Numerical Simulation** |
| Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science & Engineering |
| Pre–requisite, if any (for the students) | Calculus, Linear Algebra and Ordinary Differential Equations, Complex Analysis and Differential Equations, Numerical Methods |
| Scope of the course | Simulation is a useful tool in almost all areas of engineering and science. This course will introduce computational techniques for simulating applications from Electrical Engineering, Mechanical Engineering, Material Science, Physics, and Operations Research. |
| Course Syllabus | **Problem Types:** Circuit analysis, structural analysis of automobiles, analyzing drag force in aircrafts, engine thermal analysis, virtual environments for computer games, stock option pricing, electrostatic optimization for biomolecules etc.<br><br>**Equation Formulation Methods:** Stamping, node-branch, and nodal.<br><br>**Direct and Iterative Matrix Solution:** Error analysis, dense and sparse matrix factorizations, and Krylov methods.<br><br>**Nonlinear Systems Solution:** Multi-dimension Newton, fixed-point and functional iterations, and continuation schemes.<br><br>**Numerical Integration and Monte Carlo Methods:** Newton-Cotes, composite quadrature, Gauss quadrature, multiple integrals, generating samples, random tours, designing and analyzing random paths.<br><br>**Discretization Methods for Partial Differential Equations:** Finite difference, finite element, multi-grid, and spectral methods. |
| Suggested books | 1. G. Strang, **Computational Science and Engineering**, Wellesley-Cambridge Press (2007).<br>2. D. Kincaid and W. Cheney, **Numerical Analysis: Mathematics of Scientific Computing**, Brooks / Cole (2002).<br>3. Y. Saad, **Iterative Methods for Sparse Linear Systems**, SIAM (2003).<br>4. C. T. Kelley, **Solving Nonlinear Equations with Newton's Method**, SIAM (2003).<br>5. E. L. Allgower and K. Georg, **Introduction to Numerical Continuation Methods**, SIAM (2003).<br>6. G. S. Fishman, **Monte Carlo Concepts, Algorithms, and Applications**, Springer (1996).<br>7. W. L. Briggs, V. E. Henson, and S. F. McCormick, **A Multigrid Tutorial**, SIAM (2000). |

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|---|---|
| Course Code | **CS 701** |
| Title of the Course | **Selected Topics in Advanced Algorithms** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Computer Science & Engineering |
| Pre–requisite, if any | Courses on Automata Theory and Logic, Design and Analysis of Algorithms & associated lab, Artificial Intelligence & associated lab, and Parallel Computing & associated lab |
| Scope of the Course | |
| Course Syllabus | **Complexity:** Turing Complexity. Computationally hard probleM.S.. Polynomial Reducibility and its implications for algorithm design.<br>**Data Structures and Algorithm Design:** Data Structure oriented algorithm design. Data structures for computationally hard probleM.S.. Software design, implementation and testing for selected computationally hard probleM.S..<br>**Parallel Algorithms:** Data structures and algorithms for parallel computing models like MPI and OpenMP.<br>**Examples and applications** of the above methods for a few selected recent problems. |
| Suggested Books | 1. D. E. Knuth, **The Art of Computer Programming**, Vol. 1 and 3, (2nd Edition), Addison-Wesley, 1998.<br>2. J.E. Hop croft, R. Motwani, and J. D. Ullman, **Introduction to Automata Theory**, Languages and Computation, Pearson Education Asia, 2006.<br>3. H.R. Lewis, and C.H. Papadimitrou, **Elements of the Theory of Computation**, Prentice Hall Inc, 1981.<br>4. T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, **Introduction to Algorithms**, (2nd Edition), Prentice Hall India, 2002. |

| | |
|---|---|
| Course Code | **CS 797 (Autumn Semester)**<br>**CS 798 (Spring Semester)** |
| Title of the Course | **Seminar Course** |
| Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| Name of the Concerned Discipline | Computer Science and Engineering |
| Pre–requisite, if any | None |
| Scope of the Course | |
| Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| Textbook | None |
| Other references | Books and research publications in various relevant journals. |

# Course Structure

# of

# PG and Ph.D. Program in

# Electrical Engineering and

# Syllabi of Courses

# Course Structure of M.Tech. / M.Tech. + Ph.D. Dual Degree Program in Communications and Signal Processing (CSP) (From AY 2013-14)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Electrical or Electronics and Communication or Electronics and Instrumentation or Telecommunication or Computer Science and Engineering or Information Technology. Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.

**Qualifying Examination:**
**(a) International students:** Valid score of TOEFL or IELTS and valid score of GRE.
**(b) Indian students:** Valid GATE qualification in Electronics and Communication (EC).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R and D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis.

### Course Structure of 2-Year Full Time M. Tech. Program in CSP

**1st Year: Semester-I**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 603 | Optimization Techniques | 2-1-0 | 3 |
| EE 641/ EE 441 | Advanced Signal Processing | 2-1-0 | 3 |
| EE 643 | Detection and Estimation Theory | 2-1-0 | 3 |
| EE 701 | Time-Frequency Analysis | 2-1-0 | 3 |
| ZZ XXX | Elective-I | X-X-X | 3 |
| | | **Total minimum credits earned during the semester** | **15** |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 642 | Wireless Communication | 2-1-0 | 3 |
| EE 644 | Image Processing | 2-1-0 | 3 |

| | | | |
|---|---|---|---|
| EE 646 / EE 446 | Information and Coding Theory | 2-1-0 | 3 |
| EE 740 | Speech Signal Processing | 2-1-0 | 3 |
| ZZ XXX | Elective-II | X-X-X | 3 |
| EE 698 | PG seminar course | 0-2-0 | 2 |
| | | **Total minimum credits earned during the semester** | **17** |

**2 nd Year: Semester-III**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 799 | M. Tech. Research Project (Stage-I) | 0-0-36 | 18 |

**2 nd Year: Semester-IV**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 800 | M. Tech. Research Project (Stage-II) | 0-0-36 | 18 |
| | | **Total minimum credits to be earned during the program** | **68** |

| **Electrical Engineering Courses for Elective-I @** | | | |
|---|---|---|---|
| **Course Code** | **Course Title** | **Contact hours (L-T-P)** | **Credits** |
| EE 625 | VLSI Signal Processing | 2-1-0 | 3 |
| EE 645 | Mathematical Methods for Signal Processing | 2-1-0 | 3 |
| CS 617 / CS 417 | Cryptography & Network Security | 2-1-0 | 3 |

| **Electrical Engineering Courses for Elective-II @** | | | |
|---|---|---|---|
| **Course Code** | **Course Title** | **Contact hours (L-T-P)** | **Credits** |
| EE 622 / EE 422 | Digital Circuit Design | 2-1-0 | 3 |
| EE 628 / EE 428 | Advanced Memory Technology | 2-1-0 | 3 |
| EE 648/ EE 448 | Antennas and Propagation | 2-1-0 | 3 |
| EE 742 | MIMO Wireless Communications | 2-1-0 | 3 |
| ME 644 / ME 444 | Robotics | 2-1-0 | 3 |

| | | | |
|---|---|---|---|
| CS 601/ CS 401 | Soft Computing | 2-0-2 | 3 |
| CS 606 / CS 406 | Data Mining and Data Warehousing | 2-0-2 | 3 |
| CS 618 / CS 418 | Systems and Usable Security | 2-1-0 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.**
**2.** If a student opts for the Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.
3. The enhancement in the scholarship will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled, whichever is later**.**

# Course Structure of M.Tech. / M.Tech. + Ph.D. Dual Degree Program in VLSI Design and Nanoelectronics (from AY 2017-18 to 2019-20)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Electronics and Communication Engineering or Electronics Engineering or Electrical Engineering or Instrumentation and Control Engineering or Computer Science and Engineering. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid GRE and TOEFL score **and** valid GATE qualification in EC/EE/IC/CS.
**(b) Indian Students:** valid GATE qualification or CSIR-JRF or equivalent fellowship in EC/EE/IC/CS.

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis.

### Course Structure of 2-Year Full Time M. Tech. Program in VLSI Design and Nanoelectronics

**1st Year: Semester-I**

| Course Code | Course Title | Contact hours (L-T-P) | Credit |
|---|---|---|---|
| EE 621 / EE 421 | MOS Devices & Modeling | 2-1-0 | 3 |
| EE 622 / EE 422 | Digital Circuit Design | 2-1-0 | 3 |
| EE 635 / EE 435 | VLSI Technology | 2-1-0 | 3 |
| EE 651 | Digital Circuit Design Laboratory | 0-0-4 | 2 |
| EE 653 | Discrete Device Fabrication and Characterization Lab | 0-1-4 | 3 |
| ZZ XXX | Elective-I | 2-1-0 | 3 |
| | | **Total minimum credits earned during the semester** | **17** |
| **Additional course (as per the requirement basis)** | | | |
| **HS 641** | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course Code | Course Title | Contact hours (L-T-P) | Credit |
|---|---|---|---|
| EE 628 / EE 428 | Advanced Memory Technology | 2-1-0 | 3 |
| EE 638 | System on Programmable Chip Design | 2-1-0 | 3 |
| EE 640 / EE 440 | Analog and Mixed Signal IC Design | 2-1-0 | 3 |
| EE 652 | System on Programmable Chip Design Lab | 0-0-4 | 2 |
| EE 654 | Analog and Mixed Signal IC design Lab | 0-0-4 | 2 |
| EE 698 | PG Seminar course | 0-2-0 | 2 |
| ZZ XXX | Elective-II | 2-1-0 | 3 |
| | | **Total minimum credits earned during the semester** | **18** |

**2 nd Year: Semester–III**

| S. No. | Course code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | EE 799 | M. Tech. Research Project (Stage-I) | 0-0-36 | 18 |
| | | | **Total minimum credits to be earned during the semester** | **18** |

**2 nd Year: Semester–IV**

| S. No. | Course code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | EE 800 | M. Tech. Research Project (Stage-II) | 0-0-36 | 18 |
| | | | **Total minimum credits to be earned during the semester** | **18** |
| | | | **Total minimum credits to be earned during the program** | **71** |

**Suggested Electrical Engineering courses for Elective-I @**

| Course Code | Name of the course | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 605 | Nanotechnology | 2-1-0 | 3 |
| EE 625 | VLSI Signal Processing | 2-1-0 | 3 |
| EE 631/ EE 431 | Organic Electronics | 2-1-0 | 3 |
| EE 641 EE 441 | Advanced Signal Processing | 2-1-0 | 3 |
| EE 648/ EE 448 | Antennas and Propagation | 2-1-0 | 3 |
| EE 701 | Time Frequency Analysis | 2-1-0 | 3 |
| EE 721 | Embedded Systems and Computing | 2-1-0 | 3 |
| EE 725 | RF-IC Design | 2-1-0 | 3 |
| EE 726 | Testing and Verification of VLSI Circuits | 2-1-0 | 3 |

**Suggested Electrical Engineering courses for Elective-II @**

| Course Code | Name of the course | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 610 / EE 410 | Power Electronics Application to Power Transmission | 2-1-0 | 3 |
| EE 624 | Interface Effects in Electronic Devices | 2-1-0 | 3 |
| EE 626 / EE 426 | MOSFET Reliability Issues | 2-1-0 | 3 |
| EE 634 / EE 434 | Semiconductor Based Sensors | 2-1-0 | 3 |
| EE 722 | IC Design for IoT System | 2-1-0 | 3 |
| EE 724 / EE 424 | Advanced Micro-processes and Nanotechnology | 2-1-0 | 3 |
| EE 728 | Architectural Design of ICs | 2-1-0 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.**

**2.** If a student opts for the Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.

3. The enhancement in the scholarship will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled, whichever is later**.**

# Course Structure of M.Tech. / M.Tech. + Ph.D. Dual Degree Program in VLSI Design and Nanoelectronics (from AY 2020-21)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Electronics and Communication Engineering or Electronics Engineering or Electrical Engineering or Instrumentation and Control Engineering or Computer Science and Engineering. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid GRE and TOEFL score **and** valid GATE qualification in EC/EE/IC/CS.
**(b) Indian Students:** valid GATE qualification or CSIR-JRF or equivalent fellowship in EC/EE/IC/CS.

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis.

### Course Structure of 2-Year Full Time M. Tech. Program in VLSI Design and Nanoelectronics

**1st Year: Semester-I**

| Course Code | Course Title | Contact hours (L-T-P) | Credit |
|---|---|---|---|
| EE 621 / EE 421 | MOS Devices & Modeling | 2-1-0 | 3 |
| EE 622 / EE 422 | Digital Circuit Design | 2-1-0 | 3 |
| EE 635 / EE 435 | VLSI Technology | 2-1-0 | 3 |
| EE 651 | Digital Circuit Design Laboratory | 0-0-4 | 2 |
| EE 653 | Discrete Device Fabrication and Characterization Lab | 0-1-4 | 3 |
| ZZ XXX | Elective-I | 2-1-0 | 3 |
| | | **Total minimum credits earned during the semester** | **17** |
| **Additional course (as per the requirement basis)** | | | |
| **HS 641** | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course Code | Course Title | Contact hours (L-T-P) | Credit |
|---|---|---|---|
| EE 629 / EE 429 | Nanotechnology and Nanoelectronics | 2-1-0 | 3 |
| EE 638 | System on Programmable Chip Design | 2-1-0 | 3 |
| EE 640 / EE 440 | Analog and Mixed Signal IC Design | 2-1-0 | 3 |
| EE 652 | System on Programmable Chip Design Lab | 0-0-4 | 2 |
| EE 654 | Analog and Mixed Signal IC design Lab | 0-0-4 | 2 |
| EE 698 | PG Seminar course | 0-2-0 | 2 |
| ZZ XXX | Elective-II | 2-1-0 | 3 |
| | | **Total minimum credits earned during the semester** | **18** |

**2nd Year: Semester–III**

| S. No. | Course code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | EE 799 | M. Tech. Research Project (Stage-I) | 0-0-36 | 18 |
| **Total minimum credits to be earned during the semester** | | | | **18** |

**2nd Year: Semester–IV**

| S. No. | Course code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | EE 800 | M. Tech. Research Project (Stage-II) | 0-0-36 | 18 |
| **Total minimum credits to be earned during the semester** | | | | **18** |
| **Total minimum credits to be earned during the program** | | | | **71** |

**Suggested Electrical Engineering courses for Elective-I @**

| Course Code | Name of the course | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 605 | Nanotechnology | 2-1-0 | 3 |
| EE 625 | VLSI Signal Processing | 2-1-0 | 3 |
| EE 631/ EE 431 | Organic Electronics | 2-1-0 | 3 |
| EE 641 EE 441 | Advanced Signal Processing | 2-1-0 | 3 |
| EE 648/ EE 448 | Antennas and Propagation | 2-1-0 | 3 |
| EE 701 | Time Frequency Analysis | 2-1-0 | 3 |
| EE 721 | Embedded Systems and Computing | 2-1-0 | 3 |
| EE 725 | RF-IC Design | 2-1-0 | 3 |
| EE 726 | Testing and Verification of VLSI Circuits | 2-1-0 | 3 |

**Suggested Electrical Engineering courses for Elective-II @**

| Course Code | Name of the course | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| EE 610 / EE 410 | Power Electronics Application to Power Transmission | 2-1-0 | 3 |
| EE 624 | Interface Effects in Electronic Devices | 2-1-0 | 3 |
| EE 626 / EE 426 | MOSFET Reliability Issues | 2-1-0 | 3 |
| EE 628 / EE 428 | Advanced Memory Technology | 2-1-0 | 3 |
| EE 634 / EE 434 | Semiconductor Based Sensors | 2-1-0 | 3 |
| EE 722 | IC Design for IoT System | 2-1-0 | 3 |
| EE 724 / EE 424 | Advanced Micro-processes and Nanotechnology | 2-1-0 | 3 |
| EE 728 | Architectural Design of ICs | 2-1-0 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.**

**2.** If a student opts for the Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.

3. The enhancement in the scholarship will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled, whichever is later**.**

## Course Structure of M.S. (Research) Program in Electrical Engineering with an option to convert to M.S. (Research) + Ph.D. dual degree program (From AY 2019-20)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Electrical Engineering or Electronics Engineering or Electronics and Communication Engineering or Electronics and Instrumentation Engineering. (Relaxation of 5% in CPI/CPGA or percentage marks of the qualifying degree is applicable for Indian applicants belonging to SC and ST categories)

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS and valid score of GRE
**(b) Indian Students:** Valid GATE qualification in Electrical Engineering (EE) or Electronics and Communication Engineering (EC) or Electronics and Instrumentation Engineering (IN)

**Categories of Admission:**
**(a) International applicants:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian applicants:** Teaching Assistantship (**TA**); (ii) Highly motivated sponsored candidate (**SW**) on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces (**DF**): Candidates sponsored by the Defense Forces; (iv) Institute Staff (**IS**) of IIT Indore on part-time basis only.

**Duration of Program:** 2 years on full-time basis with maximum extension of one semester.

**Evaluation of Research Work and Thesis:** Students are expected to identify their Thesis Supervisor(s) within one month of joining the program so that PG Student Progress Committee (PSPC) can be formed and student can start research work from beginning of the program. Progress of the M.S. thesis will be monitored by PSPC through CERP to be conducted at the end of every semester with preferably Mid Semester evaluation also. Final evaluation of M.S. thesis will be done by at-least one External Examiner. Student must have one journal publication in SCI index from his/ her M.S. thesis for completion of the degree. Final evaluation of MS thesis will be done by at-least one Professor or equivalent level External Examiner from outside the Institute but within India. Student must have one journal publication in SCI index from his/ her MS thesis for completion of the degree.

**1st year: Semester-I**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ZZ XXX | Elective-I | X-X-X | 3 |
| ZZ XXX | Elective-II | X-X-X | 3 |
| ZZ XXX | Elective-III | X-X-X | 3 |
| EE 697 | PG Seminar Course | 0-2-0 | 2 |
| EE 791 | M S Thesis (Stage-1) | 0-0-14 | 7 |

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|---|---|---|---|
| **Total minimum credits earned during the semester** | | | **18** |
| HS 641 | English Communication Skills | 2-0-2 | Non-credit course (with PP/NP grade) |

**1st year: Semester-II**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| EE 792 | MS Thesis (Stage-II) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | **18** |

**2nd year: Semester-III**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| EE 793 | MS Thesis (Stage-III) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | **18** |

**2nd year: Semester-IV**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| EE 794 | MS Thesis (Stage-IV) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | **18** |

**Courses from Electrical Engineering for the Electives Courses:**
(In addition to these courses the students can also take courses offered by other disciplines based on their learning needs/ interests)

| Course Code | Course Title | Contact Hours (L-T-P) and Credits |
|---|---|---|
| EE 601 | Power Electronics | 2-1-0-3 |
| EE 603 | Optimization Techniques | 2-1-0-3 |
| EE 604 | Soft Computing Techniques | 2-1-0-3 |
| EE 605 | Nanotechnology | 2-1-0-3 |
| EE 607 | Power System Operation and Control | 2-1-0-3 |
| EE 610/410 | Power Electronics Applications to Power Transmission | 2-1-0-3 |
| EE 612/412 | Digital Communication Systems | 2-1-0-3 |
| EE 619/419 | Biomedical Optics | 3-0-0-3 |
| EE 620/420 | IC Fabrication Technology | 2-1-0-3 |
| EE 621/421 | MOS Devices and Modeling | 2-1-0-3 |
| EE 622/422 | Digital Circuit Design | 2-1-0-3 |
| EE 623 | Introduction to VLSI Design | 3-0-2-4 |
| EE 624 | Interface Effects in Electronic Devices | 2-1-0-3 |
| EE 625 | VLSI Signal Processing | 2-1-0-3 |
| EE 626/426 | MOSFET Reliability Issues | 2-1-0-3 |

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|---|---|---|
| EE 628/428 | Advanced Memory Technology | 2-1-0-3 |
| EE 629/429 | Nanotechnology and Nanoelectronics | 2-1-0-3 |
| EE 630/430 | Analog CMOS IC Design | 2-1-0-3 |
| EE 631/431 | Organic Electronics | 2-1-0-3 |
| EE 632/432 | Optoelectronics | 2-1-0-3 |
| EE 633 | Low Power RF CMOS IC Design | 2-1-0-3 |
| EE 634/434 | Semiconductor Based Devices | 2-1-0-3 |
| EE 635/ 435 | VLSI Technology | 2-1-0-3 |
| EE 638 | System on Programmable Chip Design | 2-1-0-3 |
| EE 640/440 | Analog and Mixed Signal IC Design | 2-1-0-3 |
| EE 641/441 | Advanced Signal Processing | 2-1-0-3 |
| EE 642 | Wireless Communication | 2-1-0-3 |
| EE 643 | Detection and Estimation Theory | 2-1-0-3 |
| EE 644 | Image processing | 2-1-0-3 |
| EE 645 | Mathematical Methods for Signal Processing | 2-1-0-3 |
| EE 646/446 | Information and Coding Theory | 2-1-0-3 |
| EE 648/ EE 448 | Antennas and Propagation | 2-1-0-3 |
| EE 701 | Time Frequency Analysis | 2-1-0-3 |
| EE 721 | Embedded Systems and Computing | 2-1-0-3 |
| EE 722 | IC Design for IOT System | 2-1-0-3 |
| EE 724/424 | Advanced Microprocesses and Nanotechnology | 2-1-0-3 |
| EE 725 | RF-IC Design | 2-1-0-3 |
| EE 726 | Testing and Verification of VLSI Circuits | 2-1-0-3 |
| EE 728 | Architectural Design of ICs | 2-1-0-3 |
| EE 740 | Speech Signal Processing | 2-1-0-3 |
| EE 742 | MIMO Wireless Communications | 2-1-0-3 |

## Course Structure for Ph.D. program in Electrical Engineering

**(A) Semester-I (Autumn/Spring)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III | x-x-x-3 |
| 4 | EE 797 * / EE 798* | Seminar Course | 0-2-0-2 |

**(B) Semester-II (Spring/Autumn)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI | x-x-x-3 |
| 4 | EE 798 * / EE 797* | Seminar Course | 0-2-0-2 |

Note

1. A Ph.D. student having **M.Tech./ M.E./ M.Phil.** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.
2. A Ph.D. student having **B.Tech./ BE / M.Sc. or equivalent qualification** admitted to Ph.D. Program in an **Engineering discipline** shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 20 credits).*

   * Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

**Electrical Engineering courses for Electives-I to VI**

*(in addition to these courses, students can also take courses from other disciplines)*

| S. No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | EE 601 | Power Electronics | 2-1-0-3 |
| 2. | EE 603 | Optimization Techniques | 2-1-0-3 |
| 3. | EE 604 | Soft Computing Techniques | 2-1-0-3 |
| 4. | EE 605 | Nanotechnology | 2-1-0-3 |
| 5. | EE 607 | Power System Operation and Control | 2-1-0-3 |
| 6. | EE 610 / EE 410 | Power Electronics Applications to Power Transmission | 2-1-0-3 |
| 7. | EE 612 / EE 412 | Digital Communication Systems | 2-1-0-3 |
| 8. | EE 619 / EE 419 | Biomedical Optics | 3-0-0-3 |
| 9. | EE 620 / EE 420 | IC Fabrication Technology | 2-1-0-3 |
| 10. | EE 621 / EE 421 | MOS Devices & Modeling | 2-1-0-3 |
| 11. | EE 622 / EE 422 | Digital Circuit Design | 2-1-0-3 |
| 12. | EE 623 | Introduction to VLSI Design | 3-0-2-4 |
| 13. | EE 624 | Interface Effects in Electronics Devices | 2-1-0-3 |
| 14. | EE 625 | VLSI Signal Processing | 2-1-0-3 |
| 15. | EE 626 / EE 426 | MOSFET Reliability Issues | 2-1-0-3 |
| 16. | EE 628 / EE 428 | Advanced Memory Technology | 2-1-0-3 |
| 17. | EE 629 / EE 429 | Nanotechnology and Nanoelectronics | 2-1-0-3 |
| 18. | EE 630/ EE 430 | Analog CMOS IC Design | 2-1-0-3 |
| 19. | EE 631 / EE 431 / IEE 431 | Organic Electronics | 2-1-0-3 |
| 20. | EE 632 / EE 432 | Optoelectronics | 2-1-0-3 |
| 21. | EE 633 | Low Power RF CMOS Design | 2-1-0-3 |
| 22. | EE 634 / EE 434 | Semiconductor Based Devices | 2-1-0-3 |
| 23. | EE 635 / EE 435 | VLSI Technology | 2-1-0-3 |
| 24. | EE 638 | System on Programmable Chip Design | 2-1-0-3 |
| 25. | EE 640 / EE 440 | Analog and Mixed Signal IC Design | 2-1-0-3 |
| 26. | EE 641 / EE 441 | Advanced Signal Processing | 2-1-0-3 |
| 27. | EE 642 | Wireless Communication | 2-1-0-3 |

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|---|---|---|---|
| 28. | EE 643 | Detection and Estimation Theory | 2-1-0-3 |
| 29. | EE 644 | Image Processing | 2-1-0-3 |
| 30. | EE 645 | Mathematical Methods for Signal Processing | 2-1-0-3 |
| 31. | EE 646 / EE 446 | Information and Coding Theory | 2-1-0-3 |
| 32. | EE 647/ EE 447 | Advanced Photonics | 2-1-0-3 |
| 33. | EE 648/ EE 448 | Antennas and Propagation | 2-1-0-3 |
| 34. | EE 701 | Time-Frequency Analysis | 2-1-0-3 |
| 35. | EE 721 | Embedded Systems and Computing | 2-1-0-3 |
| 36. | EE 722 | IC Design for IoT System | 2-1-0-3 |
| 37. | EE 724 / EE 424 | Advanced Micro-processes and Nanotechnology | 2-1-0-3 |
| 38. | EE 725 | RF-IC Design | 2-1-0-3 |
| 39. | EE 726 | Testing and Verification of VLSI Circuits | 2-1-0-3 |
| 40. | EE 728 | Architectural Design of ICs | 2-1-0-3 |
| 41. | EE 740 | Speech Signal Processing | 2-1-0-3 |
| 42. | EE 742 | MIMO Wireless Communications | 2-1-0-3 |

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|---|---|---|
| 1. | Course Code | **EE 601** |
| 2. | Title of the Course | **Power Electronics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Power electronics at UG level |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Power Switches: BJT, MOSFET, IGBT, SCR and GTO characteristics, control and protection.<br>Electromagnetic components: Design of Inductor and Transformers.<br>Review of Line Commutated Converters.<br>Switched Mode Rectifiers: Circuits and Techniques.<br>DC-DC converters: steady state analysis and dynamic modeling of DC-DC converters.<br>Voltage Source Inverters: Single Phase Inverters, Three Phase Inverters, Multilevel Inverters, PWM strategies for Inverters.<br>Current Source Inverters: Single phase and three phase circuit configuration.<br>Overview of modeling and simulation of power electronic converters |
| 8. | Suggested Books | 1. N. Mohan, T.M. Undeland & W.P. Robbins, **Power Electronics: Converter, Applications & Design**, John Wiley & Sons, 2007.<br>2. Umanand L, **Power Electronics: Essentials and Applications**, Wiley India, 2009.<br>3. Erickson, R.W. and Maksimovic, D., **Fundamentals of Power Electronics**, 2$^{nd}$ Edition, Kluwer Academic Publishers, 2002.<br>4. Patil M.B., Ramanarayanan V., Ranganathan, V.T., **Simulation of Power Electronic Circuits**, Narosa Publishers, 2009 |

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|---|---|---|
| 1. | Course Code | **EE 603** |
| 2. | Title of the Course | **Optimization Techniques** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | The objective of this course is to introduce the various types of optimization problems., their solution techniques and applications in signal processing and communications. |
| 7. | Course Syllabus | Fundamental concepts in optimization, optimality conditions for constrained and unconstrained problems., duality theory, various algorithms for single variable as well as multivariable unconstrained optimization problems., constrained optimization algorithms, linear programming, integer programming, geometric programming and introduction to evolutionary algorithms. |
| 8. | Suggested Books | 1. S.S. Rao, **Engineering optimization: theory and practice** (3rd edition), John Wiley and Sons, 2009, ISBN: 978-0471550341.<br>2. K. Deb, **Optimization for engineering Design: algorithms and examples**, Prentice Hall India Learning Pvt. Ltd. New Delhi, 2009, ISBN: 978-8120309432.<br>3. A. Ravindran, K. M. Ragsdell, G. V. Reklaitis, **Engineering Optimization: methods and applications** (2nd edition), Wiley India Pvt. Ltd., 2006, ISBN: 978-0471558149. |

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|---|---|---|
| 1. | Course Code | **EE 604** |
| 2. | Title of the Course | **Soft Computing Techniques** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | The objective of this course is to introduce the various types of Soft Computing Techniques such as ANN, Fuzzy logics, genetic algorithms and their applications in signal processing and communications. |
| 7. | Course Syllabus | Basic concepts of Artificial Neural Network (ANN), characteristics and classification of ANN, perceptron model and concept of linear separability, Multilayer perceptron model, various types of training algorithms and models of ANN, introduction to fuzzy sets and operations, fuzzy relations, measure of fuzziness, fuzziness and probability theory, membership function and their features, fuzzification, defuzzification, fuzzy inference system (FIS), fuzzy inference methods, Mamdani and Takagi-Sugeno fuzzy method, Genetic algorithm (GA) concepts and working principle, concept of schema, constraint handling in GA, integration of various soft computing techniques. |
| 7. | Suggested Books | 1. P.D. Wasserman, **Neural Computing Theory and Practice,** Coriolis Group C/O Publishing Resources Inc., 1989, ISBN: 978-0442207434.<br>2. B. Yegnanarayana, **Artificial Neural Networks,** Prentice-Hall of India Pvt. Ltd, New Delhi, 2004, ISBN: 978-8120312531.<br>3. F. Limin, **Neural Networks in Computer Intelligence,** McGraw-Hill Inc., 1994, ISBN: 978-0079118172.<br>4. S.N. Sivanandam, S. Sumathi and S.N. Deepa, **Introduction to Neural Networks using Matlab 6.0,** Tata McGraw-Hill Education, New Delhi, 2006, ISBN: 9780070591127.<br>5. S. Rajasekaran and G.A. Vijayalakshmi Pai, **Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications,** Prentice Hall India Learning Pvt. Ltd. New Delhi, 2004, ISBN: 9788120321861.<br>6. N.P. Padhy, **Artificial Intelligence and Intelligent Systems,** Oxford University Press, 2005, ISBN: 9780195671544.<br>7. S.N. Sivanandam, S. Sumathi and S.N. Deepa, **Introduction to Fuzzy Logic using Matlab,** Springer, 2007, ISBN: 978-3-540-35780-3.<br>8. K. Deb, **Multi-objective Optimization using Evolutionary Algorithms,** John Wiley & Sons, 2009, ISBN: 9780470743614. |

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|---|---|---|
| 1. | Course Code | **EE 605** |
| 2. | Title of the Course | **Nanotechnology** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards nanoscience and nanotechnology |
| 7. | Course Syllabus | • **Past, Present and Future of Nanotechnology:** Applications in diverse domestic and commercial aspects: food, energy, transportation, communication, entertainment, healthcare and medicine etc. Necessity of Nanotechnology and future prospects.<br>• **Review of Crystalline properties of solid:** Crystal lattice and seven crystal systems, The unit cell concept, The Weigner-Seitz cell, Bravais lattices, Space and point groups, Miller indices, reciprocal lattice, Brillouin zone<br>• **Semiconductor Heterostructures and Low-dimensional Quantum Structures:** Energy bands, Application of model solid theory, Anderson model for heterojunctions, Multiple quantum wells (MQWs) and superlattices, Two-dimensional nanostructure: quantum well, One-dimensional nanostructure: quantum wire, Zero-dimensional nanostructure: quantum dot, Optical properties of low-dimensional structures, Examples and applications in real world<br>• **Fabrication of Nanostructures:** Basic compound semiconductors, Bulk single crystal growth techniques, Epitaxial growth techniques, Physical vapor deposition and sputtering, Thermodynamics and kinetics of growths, Nanoscale growth modes<br>• **Characterization Techniques:** Structural, X-ray diffraction, Electron microscopy, Energy dispersive analysis using X-rays, Auger electron spectroscopy, X-ray photoelectron spectroscopy, Secondary ion mass spectroscopy, Rutherford backscattering, Scanning probe microscopy, Optical, Photoluminescence spectroscopy, Cathodoluminescence spectroscopy, Reflectance measurement, Absorbance measurement, Ellipsometry, Raman spectroscopy, Fourier transform spectroscopy, Hall effect, Capacitance techniques, Electrochemical capacitance-voltage profiling<br>• **Innovative Devices based on Nanostructures:** Resonant tunneling diode, Quantum cascade laser, Carbon nanotube devices, Single electron transistor |

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|---|---|---|
| 8. | Suggested Books | 1. M. Razeghi, **Fundamentals of Solid state Engineering** ($2^{nd}$ edition), Springer, 2006, ISBN-13: 978-0-387-28152-0.<br>2. W. R. Fahrner, **Nanotechnology and Nanoelectronics: Materials, Devices, Measurement Techniques,** Springer-Verlag Berlin Heidelberg, 2005, ISBN 3-540-22452-1.<br>3. R. W. Kelsall, I. W. Hamley, and M. Geoghegan, **Nanoscale Science and Technology,** John Wiley & Sons Ltd., England 2005, ISBN: 0-470-85086-8. |

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|---|---|---|
| 1. | Course Code | **EE 607** |
| 2. | Title of the Course | **Power System Operation and Control** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Power Systems at UG level |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Overview of power system operations and control, load flow analysis, security analysis, stability analysis, automatic generation control, state estimation, brief introduction to power system restructuring and power market operations. |
| 8. | Suggested Books | 1. A. J. Wood and B. F. Wollenberg, **Power generation, Operation and Control,** 2nd eddition, New York: John Wiley and Sons, 1996.<br>2. Prabha Kundur, **Power System Stability and Control,** 1st edition, Tata Mcgraw Hill Education Private Limited, 2006.<br>3. Loi Lei Lai, **Power System Restructuring and Deregulation: Trading, Performance and Information Technology,** John Wiley & Sons, 2001. |

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|---|---|---|
| 1. | Course Code | **EE 610/ EE 410** |
| 2. | Title of the Course | **Power Electronics Applications to Power Transmission** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Power Systems and Power Electronics |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Review of load flow and power system stability, introduction to power electronics applications to power system, HVDC transmission, analysis of HVDC converters, HVDC control, mal-operation and protection of converters, Basic FACTS controllers: SVC, STATCOM, TCSC, SSSC, TCPAR, UPFC, IPFC, Modeling of FACTS controllers, improvement in system performance with FACTS controllers. |
| 8. | Suggested Books | 1. K.R. Padiyar, "**HVDC Power Transmission Systems**", New Age International, 1990.<br>2. J. Arrillaga, "**High Voltage Direct Current Transmission**", IEE, 1998.<br>3. E.W. Kimbark, "**Direct Current Transmission**", Wiley-Interscience, 1971.<br>4. N.G. Hingorani and L. Gyugyi, "**Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems**", IEEE Press, 2000.<br>5. Y.H. Song and A. T. Johns, "**Flexible AC Transmission System**", IEE Press, 1999.<br>6. R.M. Mathur and R. K. Varma, "**Thyristor-Based FACTS Controllers for Electrical Power Systems**", IEEE Press and John Wiley, 2002. |

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|---|---|---|
| 1. | Course Code | **EE 612/ EE 412** |
| 2. | Title of the Course | **Digital Communication Systems** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | Elements of digital communication systems: source coding, channel coding, modulation/demodulation, Information and channel capacity: Discrete communication channels and their analysis. Baseband data transmission of analog signals. Time-division multiplexing of digital signals. Synchronization methods. |
| 8. | Suggested Books | 1. K.S. Shanmugam, **Digital and Analog Communication Systems**, Wiley International Publication, 1980.<br>2. M. Schwartz, **Information Transmission, Modulation and Noise**, McGraw Hill International Student Edition, 1980.<br>3. J.J. Proakis, **Digital Communications**, 2$^{nd}$ edition, McGraw Hill 1989.<br>4. S.S. Haykin**, An Introduction to Analog and Digital Communication Systems**, Wiley Eastern, 1989. |

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|---|---|---|
| 1. | Course Code | **EE 619/ EE 419** |
| 2. | Title of the Course | **Biomedical Optics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Fundamentals of Electromagnetic wave theory and optics |
| 6. | Scope of the Course | |
| 7.. | Course Syllabus | **Introduction to tissue engineering:** Cells as therapeutic agents, cellular fate processes, cell differentiation, cell division, cell death/apoptosis, Types of tissues and their functions, tumors and cancers<br><br>Interaction of light with cells and tissues, spectroscopy, optical biopsy, optics of blood, tissue phantoms., absorption and fluorescence spectroscopy<br><br>**Bioimaging:** Transmission microscopy, Phase contrast Microscopy, Fluorescence Microscopy, Multiphoton Microscopy, Optical Coherence Tomorgaphy.<br><br>**Optical Biosensors:** Principles of optical biosensing, Fiber-optic biosensors, Interferometric biosensors, Surface Plasmon Resonance biosensors<br><br>Case studies of cellular and biomolecular imaging |
| 8. | Suggested Books | **Text Books**<br>1. Valery V. Tuchin, Handbook of Optical Biomedical Diagnostics, Kluwer Academic Publishers, 2004, ISBN: 1402075766<br>2. Paras N Prasad, Introduction to Biophotonics, John Wiley and Sons, 2003, ISBN: 9780471287704.<br>**Reference Books**<br>1. M.H. Niemz, Laser-Tissue Interactions: Fundamental and Applications (Biological and Medical Physics, Biomedical Engineering), Springer, 2007, ISBN: 978-3540721918.<br>2. R.W. Waynant, Lasers in Medicine, CRC Press, 2002, ISBN: 0-8493-1146-2.<br>3. Bernhard O. Palsson, Tissue Engineering, CRC Press 2003. |

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|---|---|---|
| 1. | Course Code | **EE 620/ EE 420** |
| 2. | Title of the Course | **IC Fabrication Technology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Introduction** to microelectronic fabrication<br>**Semiconductor substrate:** Phase diagram and solid solubility, Crystal structure, Crystal defects, Crystal growth<br>**Diffusion:** Atomistic models of diffusion, Analytic solutions of Fick's law, Diffusion coefficients, Two step diffusion, Diffusion system<br>**Thermal Oxidation:** The Deal-Grove model, The initial oxidation, Oxide characterization, Oxidation induced stacking faults, Oxidation systems<br>**Ion implantation:** Ion implantation system, Vertical projected range, Channeling effect, Implantation damage, Problems and concerns<br>**Optical lithography:** Overview, Source systems, Contact/proximity printers. Projection printers, Alignment<br>**Photo resist:** Contrast curves, Applying and developing photo resist<br>**Etching:** Wet etching, Plasma etching, Ion milling, Reactive ion etching, Liftoff<br>**Chemical Vapor Deposition:** CVD system, Advanced CVD systems,<br>**Epitaxial growth:** Wafer cleaning and native oxide removal, The thermal dynamics, Surface reactions, Do pants, Defects in epitaxial growth, MOCVD, MBE and CBE<br>**Contacts and metallization:** Junction and oxide isolation, Si on insulator, Schottky and Ohmic contacts, Multilevel metallization<br>**CMOS technologies:** Device behavior, Basic 3 µm technologies, Device scaling<br>**Circuit Manufacturing:** Yield, Particle control, Design of experiments, Computer integrated manufacturing |
| 8. | Suggested Books | 1. Stephen A. Campbell, ***The Science and Engineering of Microelectronic Fabrication***, 2nd edition (Oxford University Press, 2001)<br>2. Sorab K. Gandhi, ***VLSI Fabrication Principles****, 2nd Edition* (John Wiley & Sons, Inc., 1994) |

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|---|---|---|
| 1. | Course Code | **EE 621 / EE 421** |
| 2. | Title of the Course | **MOS Devices & Modeling** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Knowledge of basic physics of diodes, BJTs, FETs, MOS structure. Semiconductors, Junctions and MOSFET |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Overview:** Introduction, Semiconductors, Conduction, Contact Potentials, P-N Junction, Overview of the MOS Transistor.<br>**Two Terminal MOS Structure:** Flat-band voltage, Potential balance & charge balance, Effect of Gate- substrate voltage on surface condition, Inversion, Small signal capacitance;<br>**Three Terminal MOS Structure:** Contacting the inversion layer, Body effect, Regions of inversion, Pinch-off voltage.<br>**Four Terminal MOS Transistor:** Transistor regions of operation, general charge sheet models, regions of inversion in terM.S. of terminal voltage, strong inversion, weak inversion, moderate inversion, interpolation models, effective mobility, temperature effects, breakdown p-channel MOS FET, enhancement and depletion type, model parameter values, model accuracy etc.<br>**Small dimension effects:** channel length modulation, barrier lowering, two dimensional charge sharing and threshold voltage, punch- through, carrier velocity saturation, hot carrier effect s, scaling, and effect s of surf ace and drain series resistance, effects due to thin oxides and high doping. Sub threshold regions, Advanced SOI structures.<br>**CMOS Device Design**: Scaling, Threshold voltage, MOSFET channel length. |
| 8. | Suggested Books | **Text:**<br>1. Yuan Taur & Tak H. Ning (Cambridge), **Fundamentals of Modern VLSI Devices**<br>2. Yannis Tisividi s (Oxford), The MOS Transistor (2nd edition)<br>**Reference:**<br>1. B.G. Streetman, Solid State Electronics Devices, Prentice Hall of India, New Delhi.<br>2. D.A. Neaman, Semiconductor Physics and Devices, McGraw-Hill. |

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|---|---|---|
| 1. | Course Code | **EE 622 / EE 422** |
| 2. | Title of the Course | **Digital Circuit Design** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of MOS Transistor theory and CMOS Circuit Design |
| 6. | Scope of the Course | The objective of this course is to develop the concepts of designing circuits associated with signal processing methods. |
| 7. | Course Syllabus | **Module 1:** MOS scaling, Short channel effects, MOSFET models, Nano CMOS, Effects of gate oxide tunnelling, high-k dielectrics, Advanced CMOS structures, SOI, MOSFET capacitances, MOSFET models for calculation- Transistors and Layout, CMOS layout elements, SPICE simulation of MOSFET I-V characteristics and parameter extraction.<br>**Module 2:** CMOS inverter, static characteristics, noise margin, dynamic characteristics, inverter design for a given VTC and speed, effect of input rise time and fall time, power dissipation, energy & power delay product, sizing chain of inverters, latch up effect-Simulation of static and dynamic characteristics, layout<br>**Module 3:** Combinational and sequential MOS logic design, static properties, propagation delay, Elmore delay model, power consumption, low power design techniques, rationed logic, pseudo NMOS inverter, DCVSL, PTL, DPTL & Transmission gate logic, dynamic CMOS design, speed and power considerations, Domino logic and its derivatives, C2MOS, TSPC registers, NORA CMOS.<br>**Module 4:** Semiconductor memories, SRAM and DRAM, BiCMOS logic - static and dynamic behavior -Delay and power consumption in BiCMOS Logic |
| 8. | Suggested Books | **Text:**<br>1. S.M. Kang and Y. Leblebici, **CMOS Digital Integrated Circuits Analysis & Design (**3rd edition**)**, Tata McGraw Hill, New Delhi, 2003, ISBN: 978-0-07-053077-5.<br>2. J. M. Rabaey, A.P. Chandrakasan and B. Nikolic, **Digital Integrated Circuits: A Design Perspective (**2nd edition**)**, Prentice Hall, 2003, ISBN: 978-0130909961.<br>**Reference:**<br>1. D. A. Hodges, H. G. Jackson, and R. A. Saleh, **Analysis and Design of Digital Integrated Circuits** (3rd edition), McGraw Hill, 2004, ISBN: 978-0070593756. |

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|---|---|---|
| 1. | Course Code | **EE 623** |
| 2. | Title of the Course | **Introduction of VLSI Design** |
| 3. | Credit Structure | L-T- P-Credits<br>3-0-2-4 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Basic of MOS Transistor Theory |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **UNIT 1:** MOS theory, scaling and characteristics, MOS capacitance, CMOS Processing Technology, Layout and VLSI Design Flow.<br>**UNIT 2**: CMOS Inverter and Characteristics, Inverter switching Characteristics, delay and power analysis, CMOS layout design rule and layout of complex circuits, Transistor sizing, Inverter Chain, power dissipation, design corner.<br>**UNIT 3:** Combinational circuit design, Transmission gate and pass transistor logic, design, Sequential circuit design, Data processing circuit design, Semiconductor memories.<br>**UNIT 4:** Dynamic circuits, Introduction of Low power CMOS logic design techniques, Adiabatic logic circuits.<br>**<u>LAB: Exposure on Cadence EDA Tool</u>**<br>Design and analysis (Circuit simulation and layout design) of CMOS inverter characteristic with the given design goal (power, delay etc.), Parametric variation on CMOS characteristics.<br>Design and analysis of Combinational and Sequential logic design (NOT, NAND, NOR, FF etc.) and data processing circuits.<br>Design and analysis of Memory Cells and Low Power Circuits. |
| 8. | Suggested Books | **Text:**<br>1. Cadence Design Software and Manual.<br>2. Yuan Taur & Tak H. Ning (Cambridge), Fundamentals of Modern VLSI Devices<br>3. Neil H. Weste, David Harris, Ayan Banerjee, CMOS VLSI Design- A Circuit and System Perspective, 3rd Edition, Pearson Publishers.<br>4. Sung-Mo Kang & Yusuf Leblebici, CMOS Digital Integrated Circuits - Analysis & Design, , MGH, 3rd edition., 2003.<br>**Reference:**<br>1. B.G. Streetman, Solid State Electronics Devices, Prentice Hall of India, New Delhi.<br>2. D.A. Neaman, Semiconductor Physics and Devices, McGraw-Hill.<br>3. David A. Hodges, Horace G. Jackson, and Resve A. Saleh, Analysis and Design of Digital Integrated Circuits, 3rd Edition, McGraw-Hill, 2004. |

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|---|---|---|
| 1. | Course Code | **EE 624** |
| 2. | Title of the Course | **Interface Effects in Electronic Devices** |
| 3. | Credit Structure | 2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | To expose students towards interface effect in electronic devices |
| 7. | Course Syllabus | 1) **Fundamentals of solid state engineering: Future of** Metals, Semiconductors and Insulators**.** Band theory of solids, Carrier Transport phenomena, charge carrier mobility, diffusion and basic principles involving semiconductor device under operation.<br>2) Metal Semiconductor and Metal Insulator Semiconductor junctions, and their biasing effects. PN-junction diode, MESFET and MOSFET devices and principle of their operation. Basic device characteristics Solar cells and LEDs.<br>3) Interface effects in MOSFETs, LEDs and Photovoltaic devices. Interface traps and their characterization using *I-V*, *C-V* and charge pumping etc., Low frequency noises and RTS in MOS devices. Absorption/emission spectroscopy, Deep level transient spectroscopy (DLTS), Kelvin Force Probe Microscopy, Scanning Probe Microscopy, Self assembly and Self Organization, surface passivation, surface effects in nano structured materials and devices. |
| 8. | Suggested Books | 1. K. Iniewski, **Nanoelectronics: Nanowires, Molecular Electronics and Nanodevices,** Mc. Graw Hill, ISBN: 987-0-07-166449-3.<br>2. M. D. Ventra, S. Evoy and J. R. Heflin, **Introduction to Nanoscale Science and Technology,** Kluwer Academic Publishers, ISBN: 1-4020-7720-3.<br>3. M. Iwamoto, Y. S. Kwon and T. Lee, **Nanoscale Interface for Organic Electronic,** World Scientific, ISBN: 978-981-4322-48-5.<br>4. S. M. Sze, **Physics of semiconductor devices,** John Wiley and Sons, 1981, ISBN: 0-471-05661-8.<br>5. R. Kelsall, I. Hamley and M. Geoghegan, **Nanoscale Science and Technology,** John Wiley and Sons Ltd, 2005, ISBN: 0-470-85086-8. |

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| 1. | Course Code | **EE 625** |
| 2. | Title of the Course | **VLSI Signal Processing** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Digital Electronics, Semiconductor Theory, Knowledge of Communication and Signal Processing. |
| 6. | Scope of the Course | The main aim of this course to develop understanding of implementation of algorithms for signal processing and communications. |
| 7. | Course Syllabus | **UNIT 1:** MOS Transistor Theory and Operation, CMOS Scaling limits, Double Gate and FinFET, Design and analysis of CMOS inverter, NAND, NOR, Flip Flop, Transmission gate technology, Transistor sizing, Power, Delay and PDP, Layout design rule.<br><br>**UNIT 2:** Concept of semiconductor memory, Low power and high performance circuit and System Design, Brief introduction of VHDL/Verilog Language, ASIC and FPGA Design and Technology, FPGA architecture.<br><br>**UNIT 3:** Introduction of Digital signal processing systems, Wireless communication concept: circuit design prospective, DSP Technology Requirement, FPGA and Digital Signal processors.<br><br>**UNIT 4:** FPGA implementation and Circuit design aspect of digital signal processing blocks, Filter design, Frequency Synthesizer, Digital Transceiver architecture and design. |
| 8. | Suggested Books | 1. S. M. Kang and Y. Leblebici, **CMOS Digital Integrated Circuits Analysis & Design** (3rd edition), Tata McGraw Hill, New Delhi, 2003, ISBN: 978-0-07-053077-5.<br>2. K.K. Parhi, **VLSI Digital Signal Processing Systems: Design and Implementation**, Wiley-Interscience; 1999, ISBN: 978-0471241867.<br>3. U.M. Baese, **Digital Signal Processing with Field Programmable Gate Arrays (Signals and Communication Technology)**, (3rd edition), Springer, 2007, ISBN: 978-3540726128.<br>4. B. Leung, **VLSI for Wireless Communication** (2nd edition), Springer, 2011, ISBN: 978-1461409854.<br>5. C. Chien, **Digital Radio Systems on a Chip-A System Approach**, Springer, 2001, ISBN: 978-0792372608. |

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| 1. | Course Code | **EE 626/ EE 426** |
| 2. | Title of the Course | **MOSFET Reliability Issues** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical |
| 5. | Pre–requisite, if any | Basic knowledge of MOS device and technology. |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Evolution of VLSI Device Technology:** Modern CMOS Devices, MOSFET I-V characteristics, Substrate bias and temperature dependence of threshold voltage, Channel mobility, inversion layer capacitance effect. Short channel effects, velocity saturation, channel length modulation, source-drain series resistance, MOSFET breakdown.<br>**High Field Effects**: Impact ionization and avalanche breakdown, Band to band tunneling, Tunneling into and through silicon dioxide, Injection of hot carriers from silicon into silicon dioxide, High field effects in gated diodes.<br>**Modeling Hot carrier Effects:** Substrate current model, Gate current model, Correlation between gate and substrate current, Mechanism of MOSFET degradation, Impact of degradation on circuit performance, Temperature dependence of device degradation.<br>**Electrostatic Discharge Damage:** Introduction to reliability concepts and modeling. Triboelectricity, ESD control, On-chip protection, ESD models and testing, ESD models and testing procedures, failure models.<br>**Metal Electro migration:** Phenomenon of Electro migration, Theoretical and empirical relations, Effects of stress and gases on electro migration, effects of geometric variation and defects, Electro migration at the contacts and windows, layered metallization, Electro migration in polysilicon, Electro migration under pulsed currents.<br>**Dielectric Breakdown:** Introduction, Complex nature of oxide breakdown, Oxide breakdown strength distribution, TDDB life test, Oxide defects, Concept of distance to fail, Step stress techniques, correlation of ramp test data to TDDB data.<br>**Packaging Relation Reliability Issues:** Effects of moisture, Detection and package evaluation, stress in packaging, Issues related to die bonding, Solder joint problem, Electrolytic corrosion, Accelerated reliability tests for packages. |
| 8. | Suggested Books | 1. Y. Taur and T.H. Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press (ISBN: 0-521-55959 6). |

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| | | 2. N. Arora, MOSFET Modeling for VLSI Simulation: Theory and Practice, World Scientific, (ISBN-13 978-981-256-862-5).<br>3. Y. Leblebici, S.-M. Kang, Hot-Carrier Reliability of MOS VLSI Circuits, Springer, 1993 (ISBN 978-0-792393528).<br>4. A.W. Strong, E.Y. Wu, R.-P. Vollertsen, J. Sune, G.L. Rosa, T.D. Sullivan, S.E. Rauch III, Reliability Wearout Mechanisms in Advanced CMOS Technologies, Wiley-IEEE Press, 1999 (ISBN: 978-0471731726). |

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| 1. | Course Code | **EE 628 / EE 428** |
| 2. | Title of the course | **Advanced Memory Technology** |
| 3. | Credit structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the concerned Discipline | Electrical Engineering |
| 5. | Pre-requisite, if any | Courses on Electronic Devices, and VLSI Systems and Technology |
| 6. | Scope of the Course | Motivation of this course is to provide a brief background on the evaluation on the memory technologies (both optical/ electronic). In addition to that this course will cover sufficient technical knowledge on non-volatic and voltaic memories. Further an over view of emerging memory technologies and their importance towards future memory technology will be discussed. |
| 7. | Course syllabus | **Introduction to memory devices**: Evolution and history; archival data storage; advances in optical memories.<br>**Nonvolatile memories:** Magnetic memories, HDDs; Silicon based thin film transistor nonvolatile memories; Flash memories, classification and operation; challenges; advancements.<br>**Volatile memories:** Random access memories, classification and operation; SRAM.S.; DRAM.S.; history and challenges.<br>**Emerging memory technologies:** Phase Change Memory (PCM); Magnetoresistive Random Access Memory (MRAM); Ferroelectric Random Access Memory (FeRAM); Comparison and future directions. |
| 8. | Suggested books | 1. T.Y. Tseng and S.M. Sze, **Nonvolatile memories-Materials, Devices and Applications,** American Scientific Publishers; Volume 1 and 2, 2012, ISBN: 978-1588832504.<br>2. J. Brewer and M. Gill, **Nonvolatile memory technologies with emphasis on Flash**, IEEE Press series on microelectronic systems, WILEY-INTERSCIENCE 2008, ISBN: 978-0471-77002-2.<br>3. S. Raoux and M. Wuttig, **Phase change materials-Science and Applications**, Springer**,** 2009, ISBN:978-0-387-84873-0.<br><br>**References:**<br>1. S. Lai, **Flash memories: Successes and challenges**, IBM Journal of Res. And Dev. Vol. 52, p 529, 2008.<br>2. H.S. Philip Wong et. Al., **Phase change memory**, Proceedings of the IEEE, Vol. 98, p 2201, 2010. |

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|---|---|---|
| 1. | Course Code | **EE 629 / EE 429** |
| 2. | Title of the Course | **Nanotechnology and Nanoelectronics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Fundamentals of solid state engineering:** Future of semiconductor device and research, Applications in food, energy, transportation, communication, entertainment, health and medicine etc. Necessity of innovative technology and prospect for future.<br>**Crystalline properties of solid:** Crystal lattice and seven crystal systems, the unit cell concept, The Weigner-Seitz cell, Bravais lattices, Space and point groups, Miller indices, reciprocal lattice, Brillouin zone.<br>**Semiconductor heterostructures and low-dimensional quantum structures:** Energy bands, Application of model solid theory, Anderson model for heterojunctions, Multiple quantum wells (MQWs) and super lattices, Two-dimensional nanostructure: quantum well, One-dimensional nanostructure: quantum wire, Zero-dimensional nanostructure: quantum dot, Optical properties of low-dimensional structures, Examples and applications in real world.<br>**Fabrication of nanostructures:** Basic compound semiconductors, Bulk single crystal growth techniques, Epitaxial growth techniques, Physical vapor deposition and sputtering, Thermodynamics and kinetics of growths, Nan scale growth modes<br>**Characterization Techniques:** Structural, X-ray diffraction, Electron microscopy, Energy dispersive analysis using X-rays, Auger electron spectroscopy, X-ray photoelectron spectroscopy, Secondary ion mass spectroscopy, Rutherford backscattering, Scanning probe microscopy, Optical, Photoluminescence spectroscopy, Cathodoluminescence spectroscopy, Reflectance measurement, Absorbance measurement, Ellipsometry, Raman spectroscopy, Fourier transform spectroscopy, Electrical Resistivity, Hall effect, Capacitance techniques, Electrochemical capacitance-voltage profiling<br>**Innovative devices based on nanostructures:** Resonant tunneling diode, Quantum cascade laser, Carbon nanotube devices, Single electron transistor |
| 8. | Suggested Books | 1. M. Razeghi, *Fundamentals of Solid State Engineering*, 2nd Edition (Springer, 2006)<br>2. W. R. Fahrner, *Nanotechnology and Nan electronics: Materials, Devices, Measurement Techniques* (Springer-Verlag Berlin Heidelberg 2005)<br>3. R. W. Kelsall, I. W. Hamley, and M. Geoghegan, *Nanoscale Science and Technology* (John Wiley & Sons Ltd, England 2005) |

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| 1. | Course Code | **EE 630 / EE 430** |
| 2. | Title of the Course | **Analog CMOS IC Design** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical |
| 5. | Pre–requisite, if any | Knowledge of MOSFET device operation, physics and technology. |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Basic MOS Device Physics:** MOSFET as a switch, MOSFET structure and symbol, MOSFET I-V characteristics, Threshold voltage, Second Order Effects, MOSFET layout, capacitances, small signal model, long channel and short channel models.<br>**Short Channel Effects and Device Models:** Scaling theory, short channel effects, threshold voltage variation, mobility degradation with vertical field, velocity saturation, hot carrier effects, output impedance variation with drain source voltage, BSIM model, charge and capacitance modeling, temperature dependence.<br>**Single-Stage Amplifiers:** Basic concepts, Common-source stage, source follower, common-gate stage, cascade stage.<br>**Differential Amplifiers:** Single ended and differential operation, basic differential pair, common mode response, differential pair with MOS loads, Gilbert cell.<br>**Passive and Active Current Mirrors:** Basic current mirrors, Cascade current mirrors, Active current mirrors.<br>**Nonlinearity and Mismatch:** Nonlinearity of differential circuits, effect of negative feedback on nonlinearity, capacitor nonlinearity, linearization techniques, offset cancellation techniques, reduction of noise by offset cancellation, alternative definition of CMRR. |
| 8. | Suggested Books | 1. B. Razavi, Design of Analog CMOS Integrated Circuits, Tata McGraw-Hill, New Delhi, 2002 (ISBN: 978-0-07-052903-8).<br>2. P.E. Allen and D.R. Holberg, CMOS Analog Circuit Design, Oxford University Press, New Delhi, 2010 (ISBN: 978-0-19-806440-4).<br>3. D.M. Binkley, Tradeoffs and Optimization in Analog CMOS Design, Wiley, 2008 (ISBN: 978-0-470-03136-0). |

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| 1. | Course Code | **EE 631/ EE 431/ IEE 431** |
| 2. | Title of the Course | **Organic Electronics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/Discipline | Electrical Engineering Discipline |
| 5. | Pre–requisite, if any | Basic Semiconductor Physics/ Basic electronics |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Background towards molecular electronics, surfaces and interfaces, structures and organization. Introduction to Schrodinger equation, Hartree-Fock Theory, Density Functional Theory. Molecular Solids, π-conjugated polymers, one dimensional band structure of linear conjugated polymers, optical absorption and emission in conjugated oligomers/polymers. Device motivation for interface studies, Metal-semiconductor and Metal-Insulator-Semiconductor Interface. Charge transport in conjugated polymers. Hopping and Multiple trap and release model. Interface effects viz. Dipole, doping, band bending etc. in organic semiconductor devices.<br>Materials and Interface Engineering in Organic Light Emitting Diodes (OLEDs). OLED materials and device architecture for full color displays and solid state lighting. Theory and operation principle of Organic Field Effect Transistors (OFETs). Interface Characterization, Threshold Voltage and subthreshold swing and charge carrier mobility in OFETs. Application of OFETs in Displays. Organic Photovoltaic Devices (OPDs) using Polymer-Fullerene Bulk heterojunction thin filM.S.. Interface effects and improvement in Polymer Solar Cells (PSCs) efficiency. Introduction to some other advanced concepts viz. Organic electrochromic materials and devices, multiphoton absorbing materials and devices and Nonvolatile Organic Thin Film Memory Device. |
| 8. | Suggested Books | 1. S. M. Sze, ***Physics of semiconductor devices***, John Wiley and Sons, 1981, ISBN: 0-471-05661-8<br>2. R. Kelsall, I. Hamley and M. Geoghegan, ***Nanoscale Science and Technology***, John Wiley and Sons Ltd, 2005, ISBN: 0-470-85086-8.<br>3. K. Morigaki, ***Physics of amorphous semiconductors***, Imperial College Press, 1999, ISBN: 981-02-1381-6.<br>4. G. Hadziioannou and G. Malliaras, ***Semiconducting Polymers****: Chemistry, Physics and Engineering*, 2$^{nd}$ Edition, Wiley Inter science, 2007, ISBN: 978-3-527-31271-9.<br>5. F. So, Organic Electronics: **Materials Processing, Devices and Applications**, CRC Press, 2010, ISBN: 978-1-4200-7290-7.<br>6. W. R. Salaneck, **Conjugated Polymer Surfaces and Interfaces**, 2$^{nd}$ edition, Cambridge University Press, 1996, ISBN: 0-521-47206-7 |

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| 1. | Course Code | **EE 632/ EE 432** |
| 2. | Title of the Course | **Optoelectronics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Fundamentals of Lasers:** The Einstein A and B coefficient approach to the photon-atom interaction, Based on this approach, examines semi-classical quantum theory of the laser to illustrate the general applicability of the rate equation, Description of light detection.<br>**Laser Physics and Dynamics:** Threshold condition for laser oscillation, Gain saturation, Multimode Oscillation, Amplified spontaneous emission, Laser efficiency, CW laser<br>**Different Sources of Lasers:** Solid state lasers, Color center lasers, Gas lasers, Dye lasers, Chemical lasers, Semiconductor lasers. |
| 8. | Suggested Books | 1. Joseph T. Verde yen, Laser Electronics, 3rd edition (prentice-Hall, 1995)<br>2. E. Siegman, Introduction to Lasers and Masers (New York: McGraw-Hill Company, 1971)<br>3. C. Casey, Jr. and M. B. Panish, Heterostructure lasers (New York: Academic Press, 1978) |

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|---|---|---|
| 1. | Course Code | **EE 633** |
| 2. | Title of the Course | **Low Power RF CMOS Design** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of Electronic Devices and MOS operation. |
| 6. | Scope of the Course | The objective of this course is to introduce concepts related evaluation, extraction and design optimization of low power RF MOSFETs. |
| 7. | Course Syllabus | Introduction to Y-, Z-, and H-parameters. Use of S-parameters in RF Design, Conversion between parameters, Multiport S-parameters, Deembedding for MOS Transistor.<br><br>Basic concepts of modelling and parameter extraction, Requirements for RF FET modelling, Three-Terminal RF MOSFET Modelling and Parameter Extraction, Determination of the series parasitic elements, Determination of the shunt parasitic elements, Determination of the intrinsic Y-matrix, Extraction of the intrinsic elements.<br><br>Introduction to SOI technology, Properties of Fully-Depleted (FD) Silicon-on-Insulator (SOI) MOSFETs for low power applications, Intrinsic gate capacitance, Noise, Linearity, High Temperature characteristics, High Frequency behaviour of SOI substrate.<br><br>Extraction and significance of low power RF performance metrics: transconductance, cut-off frequency, frequency of maximum oscillations, capacitance, Linearity. Parasitic components of SOI MOSFETs and their minimization.<br><br>Designing RF Ultra Low Power MOSFETs in FD SOI technology: Laterally Asymmetric Channel (LAC), Dynamic Threshold MOSFET, Graded Channel (GC) Architecture, Underlap MOSFET. |
| 8. | Suggested Books | 1. N.D. Arora, **MOSFET Modeling from VLSI Simulation,** World Scientific, 2007. ISBN: 978-981-256-862-5<br><br>2. M. Jamal Deen and Tor A. Fjeldly, **CMOS RF Modeling, Characterization and Applications,** World Scientific, 2002. ISBN 981-02-4905-5<br><br>3. Y. Tsividis and Colin McAndrew, **Operation and Modeling of The MOS Transistor**, Oxford University Press, 2010. ISBN: 978- 0195170153<br><br>4. T. Ytterdal, Y. Cheng and T. Fjeldly, **Device Modeling for Analog and RF CMOS Circuit Design,** Wiley, 2003. ISBN: 0-471-49869-6 |

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| 1. | Course Code | **EE 634 / EE 434** |
| 2. | Title of the Course | **Semiconductor Based Sensors** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Basic Knowledge of Electronic Devices |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Introduction:** Introduction and classification of sensors, sensors and transducers, Semiconductor sensors and their classification, sensor characterization, Evolution of semiconductor sensors.<br>**Semiconductor Sensors Technologies**: Introduction to basic fabrication processes, Micromechanical Process Design, Bulk Micromachining, surface micromachining, other manufacturing techniques, Applied Statistics & Probability in semiconductor manufacturing.<br>**Mechanical Sensors:** Piezoresistivity, and Piezoresistive sensors, Capacitive sensors, Piezoelectric materials and acoustic sensors, SAW based sensors, strain gauge and cantilever based sensors. Thermal sensors, Thermal sensing elements, Micro/Nanoelectromechanical sensors (MEMS/ NEMS).<br>**Magnetic and Optical sensors:** Integrated Hall sensors, magnetotransistors, photodiodes and phototransistors, HgCdTe based Infrared sensors, High energy photodiodes.<br>**Chemical and Biosensors:** Introduction to interaction of gaseous species at semiconductor surfaces, thin film based sensors, Field Effect Transistor (FET) devices for gas/ ion sensing, Immobilization of enzymes in biosensors, Transduction principles and packaging on biosensors.<br>**Integrated Sensors:** Introduction, System Organization & Functions, Interface electronics, Examples of Integrated sensors. |
| 8. | Suggested Books | 1. Mohamed Gad-el-Hak, **The MEMS Handbook**, CRC Press (ISBN: 0-8493-0077-0).<br>2. S. M. Sze, **Semiconductor Sensors**, J. Wiley (ISBN: 978-0471546092).<br>3. R. Shinar and J. Shinar, **Organic Electronics in Sensors and Biotechnology**, Mc Graw Hill (ISBN: 978-0071596756).<br>4. J. W. Gardner**, Microsensors: Principles and Applications**, Wiley (ISBN: 978-0471941361).<br>5. S. Middelhoek, S. Audet, **Silicon Sensors**, Academic Press (ISBN: 0-12-495051-5).<br>6. R. F. Wolffenbuttel, **Silicon Sensors and Circuits: On Chip compatibility**, Chapman and Hall (ISBN: 0-412-70970-8). |

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|---|---|---|
| 1 | Course code | **EE 635/ EE 435** |
| 2 | Title of the course | **VLSI Technology** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | None |
| 6 | Scope of the course | This course is designed to introduce the state of the art fabrication technology used in fabrication of standard Si based CMOS Nano-devices and Very Large Scale Integrated Circuits based on them. |
| 7 | Course syllabus | **General overview of VLSI technology**<br>Introduction to VLSI technology, underlying processes, clean room, wafer cleaning procedures and physical limits of technology, Moore's law, top-down and bottom up approach.<br><br>**General fabrication processes**<br>Oxidation, diffusion, ion-implantation, wet chemical etching, dry etching and deposition techniques.<br><br>**Lithographic techniques**<br>Advancement of lithography with scaling down of devices, Figure of merits, NA and depth of focus, Issues pertaining to lithography, MTF, PCM, patterning, mask generation, Advanced lithographic techniques viz. Immersion lithography, e-beam/ion-beam lithography, X-ray lithography.<br><br>**Silicides and interconnects**<br>Silicidation, contact issues in MOSFETs, metal silicides, interconnects, resistance of interconnects, skin effect, fringing capacitances, crosstalk, lumped/distributed RC delay model, Elmore model, interconnect design for VLSI applications.<br><br>**Process sequences**<br>Process sequences for Bipolar, n-MOS and CMOS technologies. |
| 8 | Suggested books | 1. S. K. Gandhi, VLSI Fabrication principles, 2nd edition, (John Wiley & Sons Inc., 1994). (ISBN: 9780471580058).<br>2. S. M. Sze, VLSI Technology, 2nd Edition, (McGraw Hill Co. Inc., New York, 1988). (ISBN:9780070627352).<br>3. C. Y. Chang & S. M. Sze, VLSI Technology, (McGraw Hill Co. Inc., New York, 1996). (ISBN: 9780070630628).<br>4. James Plummer, M. Deal and P. Griffin, Silicon VLSI Technology, Prentice Hall Electronics and Series, 2000 VLSI. (ISBN:9780130850379).<br>5. Stephen Campbell, The Science and Engineering of Microelectronics, Oxford University Press, 1996. (ISBN:9780195136050). |

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|---|---|---|
| 1 | **Course code** | **EE 638** |
| 2 | **Title of the course** | **System on Programable Chip Design** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Digital, Microprocessor & Microcontroller |
| 6 | Scope of the course | |
| 7 | Course syllabus | **1. Introduction**<br>Driving Forces for SoC - Components of SoC - Design flow of SoC - Hardware/Software nature of SoC - Design Trade-offs - SoC Applications<br>**2. System-level Design**<br>Processor selection, Concepts in Processor Architecture: Instruction set architecture (ISA), elements in Instruction Handing-Robust processors: Vector processor, VLIW, Superscalar, CISC, RISC-Processor evolution: Soft and Firm processors, Custom-Designed processors- on-chip memory.<br>**3. Interconnection**<br>On-chip Buses: basic architecture, topologies, arbitration and protocols, Bus standards: AMBA, Core Connect, Wishbone, Avalon - Network-on-chip: Architecture-topologies-switching strategies - routing algorithms - flow control, Quality-of-Service- Reconfigurability in communication architectures.<br>**4. IP based system design**<br>Introduction to IP Based design, Types of IP, IP across design hierarchy, IP life cycle, Creating and using IP - Technical concerns on IP reuse – IP integration - IP evaluation on FPGA prototypes.<br>**5. SOC implementation**<br>Study of processor IP, Memory IP, wrapper Design - Real-time operating system (RTOS), Peripheral interface and components, High-density FPGAs - EDA tools used for SOC design.<br>**6. SOC testing**<br>Manufacturing test of SoC: Core layer, system layer, application layer P1500 Wrapper Standardization-SoC Test Automation (STAT). |
| 8 | Suggested books | 1. 1. Louise H. Crockett, Ross A. Elliot, Martin A. Enderwitz, "The Zynq Book: Embedded Processing with the Arm Cortex-A9 on the Xilinx Zynq-7000 All Programmable Soc". Strathclyde Academic Media, July 2014.(ISBN:978099297870).<br>2. 2. Michael J. Flynn, Wayne Luk, “Computer system Design: System-on-Chip”. Wiley-India, 2011. (ISBN: 978-0-470-64336-5)<br>3. 3.Sudeep Pasricha, Nikil Dutt, “On Chip Communication Architectures: System on Chip Interconnect”. Morgan Kaufmann Publishers.1st edition May 13, 2008,(ISBN-13: 9780123738929).<br>4. 4.W. H. Wolf, “Computers as Components: Principles of Embedded Computing System Design”. Elsevier, 2008.2nd edition (ISBN:9780080886213). |

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| | | 5. 5. Patrick Schaumont "A Practical Introduction to Hardware/Software Co-design". Springer, 2012. 2nd edition, (ISBN:9781461437369).<br>6. 6. Lin, Y-L.S. (ed.), "Essential issues in SOC design: designing complex systems-on-chip. Springer, 2006. (ISBN:9781402053528).<br>7. 7. Wayne Wolf, "Modern VLSI Design: IP Based Design", Prentice-Hall India, 4th edition, 2009. (ISBN: 978-0137145003). |

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|---|---|---|
| 1 | **Course code** | **EE 640/ EE 440** |
| 2 | **Title of the course** | **Analog & Mixed Signal IC Design** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Elementary knowledge about basic electronics and basic electrical circuits |
| 6 | Scope of the course | As most of the parameters we deal with in the physical world are analog, therefore this course is designed to make the students well adept in the area of Analog & mixed signal IC design. |
| 7 | Course syllabus | **Basic Analog Building Blocks:**<br>Switches, active resistors, current sources, current mirrors, current and voltage sources,Wilson and Widlar current mirrors, basic bipolar and CMOS process technology, D-A and A-D converters, filter design considerations.<br><br>**Amplifiers:**<br>CMOS based differential and operational amplifiers, multipliers, modulators, quasi differential amplifier, errors due to mismatch, replication principle, qualitative analysis, common mode response, frequency response, noise performance of differential amplifiers.<br><br>**Advanced Analog & Mixed Signal Design:**<br>Mixed signal blocks & design issues, design of high speed comparators, Opamps, design of sample and hold circuits, design of CMOS based analog multipliers and dividers, switched capacitor filters, frequency compensation schemes viz. Miller compensation. |
| 8 | Suggested books | 1. Roubic Gregorian and Gabor C Temes, Analog MOS Integrated Circuits for Signal Processing, John Wiley & Sons, 1986. **(**ISBN:1978-0137145003).<br>2. Randall Geiger, Phillip E Allen and Neol Stradder, VLSI Design Techniques for Analog and Digital Circuits, Mc Graw Hill International Edition, 1990. (ISBN: 9780070232532).<br><br>3. 3. Phillip E Allen and Douglas R Holberg, CMOS Analog Design Circuit, Oxford University Press, 2002. (ISBN: 9780199937424). |

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|---|---|---|
| 1. | Course Code | **EE 641/ EE 441** |
| 2. | Title of the Course | **Advanced Signal Processing** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Signals and Systems |
| 6. | Scope of the Course | The goal of advanced digital signal processing course is to provide a comprehensive coverage of signal processing methods and tools, including leading algorithms for various applications. |
| 7. | Course Syllabus | Review of discrete-time signals and systems concepts, Z-transform properties, Sampling, Multirate signal processing, discrete Fourier transform (DFT), Fourier-Bessel expansion, discrete cosine transform (DCT), short time Fourier transform (STFT), continuous wavelet transform (CWT), discrete wavelet transform (DWT), Wigner-Ville distribution (WVD), adaptive signal decomposition, empirical mode decomposition, parametric signal processing, data compression, signal and image processing applications. |
| 8. | Suggested Books | 1. L. Cohen, **Time-Frequency Analysis**, Prentice Hall, 1995, ISBN: 0135945321.<br>2. S. Mallat, **A Wavelet Tour of Signal Processing (**2nd edition**)**, Academic Press, 2008, ISBN: 012466606X.<br>3. T. K. Moon and W. C. Stirling, **Mathematical Methods and Algorithms for Signal Processing**, Prentice Hall, August 1999, ISBN: 978-0201361865.<br>4. Proakis and Manolakis, **Digital Signal Processing** (4th edition), Prentice Hall, 2007, ISBN: 0131873741.<br>5. Selected research papers. |

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| 1. | Course Code | **EE 642** |
| 2. | Title of the Course | **Wireless Communication** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Concepts of probability theory and communications. |
| 6. | Scope of the Course | To familiarize with the concepts of wireless communications and cellular systems. |
| 7. | Course Syllabus | **Wireless Channels:** Modelling of wireless channels, stochastic characterization and discrete-time representation, Jakes Model, Autocorrelation.<br><br>**Diversity:** Realizing diversity over time, frequency, and space, code design for wireless channels, Rayleigh/ Ricean fading channels, diversity modelling for Wireless Communications, performance improvement with diversity.<br><br>**Information Theory of Wireless Channels:** Entropy and mutual information, capacity of the Gaussian channel and of parallel Gaussian channels, capacity of fading channels: ergodic capacity and outage capacity, high versus low SNR regime, waterfilling capacity.<br><br>**Multiple-Input Multiple-Output (MIMO) Wireless Systems:** Capacity of MIMO wireless systems; MIMO-OFDM, MIMO spatial multiplexing, space-time coding and MIMO diversity.<br><br>**Cellular Communications:** Multiuser systems, multiple access and inference management, CDMA and FDMA schemes, multi-user diversity, cooperative diversity.<br><br>**3G and 4G standards:** GSM, GPRS, WCDMA, LTE, WiMAX. |
| 8. | Suggested Books | 1. D. Tse and P. Viswanath, **Fundamentals of wireless communication**, Cambridge University Press, 2005 ISBN: 978-0521845274.<br>2. T. S. Rappaport, **Wireless communications (**2$^{nd}$ edition**)**, Prentice Hall, 2002, ISBN: 978-0130422323.<br>3. G. L. Stuber, **Principles of Mobile Communication** (3$^{rd}$ edition), Springer International Ltd., 2011, ISBN: **978-1461403630**.<br>4. A. Goldsmith, **Wireless Communications**, Cambridge University Press, 2007, ISBN: 978-0521837163. |

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| 1. | Course Code | **EE 643** |
| 2. | Title of the Course | **Detection and Estimation Theory** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Concepts of probability theory |
| 6. | Scope of the Course | To get familiar with statistical inference techniques for Detection and Estimation of data or signals. |
| 7. | Course Syllabus | **Review of Probability Theory:** Selected concepts of probability theory, random variables and stochastic processes.<br><br>**Binary Decisions: Single Observation:** Maximum-likelihood decision criterion, Neyman-Pearson criterion, probability-of-error criterion, Bayes risk criterion, and min-max criterion. **Multiple Observations:** Vector observations, general Gaussian problem, waveform observations and additive Gaussian noise.<br><br>**Multiple Decisions:** Bayes risk, minimum probability of error decision rule, Gaussian case, erasure decision problems.<br><br>**Composite and Nonparametric Decision Theory:** Composite decisions, sign test, Wilcoxon test.<br><br>**Classical Estimation Theory:** Random parameter estimation, Bayes cost method, relationship of estimators, non-random parameter estimation, CRLB, linear minimum variance and least-squares methods, multiple parameter estimation.<br><br>**State Estimation:** Problem statement, Kalman filter, miscellaneous estimation techniques. |
| 8. | Suggested Books | 1. J. L. Melsa and D. L. Cohn, **Decision and Estimation Theory**, McGraw-Hill Inc, 1978, ISBN: 978-0070414686.<br>2. H. L. Van Trees, **“Detection, Estimation and Modulation Theory (Part I)**, John Wiley & Sons, 2001, ISBN: 978-0471095170.<br>3. S. M. Kay, **Fundamentals of Statistical Signal Processing - Estimation Theory (Vol. 1)**, Prentice-Hall, Inc., 1993, ISBN: 978-0133457117.<br>4. H. V. Poor, **An Introduction to Signal Detection and Estimation**, (2nd edition), Springer, 2010, ISBN: 978-1441928375. |

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| 1. | Course Code | **EE 644** |
| 2. | Title of the Course | **Image Processing** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of signals and systems. |
| 6. | Scope of the Course | The main goal of this course is to provide an overview of the concepts and algorithms for image processing. |
| 7. | Course Syllabus | Linearity and space-invariant property. Point spread function, image transforms and properties, sampling and quantization, 2-D systems.<br><br>Image coding, image representation models, image enhancement, equalization and filtering<br><br>Image restoration and reconstruction, Wiener filtering using transforms, image compression<br><br>Image analysis, Spatial and transform based features, edge detection techniques, AR models and region representation, multiresoultion analysis (MRA) based techniques, segmentation and classification. |
| 8. | Suggested Books | 1. A. K. Jain, **Fundamentals of Digital Image Processing**, Prentice Hall, 1988, ISBN: 978-0133361650.<br>2. R.C. Gonzalez and R.E. Woods; **Digital Image Processing**, (3/e), 2007, ISBN: 978-0131687288. |

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| 1. | Course Code | **EE 645** |
| 2. | Title of the Course | **Mathematical Methods for Signal Processing** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | **Electrical Engineering** |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To get familiar with the mathematical aspects of various techniques involved in signal processing applications with emphasis on matrix algebra. |
| 7. | Course Syllabus | **Vector Spaces**: Vector spaces and subspaces, linear independence, basis and dimension, linear transformations.<br>Inner product spaces: Orthogonality, projections, Gram-Schmidt procedure.<br>**Matrix Spaces**: Functions of matrices and applications to difference and difference equations, special matrices.<br>**Matrix Computations and Decompositions**: Matrix factorization, complexity, least square, singular value and eigen value decompositions, positive definiteness.<br>**Spaces of Signals**: Hilbert spaces, fundamental spaces of sequences and functions, orthogonal polynomials.<br>**Generalized Inverses**: Regularization of ill-posed problems, generalized problems, and signal processing applications. |
| 8. | Suggested Books | 1. G. Strang, **Linear Algebra and Its Applications** ($4^{th}$ edition), Brooks Cole, 2005, ISBN: 978-0030105678.<br>2. A. Bojanczyk, G. Cybenko, **Linear Algebra for Signal Processing**, Springer, 1995, ISBN 978-0387944913.<br>3. C.D. Meyer, **Matrix Analysis and Applied Linear Algebra**, SIAM, 2000, ISBN 0-89871-454-0. |

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| 1. | Course Code | **EE 646 / EE 446** |
| 2. | Title of the Course | **Information and Coding Theory** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Concepts of probability theory and communications and basic understanding of signal processing and communication. |
| 6. | Scope of the Course | To understand the quantitative theory of information and its applications to reliable, efficient communication systems. |
| 7. | Course Syllabus | Information measure and entropy, information rate, joint and conditional entropies, mutual information , discrete memoryless channels, BSC, BEC, channel capacity, Shannon limit, source coding, adaptive Huffman coding, arithmetic coding, LZW, Hamming weight, Hamming distance, minimum distance decoding, single parity codes, Hamming codes, repetition codes, linear block codes, cyclic codes, convolutional codes, sequential and probabilistic decoding, principle of Turbo coding, burst error-correcting codes. |
| 8. | Suggested Books | 1. T. M. Cover and J. A. Thomas, **Elements of Information Theory**, (2nd edition), Wiley-Interscience, 2006, ISBN: 978-0471241959.<br>2. R. Gallagher, **Information Theory and Reliable Communication**, Wiley; 1968, ISBN: 978-0471290483.<br>3. R. Bose, **Information Theory, Coding and Cryptography**, Tata McGraw Hill Education Pvt. Ltd., 2007, ISBN: 978-0070151512.<br>4. K. Sayood, **Introduction to Data Compression**, (3rd edition), Morgan Kaufmann; 2012, ISBN: 978-0124157965.<br>5. S. Gravano, **Introduction to Error Control Codes**, Oxford University Press, USA, 2001, ISBN: 978-0198562313. |

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| **Course code** | **EE 647/ EE 447** |
| **Title of the course** | **Advanced Photonics** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Electrical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course is designed for the UG and PG students with the background in Electronics, Electrical Engineering, Physics and Material Science. This course will emphasize on the fundamentals of optoelectronics, photonics and its multidisciplinary applications including optical fiber communication. The course aims to explain basics and technology of photonic devices, components and systems including device fabrication. |
| Course Syllabus | **Introduction to Optical Fiber Communication:** Nature of light_ optical communication_ optical fibers_ propagation of light in optical fibers_ transmission characteristics of optical fibers_ fabrication of optical fibers.<br>**Planar Optical Waveguides, Passive Devices & Components:** Waveguide classification, step-index waveguides, graded-index waveguides, Coupled mode theory, grating in waveguide structure, bent waveguides, Optical Cross Connects, directional coupler, Bragg reflectors, waveguide filters, Arrayed Waveguide Grating (AWG), Multiplexer, Demultiplexer.<br>**Active Photonics Devices:** Spontaneous and stimulated emission, emission from semiconductors, LEDs – Basics and Technology, Semiconductor injection lasers, Single frequency lasers, VCSEL, Optical amplifiers, Photodetectors, Electro-optic modulator, Electro-absorption modulator, Graphene based optoelectronic devices.<br>**Silicon Photonics:** Introduction, CMOS compatible fabrication, Silicon-on-insulator (SOI) Technology, silicon modulators, non-linear silicon photonics, lasers on silicon, CMOS-Photonic hybrid integration, Silicon-germanium photodetector.<br>**Elements of Nanophotonics-** Photonic crystals and their applications, Surface plasmon polaritons, Slow light and its applications, Introduction to Optical Interconnects. |
| Suggested Books | 1. J.M. Senior, ***Optical Fiber Communications***, Pearson Education, UK, 2009, 8131732665, 9788131732663<br>2. A. Yariv and P. Yeh, ***Photonics, Optical Electronics in Modern Communication***, Oxford University Press, USA, 2006, 9780195179460<br>3. B. E. A. Saleh and M. C. Teich, ***Fundamentals of Photonics***, Wiley, USA, 2007, 9780471358329<br>4. S.L. Chuang, ***Physics of Optoelectronic Devices***, Wiley, USA, 2008, 9780470293195<br>5. Keiser, ***Optical Fiber Communications***, Tata McGraw (2011), 0070648107<br>6. J. D. Joannopoulos, S. G. Johnson, J. N. Winn and R. D. |

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| | Meade, ***Photonic Crystals, Molding the flow of light***, Princeton University Press (2008), 9780691124568.<br>7. Coldren and Corzine, ***Diode Lasers and Photonic Integrated Circuits***, Wiley (2012), 9780470484128<br>8. Ghatak and Thyagarajan, ***Introduction to Fiber Optics***, Cambridge University Press (2013), 9780521577854 |

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| **Course code** | **EE 448/ EE 648** |
| **Title of the course** | Antennas and Propagation |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Electrical Engineering |
| Pre-requisite, if any | Basic knowledge of Electromagnetic Theory |
| Scope of the course | The course will provide a comprehensive overview of antenna theory and analysis, including design, synthesis, and measurement. |
| Course Syllabus | Introduction: Antenna theorems and definitions, radiation patterns, beamwidth, directivity, gain, efficiency, bandwidth, polarization, input impedance, Friis transmission equation and radar equation. Potential functions and theorems: Vector potential for electric and magnetic current source, duality theorem, reciprocity theorem, reaction theorem. Single-element antennas: Linear wire antennas, loop antennas, travelling wave antennas, broadband antennas, aperture antennas, microstrip antennas, reflector antennas, antenna measurements. Antenna arrays: Array theorems, two-element linear array, N-element linear array, array factor, superdirectivity, planar array, circular array. Antennas for modern communication: Circularly polarized antennas, base station antennas (cellular / Wi-Fi / GPS / WiMAX), multiple-input multiple-output (MIMO) antennas, smart antennas. |
| Suggested Books | 1. C. A. Balanis, ***Antenna Theory: Analysis and Design*****,** John Wiley & Sons, USA, 2005, 978-0471667827<br>2. R. S. Elliot, **Antenna Theory and Design,** Wiley-IEEE Press, USA, 2003, 978-0471449966<br>3. J. D. Kraus, R. J. Marhefka, and A. S. Khan, ***Antennas and Wave Propagation***, McGraw-Hill, USA, 2017, 978-9352606184<br>4. T. A. Milligan, ***Modern Antenna Design,*** Wiley-IEEE, Press, USA, 2005, 978-0471457763 |

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| **1** | **Course code** | **EE 651** |
| **2** | **Title of the course** | **Digital Circuit Design Lab** |
| 3 | Credit structure | 0-0-4-2 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Associated to theory course EE 422/ EE 622 |
| 6 | Scope of the course | Course in designed to augment the concepts learned by the students in associated theory course. |
| 7 | Course syllabus | 1. Functional and design parameter analysis of basic digital circuits.<br><br>2. Design and analysis of standard cells for combinational and sequential circuits *(the purpose of the above two experiments is to introduce the design and analysis approach for circuit performance parameters at lower and advanced technology nodes using schematic and layout).*<br><br>3. Design the digital blocks using HDL (Verilog/VHDL) to generate its GDSII (*the purpose of this experiment is to design digital circuits using Verilog/VHDL followed by its synthesis and verification to perform automated placement and routing optimization using physical designing tools to give GDSII format.*<br><br>4. (a) Design various architecture of SRAM (b) Design various architecture of DRAM (*the purpose of this experiment is to get acquainted with common memory architectures and analyze the performance using EDA tools).* |
| 8 | Suggested books | 1.Douglasl. perry, VHDL: Programming by Example, $4^{th}$ edition (McGraw Hill Co. Inc., New York, 2002).(ISBN: 9780071400701)<br>2. Jayaram Bhasker, A VHDL Primer, Prentice Hall,$3^{rd}$ edition. (ISBN: 0130965758)<br>3. Zainalabedin Navabi, VHDL, analysis and modeling of digital systems, McGraw-Hill. (ISBN: 978-0070464728).<br>4. PLD, FPGA data sheets. |

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| 1 | **Course code** | **EE 652** |
| 2 | **Title of the course** | **System on Programable Chip Design-Lab** |
| 3 | Credit structure | L-T-P-C<br>0-0-4-2 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Same as associated theory course: System on Prog. Chip Design |
| 6 | Scope of the course | This lab will give practical exposure of the associated course work using Xilinx Zybo/ Basys-3/Nexys-4 DDR boards and Xilinx Vivado software suite. |
| 7 | Course syllabus | 1. Building a Zynq-700 processor design in the Vivado IDE<br><br>2. Design a Microblaze processor using Xilinx Vivado.<br><br>3. Interfacing of designed Microblaze with available peripherals.<br><br>4. Design of custom peripherals using HDL.<br><br>5. Design an enhanced instruction set with custom instructions. |
| 8 | Suggested books | *Same as associated theory course of System on Prog. Chip Design.<br>Reference Manuals for Boards:<br><br>1.Digilant Basys 3™ FPGA Board Reference Manual.<br>2.Digilant ZYBO™ FPGA Board Reference Manual.<br>3.Digilant Nexys4 DDR™ FPGA Board Reference Manual. |

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| 1 | **Course code** | **EE 653** |
| 2 | **Title of the course** | **Discrete Device Fabrication and Characterization Lab** |
| 3 | Credit structure | L-T-P-C<br>0-1-4-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Elementary knowledge about basic electronics devices and VLSI technology |
| 6 | Scope of the course | To make students aware of the various fabrication and characterization techniques available in the semiconductor industry |
| 7 | Course syllabus | 1. Learning and hands-on training of various vacuum technologies and thin film deposition.<br><br>2. Thin film processing of metals/ semicondutors/ insulating materials.<br><br>3. Design and fabrication of memory devices.<br><br>4. Electrical characterization of nanoscale devices.<br><br>5. Growth of semiconductor nanostructures.<br><br>6. Fabrication and characterization of Schottky diodes and photodiodes.<br><br>7. Solution processed techniques for thin film fabrication.<br><br>8. Frequency response of a dielectric.<br><br>9. Absorption and emission spectra of semiconducting materials |
| 8 | References | |

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| 1 | **Course code** | **EE 654** |
| 2 | **Title of the course** | **System on Programable Chip Design-Lab** |
| 3 | Credit structure | L-T-P-C<br>0-0-4-2 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Same as associated theory course: System on Prog. Chip Design |
| 6 | Scope of the course | This lab will give practical exposure of the associated course work using Xilinx Zybo/ Basys-3/ Nexys-4 DDR boards and Xilinx Vivado software suite. |
| 7 | Course syllabus | 1. Building a Zynq-700 processor design in the Vivado IDE<br><br>2. Design a Microblaze processor using Xilinx Vivado.<br><br>3. Interfacing of designed Microblaze with available peripherals.<br><br>4. Design of custom peripherals using HDL.<br><br>5. Design an enhanced instruction set with custom instructions. |
| 8 | Suggested books | *Same as associated theory course of System on Prog. Chip Design.<br>Reference Manuals for Boards:<br><br>1.Digilant Basys 3™ FPGA Board Reference Manual.<br>2.Digilant ZYBO™ FPGA Board Reference Manual.<br>3.Digilant Nexys4 DDR™ FPGA Board Reference Manual. |

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| 1. | Course Code | **EE 701** |
| 2. | Title of the Course | **Time-Frequency Analysis** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of Fourier analysis |
| 6. | Scope of the Course | Many signals exhibit frequency characteristics that change over time. Examples include such as speech, marine mammal sounds, heart rate, electroencephalogram, machine vibrations, sonar, radar, and communication signals. Understanding these changes is important because they are often indicative of the underlying processes that generated the signal. Time-frequency analysis, also called time-varying spectral analysis, is a technique for studying the time-dependent spectral changes in a signal. |
| 7. | Course Syllabus | Basics of Fourier Analysis, Spectral Theory, Fundamentals of Time-Frequency Analysis, Instantaneous Frequency and Instantaneous Bandwidth, Gabor Transform, The Short-Time Fourier Transform/Spectrogram, Time-Frequency Localization, Continuous Wavelet Transform/ Scalogram, Multiresolution Analysis, Quadratic Time-Frequency Transform, Wigner-Ville Distribution, Signal Processing Applications, Image Processing Applications. |
| 8. | Suggested Books | 1. S. Mallat, **A Wavelet Tour of Signal Processing** (3rd edition), Academic Press, 2008, ISBN: 978-0123743701.<br>2. Leon Cohen, **Time-Frequency Analysis**, Prentice Hall; 1994, ISBN: 978-0135945322.<br>3. B. Boashash, **Time-Frequency Signal Analysis and Processing: A Comprehensive Reference**, Elsevier Science, 2003, ISBN-13: 978-0080443355.<br>4. R. M. Rao and A. S. Bopardikar, **Wavelet Transforms: Introduction to Theory & Applications**, Prentice Hall, 1998, ISBN-13: 978-0201634631. |

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| 1 | **Course code** | **EE 721** |
| 2 | **Title of the course** | **Embedded Systems and Computing** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Microprocessors and Digital Systems |
| 6 | Scope of the course | Embedded Systems has found wide applications in almost every electronic device. The need for any electronic engineer would be to learn how to design systems for specific applications such as mobile phones and other electronic appliances and also re-design some of the existing systems. After introducing the developments in this field, this course would focus on development of these systems through programming. |
| 7 | Course syllabus | Overview – Characteristics of embedded computing applications, Concept of real-time systems, design process and system integration.<br>Embedded System Architecture – CISC and RISC architecture and examples, memory system architecture, co-processors and hardware accelerators<br>Designing embedded computing platform – Memory devices and characteristics, I/O systems, designing with processors, design methodologies.<br>Programming embedded systems – Use of programming language characteristics, programming and run-time environment and debugging. Application examples. |
| 8 | Suggested books | 1. David E Simon, Embedded Systems Primer, Addison-Wesley, 1999, (ISBN: 9780201615692).<br>2. James K. Peckol, Embedded Systems: A Contemporary Design Tool, Wiley, 2009. (ISBN: 9788126524563).<br>3. Steve Heath, Embedded Systems Design, Elsevier India, 2005, (ISBN: 9788181479709). |

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| 1 | **Course code** | **EE 722** |
| 2 | **Title of the course** | **IC Design for IoT System** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Basic of MOSFETs and Circuit Design |
| 6 | Scope of the course | |
| 7 | Course syllabus | **Unit 1: Basics of IoT System:** Introduction to IoT landscape, use cases (Smart Home, Smart Energy, Smart Vehicle, Smart City etc.), Standardizing the IoT, Wireless Sensor Network, Design Methodologies for Smart things (Using commercial development boards).<br>**Unit 2: IoT Devices and Networks:** Types of connected device, bridging physical and digital (sensors and actuators), conserving battery life, types of network, architecture of IoT networks, network communication patterns.<br>**Unit 3. Power Optimization Techniques and Power Management Unit:** Sources of power dissipation and optimizations techniques, low power bus, parallel architecture, reference circuits, DC-DC converter, charge pumps, linear regulator.<br>**Unit 4. Standard IoT Protocol Architecture and Implementation:** Design and analysis of basic communication protocols: GPIO, SPI, I2C, UART and other upcoming standard protocol architecture: Bluetooth, ZigBee, Z-Wave, 6LowPAN, Wi-Fi, NFC, LoRaWAN, SigFox etc<br>**Unit 5: IoT-System Design:** System design using IoT development boards, Custom SoC design flow, IP-design and re-use in custom SoC, IoT System design using custom SoC. |
| 8 | Suggested books | 1. Fawzi Behmann, Kwok Wu, “Collaborative Internet of Things (C-IOT): For Future Smart Connected Life and Business”, IEEE and Wiley, April 2015.(ISBN: 1118913744)<br>2. Claire Rowland, Elizabeth Goodman, Martin Charlier, Ann Light, Alfred Lui, “Designing Connected Products UX for the Consumer Internet of Things”, O'Reilly, May 2015. (ISBN: 9781449372569).<br>3. Hakima Chaouchi, "The Internet of Things-Connecting Objects to the Web", Wiley, June 2010. (ISBN: 9781848211407).<br>4. Olivier Hersent, David Boswarthick, Omar Elloumi, "The Internet of Things: Key Applications and Protocols", 2nd Edition, Wiley, Jan 2012.(ISBN: 9781119994350).<br>5. Gary K. Yeap, “Practical Low Power Digital VLSI Design”, Springer (ISBN-9780792380092).<br>6. Liming Xiu, “VLSI Circuit Design Methodology Demystified A Conceptual Taxonomy”. October 2007 (ISBN: 9780470199107).<br>7. Youn-Long Steve Lin, “Essential Issues in SOC Design Designing Complex Systems-on-Chip”, Springer, 2006. (ISBN-13: 9789048173501). |

| | | |
|---|---|---|
| 1. | Course Code | **EE 724/ EE 424** |
| 2. | Title of the Course | **Advanced Micro-processes and Nanotechnology** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering Discipline |
| 5. | Pre–requisite, if any | A course on semiconductor device physics, MOSFETs and VLSI |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Methodologies for nanotechnology:** Introduction and classification, general properties of atoms and solids, effects at the nanometer scale, Fabrication methods for nanostructures.<br>**Characterization methodologies for Nanotechnology:** classification of characterization methods, microscopic techniques, Electron microscopy, Scanning probe techniques, Diffraction techniques, spectroscopic techniques.<br>**Semiconductor nanostructures:** General aspects of semiconductor physics, Quantum confinement in semiconductor nanostructures, fabrication techniques, Physical processes nanostructures, some applications of semiconductor nanostructures.<br>**Silicon MOSFETs:** Moore's Law, Scaling down of devices, Low frequency noises in MOSFETs, Short Channel Effect, DIBL, GIDL, recent developments and challenges in MOSFETs.<br>**Single electron devices:** Coulomb blockade effect, Single Electron Transistor, SET based detector, RF-SET, Single Electron Spectroscopy etc.<br>**Molecular materials and devices:** Organic materials, some examples of organic semiconductors, charge carrier injection and transport, Optical properties of organic semiconductors, applications and devices involving organic semiconductors viz. Organic Field Effect Transistors, Organic Light Emitting Diodes, Organic Photovoltaic's including Dye sensitized solar cells. |
| 8. | Suggested Books | 1. S. M. Sze, *Physics of semiconductor devices*, John Wiley and Sons, 1981, ISBN: 0-471-05661-8<br>2. R. Kelsall, I. Hamley and M. Geoghegan, *Nanoscale Science and Technology*, John Wiley and Sons Ltd, 2005, ISBN: 0-470-85086-8.<br>3. K. Morigaki, *Physics of amorphous semiconductors*, Imperial College Press, 1999, ISBN: 981-02-1381-6.<br>4. P. Richman, *MOS Field Effect Transistors and Integrated Circuits*, John Wiley and Sons Ltd, 1973, ISBN: 0-471-72030-5.<br>5. Y. Taur and T-H. Ning, *Fundamentals of Modern VLSI Devices*, Cambridge University Press, 1998, ISBN: 978-0-521-55959-1.<br>6. G. Hadziioannou and G. Malliaras, *Semiconducting Polymers: Chemistry, Physics and Engineering*, Wiley Interscience, 2007, ISBN: 978-3-527-31271-9. |

| | | |
|---|---|---|
| 1 | **Course code** | **EE 725** |
| 2 | **Title of the course** | **RF IC Design** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Basics of MOSFETs |
| 6 | Scope of the course | |
| 7 | Course syllabus | Basic concepts about Linearity, noise figure and dynamic range, CMOS Technology for RF, CMOS Radio challenges, CMOS circuit design, Distortion and noise in amplifiers - dynamic range – Scattering parameters - radio receiver architectures -specification of individual blocks from top level specifications - analysis and modeling of on-chip passive elements - circuit biasing techniques - low noise amplifiers - variable gain amplifiers - mixers filters – received signal strength indicators -power amplifiers and linearization - RF measurement basics, Design considerations of RF IC for wireless applications. RF power amplifier design Classes of power amplifiers Review of linear amplifier design techniques Gain match, power match, matching circuits for power amplifiers Introduction to load-pull measurements Conventional high efficiency amplifiers Nonlinear effects in RF power amplifiers Efficiency enhancement and linearization techniques |
| 8 | Suggested books | 1. Thomas Lee, Design of CMOS RF ICs, Oxford University Press, 1997.<br>2. Behzad Razavi, RF Microelectronics, Prentice Hall, 1999.2$^{nd}$ edition. (ISBN-9780137134731).<br>3. John W. M. Rogers and Calvin Plett, Radio Frequency Integrated Circuit Design, Artech House, 2010 (ISBN-1607839798) |

| | | |
|---|---|---|
| 1 | **Course code** | **EE 726** |
| 2 | **Title of the course** | **Testing and Verification of VLSI Circuits** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Digital Design |
| 6 | Scope of the course | |
| 7 | Course syllabus | **Unit 1:** Scope of testing and verification in VLSI design process. Issues in test and verification of complex chips, embedded cores and SOCs.<br>**Unit 2:** Fundamentals of VLSI testing, Fault models, Automatic test pattern generation.<br>**Unit 3:** Design for testability, Scan design, Test interface and boundary scan, System testing and test for SOCs, $I_{ddq}$ testing, Delay fault testing, BIST for testing of logic and memories, Test automation.<br>**Unit 4:** Design verification techniques based on simulation, analytical and formal approaches.<br>**Unit 5:** Functional verification, Timing verification, Formal verification, Basics of equivalence checking and model checking, Hardware emulation. |
| 8 | Suggested books | 1. S.M. Kang and Y. Leblebici, CMOS Digital Integrated Circuits Analysis & Design, 4th Edition, McGraw Hill, 2014. (ISBN: 9780072460537).<br>2. M. Tehranipoor, K. Peng, K. Chakrabarty, “Introduction to VLSI Testing”, Springer, 2011.<br>3. 3. M. Bushnell and V. D. Agrawal, "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", Kluwer Academic Publishers, 2000. (ISBN: 9780792379911).<br>4. M. Abramovici, M. A. Breuer and A. D. Friedman, "Digital Systems Testing and Testable Design", IEEE Press, 1994. (ISBN: 9780780310629).<br>5. Erik Seligman, Tom Schubert, M V Achutha Kiran Kumar, “Formal Verification: An Essential Toolkit for Modern VLSI Design”, Morgan Kaufmann, 2015. (ISBN-13: 9780128007273).<br>6. T.Kropf, "Introduction to Formal Hardware Verification", Springer Verlag, 2000. (ISBN: 9783540654452).<br>7. P. Rashinkar, Paterson and L. Singh, "System-on-a-Chip Verification-Methodology and Techniques", Kluwer Academic Publishers(ISBN: 9780792372790). |

| | | |
|---|---|---|
| 1 | **Course code** | **EE 728** |
| 2 | **Title of the course** | **Architectural Design of ICs** |
| 3 | Credit structure | L-T-P-C<br>2-1-0-3 |
| 4 | Name of the concerned discipline | Electrical Engineering |
| 5 | Pre-requisite (if any) | Basics of MOSFETs and ICs |
| 6 | Scope of the course | |
| 7 | Course syllabus | **Unit 1: Introduction**<br>VLSI Design flow, general design methodologies; Mapping algorithms into Architectures: Signal flow graph, data dependences, datapath synthesis, control structures, critical path and worst case timing analysis, concept of hierarchical system design.<br><br>**Unit 2: Datapath elementary**<br>Datapath design philosophies, fast adder, multiplier, driver etc., datapath optimization, application specific combinatorial and sequential circuit design, CORDIC unit.<br><br>**Unit 3: Pipeline and parallel architectures**<br>Architecture for real time systems, latency and throughput related issues, clocking strategy, power conscious structures, array architectures;<br><br>**Unit 4: Control strategies**<br>Hardware implementation of various control structures, microprogramed control techniques, VLIW architecture.<br><br>**Unit 5: Testable architecture**<br>Controllability and observability, boundary scan and other such techniques, identifying fault locations, self reconfigurable fault tolerant structures<br><br>**Unit 6: Treadeoff issues**<br>Optimization with regard to speed, area and power, asynchronous and low power system design, ASIC (application specific integrated circuits) and ASISP (application specific instruction set processors) design. |
| 8 | Suggested books | 1. James E. Stine, Digital Computer Arithmetic Datapath Design Using Verilog HDL, 1st Edition, KLUWER Academic Publisher,2004, ISBN:978-1-4419-8931-4.<br>2. M. Bushnell, Vishwani Agrawal, Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI, 1st Edition, Springer, 2002, ISBN:0-792-37991-8.<br>3. Khosrow Golshan, Physical Design Essential: an ASIC Design Implementation Perspectives, 1st Edition, Springer, 2007, ISBN: 0-387-36642-3.<br>4. Liming Xiu, VLSI Circuit Design Methodology Demystified A Conceptual Taxonomy, 1st Edition, WILEY- INTERSCIENCE A JOHN WILEY & SONS, INC., PUBLICATION, 2008 ISBN: 978-0-470-12742-1. |

| | | |
|---|---|---|
| 1. | Course Code | **EE 740** |
| 2. | Title of the Course | **Speech Signal Processing** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Discipline of Electrical Engineering |
| 5. | Pre–requisite, if any | Signals and Systems, Digital Signal Processing |
| 6. | Scope of the Course | The main objective of this course to provide concepts for speech signal analysis, synthesis recognition etc. |
| 7. | Course Syllabus | **Signal processing tools:** Digital filters, Fourier series, Fourier transform, DFT, FFT, short term Fourier transform (STFT), continuous wavelet transform, discrete wavelet transform<br>**Speech acquisition and digitization**<br>**Speech analysis and parameter extraction:** Short time analysis, frames and windows, time-domain analysis: energy, zero-crossings, statistic parameters, autocorrelation, frequency-domain analysis: spectra and spectrograms, cepstral analysis, linear prediction analysis, pitch and formant estimation, static and dynamic features<br>**Speech signal synthesis**<br>**Speech coding**<br>**Speech enhancement** |
| 8. | Suggested Books | 1. J.R. Deller, J.G. Proakis, J.H.L. Hansen, **Discrete-Time Processing of Speech Signals**, Wiley-IEEE Press, 1999, ISBN 978-0780353862.<br>2. T. F. Quatieri, **Discrete-Time Speech Signal Processing: Principles and Practice**, Prentice Hall, 2001, ISBN 978-0132429429.<br>3. L. R. Rabiner, R. W. Schafer, **Digital Processing of Speech Signals**, Prentice Hall, 1978, ISBN 978-0132136037. |

| | | |
|---|---|---|
| 1. | Course Code | **EE 742** |
| 2. | Title of the Course | **MIMO Wireless Communications** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | Concepts of random variable and communication theory. |
| 6. | Scope of the Course | To understand the concepts of space time coding, spative diversity and multiplexing involved by deploying multiple antenna at the transmitters and receiver. |
| 7. | Course Syllabus | **Review of Matrix Algebra:** Trace, Frobenius norm, positive definite matrix, singular value decomposition, vectorization, Kronecker product.<br>**MIMO System and Channel Models:** Frequency-flat and frequency-selective MIMO channel, Matrix formulations.<br>**MIMO Information Theory:** Entropy and mutual information, capacity of MIMO channel, MIMO capacity with and without transmit CSI, ergodic channel capacity, outage capacity.<br>**Receive Diversity:** SIMO receivers, flat and frequency-selective channels, linear processing and MRC, orthogonal frequency division multiplexing (OFDM).<br>**Transmit Diversity and Space-Time Coding:** Optimal beamforming with transmit CSI, beamforming for MISO systems, achieving transmit diversity, space-time coding concepts.<br>**Linear Space-Time Block Codes:** A general framework for Linear STBC, spatial multiplexing, orthogonal space-time block codes, error performance analysis, mutual information properties, diversity-multiplexing tradeoff analysis.<br>**Applications:** Multiuser MIMO, Collaborative MIMO, MIMO in WiFi and WiMAX, Large MIMO systems. |
| 8. | Suggested Books | 1. E. G. Larsson and P. Stoica, **"Space-Time Block Coding for Wireless Communications"**, Cambridge University Press, USA, 2008, ISBN: 978-0521065337.<br>2. A. Paulraj, R. Nabar, and D. Gore, **"Introduction to Space-Time Wireless Communications"**, Cambridge University Press, USA, 2008, ISBN: 978-0521065931.<br>3. E. Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith, A. Paulraj, **"MIMO Wireless Communications"**, Cambridge University Press, USA, 2010, ISBN 978-0521137096.<br>4. D. Tse and P. Vishwanath, "**Fundamentals of Wireless Communication**, Cambridge University Press, 2005, ISBN: 978-0521845274. |

| | | |
|---|---|---|
| 1. | Course Code | **EE 698** |
| 2. | Title of the Course | **PG Seminar Course** |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Course Syllabus | In this course a PG student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her PG Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 7. | References | Books and research publications in various relevant journals/conference proceeding, etc. |

| | | |
|---|---|---|
| 1. | Course Code | **EE 797 (Autumn Semester)**<br>**EE 798 (Spring Semester)** |
| 2. | Title of the Course | Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Electrical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various relevant journals. |

# Course Structure

# of

# PG and Ph.D. Program in

# Mechanical Engineering and

# Syllabi of Courses

# Course Structure of M.Tech./ M.Tech. + Ph.D. Dual Degree Program in Production and Industrial Engineering (PIE)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Mechanical, Production, Industrial, Manufacturing, Materials and Metallurgy, Mechatronics, or Automobile Engineering. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE
**(b) Indian Students:** Valid GATE qualification in Mechanical Engineering (ME) or Production and Industrial Engineering (PI).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis.

**Course Structure of 2-Year Full Time M. Tech. Program in PIE**

**1st Year: Semester-I**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 655 | Advanced Manufacturing Processes | 2-1-0 | 3 |
| ME 657 | Mechatronics and Metrology | 3-0-2 | 4 |
| ME 659 / ME 459 | Micro and Precision Manufacturing | 2-0-2 | 3 |
| MM 661 | Materials Science and Engineering | 2-1-0 | 3 |
| ME 675 / MA 675 | Probability and Statistical Methods | 2-0-2 | 3 |
| ZZ XXX | Elective-I | X-X-X | 3 |
| **Total minimum credits earned during the semester** | | | **19** |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 672 / ME 472 | Reliability Engineering | 2-0-2 | 3 |
| ME 650 | Materials Characterization Techniques | 2-0-2 | 3 |
| ME 660/ ME 460 | Technology of Surface Coatings | 2-1-0 | 3 |
| ME 698 | PG seminar course | 0-2-0 | 2 |

| | | | |
|---|---|---|---|
| ZZ XXX | Elective-II | X-X-X | 3 |
| ZZ XXX | Elective-III | X-X-X | 3 |
| | | **Total minimum credits earned during the semester** | **17** |

**2 nd Year: Semester-III**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 799 | M. Tech. Research Project (Stage-I) | 0-0-36 | 18 |

**2 nd Year: Semester-IV**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 800 | M. Tech. Research Project (Stage-II) | 0-0-36 | 18 |
| | | **Total minimum credits to be earned during the program** | **72** |

| **Mechanical Engineering Courses for Elective-I @** | | | |
|---|---|---|---|
| **Course Code** | **Course Title** | **Contact hours (L-T-P)** | **Credits** |
| ME 653/ ME 453 | Computer Aided Manufacturing | 2-0-2 | 3 |
| ME 663 | Theory of Conventional Machining | 2-1-0 | 3 |
| ME 671/ ME 471/ MA 671 | Operations Research | 2-0-2 | 3 |
| ME 751/ ME 451 | Theory of Advanced Machining Processes | 2-0-2 | 3 |

| **Mechanical Engineering Courses for Elective-II & III @** | | | |
|---|---|---|---|
| **Course Code** | **Course Title** | **Contact hours (L-T-P)** | **Credits** |
| ME 640 / ME 440 | Smart Materials and Structures | 2-1-0 | 3 |
| ME 644 / ME 444 | Robotics | 2-0-2 | 3 |
| ME 646 / ME 446 | Dynamics and Control Systems | 2-1-0 | 3 |
| ME 648 / ME 448 | MEM.S. and Micro-System Design | 2-1-0 | 3 |
| ME 654 / ME 454 | Rapid Product Manufacturing | 2-0-2 | 3 |
| ME 658 / ME 458 | Laser based Measurements and Micro-Manufacturing | 2-1-0 | 3 |
| ME 730 | Theory of Elasticity | 2-1-0 | 3 |
| ME 736 / ME 436 | Finite Element Methods | 2-0-2 | 3 |
| ME 738 / ME 438 | Composite Materials | 2-1-0 | 3 |
| ME 756 / ME 456 | Industrial Automation | 2-0-2 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.**

**2.** If the student opts for the Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. Degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.

3. The enhancement in the scholarship from M.Tech. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled whichever is later**.**

# Course Structure of M.Tech. / M.Tech. + Ph.D. Dual Degree Program in

## Mechanical Systems Design (MSD)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Mechanical Engineering. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE
**(b) Indian Students:** Valid GATE qualification in Mechanical Engineering (ME).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis with maximum extension of one semester.

### Course Structure of 2-Year Full Time M.Tech. Program in Mechanical Systems Design

**1st Year: Semester-I**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 646/ ME 446* | Dynamics and Control Systems | 2-1-0 | 3 |
| ME 647 | Dynamics and Control Systems Lab | 0-0-3 | 1.5 |
| ME 730* | Theory of Elasticity | 2-1-0 | 3 |
| ME 736/ ME 436* | Finite Element Methods | 2-0-2 | 3 |
| ME 738/ ME 438* | Composite Materials | 2-1-0 | 3 |
| ZZ XXX | Elective – I | X-X-X | 3 |
| | | **Total minimum credits earned during the semester** | 16.5 |
| **Additional course (as per the requirement basis)** | | | |
| HS 641* | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 632/ 432 | Vibrations and Noise Control | 2-1-0 | 3 |
| ME 634/ 434 | Principle of Product Design | 2-1-0 | 3 |
| ME 637/ 437 | Fracture Mechanics | 2-1-0 | 3 |
| ME 656 | Vibrations and Noise Control Lab | 0-0-3 | 1.5 |
| ZZ XXX | Elective - II | X-X-X | 3 |
| ZZ XXX | Elective - III | X-X-X | 3 |
| ME 698 | PG seminar course | 0-2-0 | 2 |
| | | **Total minimum credits earned during the semester** | **18.5** |

**2nd Year: Semester-III**

| Course Code | Course Name | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 799 | M.Tech. Research Project (Stage-I) | 0-0-36 | 18 |

**Second Year: Semester-IV**

| Course Code | Course Name | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 800 | M.Tech. Research Project (Stage-II) | 0-0-36 | 18 |
| **Total minimum credits to be earned during the program** | | | **71** |

| **Mechanical Engineering Courses for Elective I, II and III @** | | | |
|---|---|---|---|
| **Course Code** | **Course Name** | **Contact hours (L-T-P)** | **Credits** |
| ME 607/ ME 407 | Biofluid Mechanics | 2-1-0 | 3 |
| ME 608/ ME 408 | Hybrid Electric Vehicles | 2-1-0 | 3 |
| ME 630 | Robotic Control Systems | 2-1-2 | 4 |
| ME 639/ 439 | Mechanical Behavior of Materials | 2-1-0 | 3 |
| ME 640/ ME 440 | Smart Materials and Structures | 2-1-0 | 3 |
| ME 641/ 441 | Design of Laminated Composite Structures | 2-1-0 | 3 |
| ME 643/ 443 | Micromechanics and Nanomechanics | 2-1-0 | 3 |
| ME 644/ ME 444 | Robotics | 2-0-2 | 3 |
| ME 648/ ME 448 | MEM.S. and Micro-System Design | 2-1-0 | 3 |
| ME 756/ ME 456 | Industrial Automation | 2-0-2 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.**

2. If the student opts for the Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. Degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.

3. The enhancement in the scholarship from M.Tech. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled whichever is later**.**

## Course Structure of M.S. (Research) Program in Mechanical Engineering with an option to convert to M.S. (Research) + Ph.D. dual degree program (From AY 2019-20)

**Minimum Educational Qualification:** Four-year Bachelor's degree or Five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in Mechanical or Production or Manufacturing or Industrial or Mechatronics or Aerospace or Automobile or Robotics Engineering. (Relaxation of 5% in CPI/CPGA or percentage marks of the qualifying degree is applicable for Indian applicants belonging to SC and ST categories)

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS and valid score of GRE.
**(b) Indian Students:** Valid GATE qualification in Mechanical Engineering (ME) or Production and Industrial Engineering (PI) or Aerospace Engineering (AE).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship (**TA**); (ii) Highly motivated sponsored candidate (**SW**) on full-time basis from highly reputed R & D organizations such as DAE, DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces (**DF**): Candidates sponsored by the Defense Forces; (iv) Institute Staff (**IS**) of IIT Indore on part-time basis only.

**Duration of Program:** 2 years on full-time basis with maximum extension of one semester.

**Evaluation of Research Work and Thesis:** Students are expected to identify their Thesis Supervisor(s) within one month of joining the program so that PG Student Progress Committee (PSPC) can be formed and student can start research work from beginning of the program. Progress of the M.S. thesis will be monitored by PSPC through CERP to be conducted at the end of every semester with preferably Mid Semester evaluation also. Final evaluation of M.S. thesis will be done by at-least one External Examiner. Student must have one journal publication in SCI index from his/ her M.S. thesis for completion of the degree. Final evaluation of MS thesis will be done by at-least one Professor or equivalent level External Examiner from outside the Institute but within India. Student must have one journal publication in SCI index from his/ her MS thesis for completion of the degree.

**1st year: Semester-I**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ZZ XXX | Elective-I | X-X-X | 3 |
| ZZ XXX | Elective-II | X-X-X | 3 |
| ZZ XXX | Elective-III | X-X-X | 3 |
| ME 697 | PG Seminar Course | 0-2-0 | 2 |
| ME 791 | M S Thesis (Stage-1) | 0-0-14 | 7 |
| **Total minimum credits earned during the semester** | | | **18** |
| HS 641 | English Communication Skills | 2-0-2 | Non-credit course (with PP/NP grade) |

**1st year: Semester-II**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ME 792 | MS Thesis (Stage-II) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | **18** |

**2nd year: Semester-III**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ME 793 | MS Thesis (Stage-III) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | **18** |

**2nd year: Semester-IV**

| Course Code | Course Name | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ME 794 | MS Thesis (Stage-IV) | 0-0-36 | 18 |
| **Total minimum credits earned during the semester** | | | **18** |

**Courses from Mechanical Engineering for the Elective courses:**
(In addition to these courses the students can also take courses offered by other disciplines based on their learning needs/ interests)

| Course Code | Course Title | Contact hours (L-T-P) and Credits |
|---|---|---|
| ME 603 | Advanced Fluid Dynamics | 2-1-0-3 |
| ME 607 / ME 407 | Biofluid Mechanics | 2-1-0-3 |
| ME 608/ ME 408 | Hybrid Electric Vehicles | 2-1-0-3 |
| ME 611 / ME 411 | Refrigeration and Air Conditioning | 2-1-0-3 |
| ME 613 / ME 413 | Internal Combustion (IC) Engines | 2-1-0-3 |
| ME 618 / ME 418 | Computational Fluid Dynamics (CFD) | 2-1-0-3 |
| ME 634/ 434 | Principle of Product Design | 2-1-0-3 |
| ME 637/ 437 | Fracture Mechanics | 2-1-0-3 |
| ME 639/ 439 | Mechanical Behavior of Materials | 2-1-0-3 |
| ME 641/ 441 | Design of Laminated Composite Structures | 2-1-0-3 |
| ME 643/ 443 | Micromechanics and Nanomechanics | 2-1-0-3 |
| ME 646 | Dynamics and Control Systems | 2-1-0-3 |
| ME 648/ ME 448 | MEMS and Micro-System Design | 2-1-0-3 |
| ME 650 | Materials Characterization Techniques | 2-0-2-3 |
| ME 652/ ME 452 | Noise and Vibration Control | 2-1-0-3 |
| ME 655 | Advanced Manufacturing Processes | 2-1-0-3 |
| ME 657 | Mechatronics and Metrology | 3-0-2-4 |
| ME 659 / ME 459 | Micro and Precision Manufacturing | 2-0-2-3 |
| ME 660/ ME 460 | Technology of Surface Coatings | 2-1-0-3 |
| ME 672 / ME 472 | Reliability Engineering | 2-0-2-3 |
| ME 675 / MA 675 | Probability and Statistical Methods | 2-0-2-3 |
| ME 730 | Theory of Elasticity | 2-1-0-3 |
| ME 736 | Finite Element Methods | 2-0-2-3 |
| ME 738 | Composite Materials | 2-1-0-3 |
| ME 751/ ME 451 | Theory of Advanced Machining Processes | 2-0-2-3 |
| ME 756/ ME 456 | Industrial Automation | 2-0-2-3 |

## Course Structure for Ph.D. Program in Mechanical Engineering

### (A) Semester-I (autumn / spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III + | x-x-x-3 |
| 4 | ME 797* / ME 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (spring / autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective- IV + | x-x-x-3 |
| 2 | ZZ xxx | Elective-V + | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI + | x-x-x-3 |
| 4 | ME 798* / ME 797* | Ph.D. Seminar Course | 0-2-0-2 |

Note

1. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.
2. A Ph.D. student having **B.Tech./ BE / M.Sc. or equivalent qualification** admitted to Ph.D. Program in an **Engineering discipline** shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 20 credits).*

   * Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

**Mechanical Engineering Courses for Electives-I to VI** *(in addition to these courses, the students can take courses from other disciplines also.)*

| S. No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | ME 601 | Principles of Measurements | 3-0-2-4 |
| 2. | ME 602 | Advanced Heat transfer | 3-1-0-4 |
| 3. | ME 603 | Advanced Fluid Dynamics | 2-1-0-3 |
| 4. | ME 605 | Simulation of Thermal Systems | 3-0-2-4 |
| 5. | ME 607 / ME 407 | Biofluid Mechanics | 2-1-0-3 |
| 6. | ME 608/ 408 | Hybrid Electric Vehicles | 2-1-0-3 |
| 7. | ME 611 / ME 411 | Refrigeration and Air Conditioning | 2-1-0-3 |
| 8. | ME 613 / ME 413 | Internal Combustion (IC) Engines | 2-1-0-3 |
| 9. | ME 614 | Fabrication of Micro and Nanostructures | 2-1-0-3 |
| 10. | ME 616 / ME 416 | Non-conventional Energy Sources | 2-1-0-3 |
| 11. | ME 618 / ME 418 | Computational Fluid Dynamics (CFD) | 2-1-0-3 |
| 12. | ME 630 | Robotic Control Systems | 2-1-2-4 |
| 13. | ME 640 / ME 440 | Smart Materials and Structures | 2-1-0-3 |
| 14. | ME 644 / ME 444 | Robotics | 2-0-2-3 |
| 15. | ME 645/ ME 445 | Mobile Robotics | 2-0-2-3 |
| 16. | ME 646 / ME 446 | Dynamics and Control Systems | 2-1-0-3 |
| 17. | ME 648 / ME 448 | MEM.S. and Micro-System Design | 2-1-0-3 |
| 18. | ME 650 | Material Characterization Techniques | 2-0-2-3 |
| 19. | ME 651/ IME 451 | Mechatronics System Design | 2-0-2-3 |
| 20. | ME 653 / ME 453 | Computer Aided Manufacturing (CAM) | 2-0-2-3 |
| 21. | ME 654 / ME 454 | Rapid Product Manufacturing | 2-0-2-3 |
| 22. | ME 655 | Advanced Manufacturing Processes | 2-1-0-3 |
| 23. | ME 657 | Mechatronics and Metrology | 3-0-2-4 |
| 24. | ME 658 / ME 458 | Laser Based Measurements and Micro-Manufacturing | 2-1-0-3 |
| 25. | ME 659 / ME 459 | Micro and Precision Manufacturing | 2-0-2-3 |
| 26. | ME 660 / ME 460 | Technology of Surface Coatings | 2-1-0-3 |
| 27. | MM 661 | Materials Sciences and Engineering | 2-1-0-3 |
| 28. | ME 663 | Theory of Conventional Machining | 2-1-0-3 |
| 29. | ME 671/ ME 471/ MA 671 | Operations Research | 2-0-2-3 |
| 30. | ME 672 / ME 472 | Reliability Engineering | 2-0-2-3 |
| 31. | ME 675 / MA 675 | Probability and Statistical Methods | 2-0-2-3 |

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|---|---|---|---|
| 32. | ME 730 | Theory of Elasticity | 2-1-0-3 |
| 33. | ME 736 / ME 436 | Finite Element Methods | 2-0-2-3 |
| 34. | ME 738 / ME 438 | Composite Materials | 2-1-0-3 |
| 35. | ME 751 / ME 451 | Theory of Advanced Machining Processes | 2-0-2-3 |
| 36. | ME 756 / ME 456 | Industrial Automation | 2-0-2-3 |
| 37. | ME 764/ ME 464 | Microrobotics | 2-1-0-3 |

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|---|---|---|
| 1. | Course Code | **ME 601** |
| 2. | Title of the Course | **Principles of Measurements** |
| 3. | Credit Structure | L-T- P-Credits<br>3-0-2-4 |
| 4. | Name of the Concerned Discipline | Mechanical |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Basics of Measurement Systems:** Introduction, Classification of measurement systems, Errors in measurements, Statistical analysis of measured data, Regression analysis, Introduction to uncertainty, uncertainty analysis, Estimation of overall uncertainty, Presentation of data, Design of experiments.<br>**Measurement of Fundamental Quantities:** (I) Measurement of Temperature: Science and art of temperature measurement, Temperature measurement by mechanical effects, Thermo electric thermometry, Resistance thermometry, Pyrometer, Measurement of transient temperature, systematic errors in temperature measurement, Laboratory practice. (ii) Measurement of Pressure: Manometers, Bourdon gauge, Pressure transducers, Measurement of transient pressure, Measurement of vacuum, Laboratory practice. (iii) Measurement of Flow Velocity: Pitot static and impact probes, Velocity measurement based on thermal effects, Doppler velocimeter, Laboratory practice.<br>**Measurement of Derived Quantities:** (I) Measurement of Heat flux and Heat Transfer Coefficient: Foil type heat flux gauge, Thin film sensors, Cooled thin wafer heat flux gauge, Axial conduction, Guarded probe, Slug type sensor, Film coefficient transducers, cylindrical heat transfer coefficient probe, Laboratory practice. (ii) Measurement of Volume Flow Rate: Variable area type flow meters, Rota meter, Miscellaneous type of flow meters, Factors to be considered in the selection of flow meters, Calibration of flow meters, Laboratory practice. (iii) Measurement of Stagnation and Bulk Mean Temperature: Introduction, Shielded thermocouple stagnation temperature probe, Dual thin film enthalpy probe, flow in rectangular duct, Laboratory practice.<br>**Measurement of Thermo-physical Properties, Radiation Properties of Surfaces and Gas Concentration:** (I) Measurement of Thermo-physical Properties: Thermal conductivity- steady and transient methods, Measurement of heat capacity, Calorific values of fuel, Viscosity of fluids, Laboratory practice. (ii) Measurement of Radiation Properties of Surfaces: Introduction, Features of radiation measuring instruments, Integrating sphere, Measurement of emissivity, Laboratory practice. (iii) Measurement of Gas Concentration: Introduction, Non separation methods, Separation methods, Laboratory practice.<br>**Measurement of Other Engineering Quantities:** Fundamentals of measurements of force, torque, strain, vibration, noise, surface roughness, geometrical or form tolerances.<br>**Data Acquisition, Manipulation and Presentation:** Introduction, Mechanical signals conditioning, Electrical signal conditioning, Examples from laboratory practices. |
| 8. | Suggested Books | 1. S. P. Venkatesan, **Mechanical Measurements**, Ane Books Pvt. Ltd, New Delhi, 2010 (ISBN: 978-81-8052-234-5). |

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| | | 2. T. G. Beckwith, R.D. Marangoni, J. h. Lien hard, **Mechanical Measurements**, Sixth edition, Pearson Prentice Hall, New Delhi, 2009 (ISBN:978-81-317-1718-9).<br>3. E. O. Doebelin, D. N. Manik, **Measurement Systems Application and Design**, Fifth Edition, Tata McGraw Hill, New Delhi, 2007 (ISBN-13:978-0-07-061672-8).<br>4. J. P. Holman, **Experimental Methods for Engineers**, Seventh Edition, Tata McGraw Hill, New Delhi, 2010 (ISBN-13:978-0064776-3). |

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|---|---|---|
| 1. | Course Code | **ME 602** |
| 2. | Title of the Course | **Advanced Heat Transfer** |
| 3. | Credit Structure | L-T-P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre-requisite, if any | Heat Transfer |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Conduction:** Derivation of energy equation for conduction in three dimensions – Initial and boundary conditions. Transient conduction-Concept of Biot number – Lumped capacitance formulation unsteady conduction from a semi-infinite solid-solution by similarity transformation method. Solution of the general 1D unsteady problem by separation of variables, Laplace equation – solution by variable separable method – concept of superposition and homogeneous boundary conditions. Numerical solution of conduction problems. Basic ideas of finite difference method – forward, backward and central differences – Discretization for the unsteady heat equation.<br>**Convection:** Derivation of governing equation for convection. 2D laminar coquette flow and nondimensional numbers. Concept of Adiabatic wall temperature. Integral methods for momentum and thermal boundary layers. Pipe flow – concept of developed temperature profile and solutions for constant wall flux and constant wall temperature boundary conditions. Solution of entry length problem for constant wall and constant wall flux boundary conditions. Natural convection – governing equation, integral solution for flat surface.<br>**Radiation:** Introduction. Concept of black body, derivation of black body radiation laws from first principles Need for view factors, concept of view factors, mathematical definition. Shape factor calculations. Radiosity, Irradiation method for gray diffuse enclosures. Gas Radiation. |
| 8. | Suggested Books | 1. D. Poulikakos, **Conduction Heat transfer**, Prentice Hall, 1994.<br>2. G.E. Mayers, **Analytical methods in Conduction Heat Transfer**, McGraw Hill, 1971.<br>3. Kays W M and Crawford M E, **Convective Heat and Mass Transfer**, McGraw Hill Int Edition, 3rd edition, 1993.<br>4. Spalding D B, **Introduction to Convective Mass Transfer**, McGraw Hill, 1963.<br>5. R. Siegel and J.R. Howell, **Thermal Radiation Heat Transfer**, Taylor and Francis, 2002. |

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| 1. | Course Code | **ME 603** |
| 2. | Title of the Course | **Advanced Fluid Dynamics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Fundamental Concepts, Kinematics of Fluid, Control Volume Equations, Navier-Stokes Equations and their use, Boundary Layer Theory and Applications, Concept of Compressible flows, 1-D Isentropic flow, Flow with Friction and Heat Transfer. |
| 8. | Suggested Books | 1. R. W. Fox and A. T. McDonald, *Introduction to Fluid Mechanics*, 5$^{th}$ Ed, John Wiley, 1998.<br>2. F. M. White, *Fluid Mechanics*, 4$^{th}$ Ed, McGraw-Hill, 1999.<br>3. S. W. Yuan, *Foundations of Fluid Mechanics*, Prentice Hall of India, 1988.<br>4. Batchelor G.K., An Introduction to Fluid Dynamics, 2$^{nd}$ edition, Cambridge University Press, 2000.<br>5. H. Schlichting, Boundary Layer Theory, McGraw-Hill, 1979.<br>6. S. M. Yaha, Fundamentals of compressible flow, Wiley Eastern Limited, New York, 1982.<br>7. A. H. Shapiro, The dynamics and thermodynamics of compressible flow, Ronald Press, New York, 1953. |

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| 1. | Course Code | **ME 605** |
| 2. | Title of the Course | **Simulation of Thermal Systems** |
| 3. | Credit Structure | L-T- P-Credits<br>3-0-2-4 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Information flow diagram, systems identification and description, component and system design, Types of simulation, Solution techniques and curve fitting, Modeling of typical thermal equipments i.e. evaporative cooler, heat exchangers, steady state simulation, Typical case studies, Dynamic response of thermal systems, Introduction to optimization techniques, Compressive case studies of some thermal systems. |
| 8. | Suggested Books | 1. Wilbert Stoecker, "Design of thermal systems", Third edition, McGraw-Hill 1989, ISBN: 978-0070616202.<br>2. Yogesh Jaluria, "Design and optimization of thermal Systems", CRC press, Second edition, 2007, ISBN: 978-0849337536.<br>3. N.V. Suryanarayana & Oner Arici, "Design and simulation of thermal systems", First edition, 2002, ISBN: 978-0072497984. |

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|---|---|---|
| 1 | Course Code | **ME 407/ ME 607** |
| 2 | Title of the course | **Biofluid Mechanics** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of Discipline | Mechanical Engineering |
| 5 | Pre-requisites, if any | None |
| 6 | Scope of the course | (a) To understand the physiology and anatomy of different systems in the human body (b) To integrate fluid mechanics concepts to model biological flows in the human body (c) To identify specific diseases and to analyze how they are related to fluid mechanics. |
| 7 | Course Syllabus | **Introduction:** Introduction to fluid mechanics, and human physiology in relation to heart, lungs and blood vessels.<br>**Cardiovascular structure and function:** Electro-cardiogram, heart valves, cardiac cycles, heart sounds, coronary circulation, microcirculation, lymphatic circulation.<br>**Pulmonary Anatomy, Pulmonary physiology and Respiration:** Respiratory system, alveolar ventilation, mechanics of breathing, airway resistance, gas exchange and transport, pulmonary pathophysiology, respiration in extreme environment.<br>**Hematology and Blood Rhelogy:** Elements of blood, blood characteristics, viscosity measurement, erythorcytes, leukocytes; blood types, plasma.<br>**Anatomy and Physiology of Blood vessels:** General structure & types of arteries, mechanics of arterial walls, compliance, vascular pathologies, stents, coronary artery bypass grafting.<br>**Mechanics of Heart Valves:** Aortic and pulmonic valves; Mitral and Tricuspid valves; Pressure gradients across a stenotic heart valve; Prosthetic mechanical valves; Prosthetic tissue valves.<br>**Pulsatile flow in large arteries:** Introduction to blood flow in large arteries, pulsatile flow in tubes, instability in pulsatile flow.<br>Mathematical modeling: Introduction to finite difference, finite volume & finite element methods, non-Newtonian flow models, modeling of flow through Mitral valve, modeling of blood flow in vascular system. |

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| 8 | Suggested Books | **Text Book**<br>1. L. White and J.M. Fine, **Applied biofluid mechanics**, *McGraw Hill* 2007 (ISBN: 5551694623).<br>2. J.N. Mazumdar, **Biofluid Mechanics**, *World Scientific*, Singapore, 2004 (ISBN: 981-02-3801-0)<br>**Reference Books**<br>1. L. White, **Biomechanics in Cardiovascular Systems**, *McGraw Hill*, 2006.<br>2. C. Kleinstruer, **Biofluid Dynamics: Principles and Applications,** *CRC Press*, *Taylor and Francis Group*, 2006.<br>3. M. Zamir, **The Physics of Pulsatile Flow,** Springer Verlag, New York, 2000.<br>4. Sir James Lighhill, **Mathematical Biofluid Dynamics,** *Society for Industrial and Applied Mathematics, Philadelphia*, 1975 (ISBN: 0-89871-014-6) |

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| **Course code** | **ME 608/ ME 408** |
| **Title of the course** | Hybrid Electric Vehicles |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | Basic knowledge of Mechanical and Electrical Engineering |
| Scope of the course | This course is designed for final year undergraduate students and masters students who want to develop their knowledge about hybrid electric vehicles. Conventional I.C. Engine and electric powered vehicle will be analysed along with requirement of hybrid vehicle. Various mechanical layouts of hybrid powertrains will be examined to understand how they influence the performance and complexity of the powertrain. Sizing of the powertrains, Energy Management system and controls in the hybrid powertrain modes will be examined. |
| Course Syllabus | History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.<br><br>Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.<br><br>Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.<br><br>Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies.<br><br>Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, and Switch Reluctance Motor drives.<br><br>Energy Storage: Energy Storage Requirements in Hybrid and Electric Vehicles with Battery, Fuel Cell, Super Capacitor, and Flywheel based energy storage, Hybridization of different energy storage devices. Matching the electric machine and the internal combustion engine.<br><br>Energy Management Strategies. |
| Suggested Books | 1. I. Husain, ***Electric and Hybrid Vehicles*: Design Fundamentals,** CRC Press, Washington, 2011, 9781439811757<br>2. J. Larminie, J. Lowry, ***Electric Vehicle Technology Explained***, $2^{nd}$ edition, John Wiley & Sons Ltd, U.K., 2012, 9788126557608<br>3. B. D. McNicol, D. A. J. Rand, ***Power Sources for Electric Vehicles,*** Elsevier publications, New York, 1988, |

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| | 044442315X<br>4. S. Leitman, ***Build Your Own Electric Vehicle***, McGraw Hill, 1st Edition, WW, 2013, 978-0830642328 |

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|---|---|---|
| 1. | Course Code | **ME 611/ ME 411** |
| 2. | Title of the Course | **Refrigeration and Air Conditioning** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Thermodynamics |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Introduction:** Single stage and multistage vapour compression refrigeration systems, psychrometry and psychrometric processes.<br>**Vapour Absorption Refrigeration Systems:** Aqua-ammonia absorption refrigeration system, Lithum bromide-water absorption systems, p-t-x chart, enthalpy concentration chart, three fluid electrolux system, multistage absorption system, resorption absorption refrigeration, new mixtures for absorption systems.<br>**Non-conventional Refrigeration Systems:** Water refrigeration, Vortex and pulse tube refrigeration systems, thermoelectric refrigeration systems, multistage thermoelectric systems.<br>**Refrigerant Compressors:** Type of compressors; Reciprocating compressors: Volumetric efficiency, performance characteristic, capacity control, construction features, rotary compressors, screw compressors, centrifugal compressors, scroll compressors.<br>**Infiltration and Ventilation:** Basic concepts and terminology, driving mechanism of infiltration and ventilation, indoor air quality, natural ventilation, residential air leakage, residential ventilation, residential ventilation requirements, simplified models of residential ventilation and infiltration.<br>**Fenestration:** Fenestration components, determination of energy flow; U-factor, solar heat gain and visible transmission, shading, visual and thermal controls, air leakage, day lighting, selecting fenestration, condensation resistance, occupant comfort and acceptance.<br>**Cooling Load Calculations:** Residential cooling and heating load calculations: features, calculation approach, residential heat balance method, residential cooling load factor method, cooling load, heating load, nonresidential cooling and heating load calculations.<br>**Duct Design and Space Air Diffusion:** Room air distribution, total, static and velocity pressures, friction loss in ducts, dynamic loss in ducts, air duct design, equal friction method, static regain method, velocity reduction method, fitting loss coefficient, air diffusion: principles of jet behavior, room air diffusion methods.<br>**Pipe Sizing:** Pressure drop equations, water piping, hydronic system piping, steam piping, gas piping and fuel oil piping. |
| 8. | Suggested Books | 1. W.F. Stoecker, and J.W. Jones, **Elementary Refrigeration and Air conditioning**, McGraw Hill, 2002.<br>2. R.J. Dosset, **Principles of Refrigeration**, Pearson Education Asia, 2002.<br>3. C.P. Arora, **Refrigeration and Air conditioning**, Tata-McGraw |

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|---|---|---|
| | | Hill, 2002.<br>4. M. Prasad, **Refrigeration and Air Conditioning**, New Age International, 2004.<br>5. ASHRAE Handbook (Fundamentals), 2005. |

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|---|---|---|
| 1. | Course Code | **ME 613 / ME 413** |
| 2. | Title of the Course | **IC Engines** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Introduction:** Basic Nomenclature, Classification of IC Engines, working principle of 2-stroke and 4-stroke SI and CI engines. Air stand, fuel-air and actual cycles for SI and CI engines. Engine performance parameters. Valve and port timing diagrams.<br><br>**Combustion:** *In SI Engines* - Combustion initiation, Flame development and propagation, ignition lag, preignition, normal and abnormal combustion-knocking, physical and chemical aspects of knocking, effect of operating parameter and chemical structure on knocking tendency, Octane number, design considerations of combustion chamber, Stratified charge combustion, Concept of lean burning engines. *In CI Engines***-** Various stages of combustion-Vaporization of fuel droplets and spray formation<br>**Engine Accessories:** *SI Engines* - Carburetors**,** Properties of air-fuel mixtures, mixture requirement, Main metering system, Idling system, Economizer system, acceleration pump and cold starting system. Spark plug, fly wheel, DTS-I system. Nozzle lip, venturi depression, calculation of fuel jet and venturi throat diameter for given air fuel ratio, Battery and magneto ignition system and their comparative study, firing order, Ignition timing, Petrol Injection system, electronic fuel injection, advantage and disadvantage of petrol injection. *CI Engine*- Fuel pump, types of fuel injector, fly-wheel, types of piston and properties, high pressure pipe, Governor- Necessity of governing, various methods of governing. Fuel injection system- Requirement, types of nozzle, atomization, spray penetration and spray direction, multiple point fuel injection system, injection timing, common rail fuel injection system.<br>**Cooling and Lubrication Systems:** Cooling requirement, air cooling, liquid cooling, type of liquid cooling system, advantage and disadvantage of air cooling and water cooling system, Antifreeze mixture. Function of lubricating system, properties of lubricating oil, wet sump, dry sump and mist lubrication system.<br>**Fuels:** Basic requirement of I.C. Engine fuels, requirement of an ideal gasoline, structure of petroleum, effect of fuel structure on combustion, volatility of liquid fuels, effect of volatility on engine performance for starting, vapor lock, acceleration, percolation, carburetor icing, and crank case dilution, Alternative fuels-Bio Diesel types, Compressed Natural Gas, Hydrogen Energy- Solid, Liquid, Gas. Fuel Cells.<br>**Emissions:** Emissions from SI and CI engines, types of emission gasses, emission control system, types of emission control system, EGR system. |
| 8. | Suggested Books | 1. J. B. Heywood, **Internal Combustion Engine**, McGraw Hill, ISBN-0- |

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| | | 07-100499-8; ,<br>2. V. Ganeshan, **Internal Combustion Engine**, Tata McGraw Hill, 1992.<br>3. M.L. Mathur and R.P. Sharma, **A Course in Internal Combustion Engines,** Dhanpat Rai and Sons<br>4. V. Ganeshan, **Computer simulation of SI Engine Process**, Orient, 1996. |

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|---|---|---|
| 1. | Course Code | **ME 614** |
| 2. | Title of the Course | **Fabrication of Micro and Nanostructures** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards synthesize and characterization of nanostructures s |
| 7. | Course Syllabus | **Introduction to Manipulation of Materials in Nano scale:** Nano and Nature an overview- Emergence of nanotechnology –Bottom up and top down approaches- -Diversity in nanosytems -Evolving interfaces of nano structures-manipulating materials in the nano scale-Physical chemistry of solid surfaces-surface energy-electrostaic stabilize-DLVO theory-steric stabilization-Template based self assembly of nano structures.<br>**Zero-Dimensional Nanostructures (Nano-particles):** Nanoparticle through homogenous and heterogeneous nucleation's-mechanism of homogenous and heterogeneous nucleation-growth of nuclei-synthesis of metallic nanoparticles-synthesis of semiconductor nanoparticles-sol-gel processing-Forced hydrolysis-controlled release of ions-Vapor phase reactions-Solid-state phase segregations-kinetically confined synthesis of nanoparticles-Aerosol synthesis-Growth termination-spray pyrolysis-template based synthesis-epitaxial core-shell nanoparticles-Nanocomposite and Nanogrined materials-Bio induced materials-carbon fullerene-micro and mesoporous materials<br>**One dimensional (i.e. Nanowires and Nanorods) and Two dimensional nanostructures (i.e. Thin films):** Fundamentals of film growth-Vacuum science-Physical vapor deposition(PVD)-evaporation –molecular beam epitaxy (MBE)-Sputtering-CVD-Reaction kinetics and transport phenomena--atomic layer deposition-Langmuir Blodgett films-electrochemical deposition-sol-gel films-Nanotribology of ultra thin and hard amorphous carbon films – Surface forces and nano rheology of molecularly thin films.<br>**Three dimensional nanostructure , MEMS/ NEMS and Bio MEM.S./NEM.S.:** Three-dimensional nanostructure fabrication by focused ion beam CVD- three dimensional nanostructure fabrication-MEM.S./NEM.S. device and applications-Generation DNA hybridization and self-assembly nanofabrication devices-single-walled carbon nanotube sensor concept-nanomechanical cantilever array sensors-biological molecules in therapeutic nanodevices-surface display and biosensor technology-microfluidic devices and their applications to Lab-on-a-chip-centrifuge-based fluidic platforms-micro-/nanodroplets in micro fluidic devices-multifunctional plant surfaces ad smart materials.-Lotus effect: surface with superhydrophobicity, self-cleaning and low adhesion. |
| 8. | Suggested Books | 1. G. Cao, Y. Wang, **Nanostructure and Nano materials, Synthesis, Properties and Applications**, World scientific Publishing Co., 2011, ISBN-13**:** 978-9814324557.<br>2. Bhusan, **The Handbook on Nanotechnology**, Springer series, ISBN: |

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| | | 978-3-642-02524-2.<br>3. R. Kelsall, I. W. Hamley and M. Geoghegan, **NanoScale Science and Technology**, ISBN 13:9780470850862.<br>4. L. Chi, **Nano Technology-Volume 8: Nanostructured surfaces**, Wiley Publication, ISBN13:9783527317394.<br>5. R. K. Leach, **Fundamental Principles of Engineering Nanometrology**, Elesevier publication, ISBN: 9780080964546. |

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| 1. | Course Code | **ME 616 / ME 416** |
| 2. | Title of the Course | **Non-Conventional Energy Sources** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | To inculcate energy consciousness and environment sensitivity among engineering graduates |
| 7. | Course Syllabus | **Introduction:** Energy resources; conventional and non-conventional, Energy and infrastructural development; Ecosystems, the environment and its cycles, energy and environment relationship<br>**Solar energy:** Solar radiation, radiation measurement and predictions; solar thermal conversions, basics, flat plate collectors-liquid and air type, theory of flat plate collectors, selective coating, advances collectors,; concentrators; Solar water heater, solar dryer; Solar phtovoltaic, science and technology of photovoltaic devices. organic PV cells<br>**Wind Energy:** Metrology of wind speed distribution, energy estimation of wind regimes; Wing energy conversion, power torque and speed characteristics, wind turbine; Application of wind energy<br>**Biomass:** Biomass sources, $CO_2$ fixation potential of biomass, physicochemical characterstics of biomass as fuel; Biomass conversion, biochemical, chemical and thermal; biogas production mechanism, technology, types of digesters, plant design, biogas plant manure-utilization and manure values; Biomass gasification and combustion; anaerobic digestion of biomass; biomass utilization to produce solis, liquid and gaseous fuels<br>**Hydro-energy**: Overview of micro, mini and small hydro system; hydrology; elemnets of turbine; assessment of hydropower; selection and design criteria of turbines; speed and voltage regulations; Ocean energy; principle of ocean thermal energy conversion system, principles of ocean wave energy and tidal energy conversion<br>**Geothermal energy**: Origin of geothermal resources, types of geothermal deposits;<br>**Hydrogen energy**; Hydrogen production and storage; Fuel cells, principles of working, basic thermodynamics |
| 8. | Suggested Books | 1) Donald K**., Biomass for renewable energy, Fuels and chemicals**, Academic press<br>2) S.P. Sukhatme: **Solar energy principles of thermal collection and storage**, 2nd edition, Tata McGraw Hill<br>3) G. Boyle, **Renewable energy: Power for sustainable future**, Oxforfd OUP |

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| | | 4) J. Twidell and T. Weir, **Renewable Energy Resources**.<br>5) T. B. Johansson, H. Kelly, A.K.N. Reddy, R. H. William, **Renewable Energy- Sources for fuels and Electricity**. |

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|---|---|---|
| 1. | Course Code | **ME 618 / ME 418** |
| 2. | Title of the Course | **Computational Fluid Dynamics (CFD)** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Heat Transfer |
| 6. | Scope of the course | |
| 7. | Course Syllabus | Control volume discretization of heat conduction equation in Cartesian and general curvilinear coordinate systems – Dirichlet, Neumann and Periodic boundary conditions;<br>Gauss Seidel, TDMA, TVA, STONE, CD algorithms for solving resulting algebraic equations; convergence and accuracy and multigrid methods for convergence enhancement;<br>General equations for boundary layer flows with heat and mass transfer and chemical reaction;<br>boundary conforming transformation of equations, control volume discretization of equations; marching integration; application to wall boundary layers, free shear layers and mixing layers with and without comport equations in Cartesian and curvilinear coordinates;<br>control volume discretization of equations; staggered and non-staggered grids; pressure correction algorithm; time marching predictor-corrector algorithm; application to recirculating elliptic flows and partially parabolic flows; compressible flows and shock capturing.<br>Diffusion models; turbulence – zero, one and two equation models; stress equation models; low Reynolds number models; algebraic models; equivalent flux models.<br>Source laws; Combustion models, radiation models, porous body models, mass sources; Numerical grid generation; algebraic, parabolic and elliptic equations. |
| 8. | Suggested Books | 1. S.V. Patankar, **Conduction and Laminar Fluid Flow**, Innovative Press, 1992.<br>2. S.V. Patankar, **Numerical Heat Transfer and Fluid Flow**, Academic Press, 1983.<br>3. S.V. Patankar, and D.B. Spalding, **Heat and Mass Transfer in Boundary Layers**, Academic Press, 1968.<br>4. W.M. Kays, **Convective Heat and Mass Transfer** ($6^{th}$ edition), Tata McGraw Hill, New Delhi, 1992.<br>5. C.A.J. Fletcher, **Computational Techniques for Fluid Dynamics** (Vol. 1 & 2), Springer Verlag, 1988. |

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| 1. | Course Code | **ME 630** |
| 2. | Title of the Course | **Robotic Control Systems** |
| 3. | Credit Structure | L-T- P-C<br>2-1-2-4 |
| 4. | Name of the Concerned Discipline/School | Mechanical Engineering / School of Engineering |
| 5. | Pre–requisite, if any | Robotics and Dynamics and Control Systems |
| 6. | Scope of the course | The objectives and scope of this course are to develop in mechanical engineering graduate students the knowledge and skills required<br>• To establish the fundamental techniques for understanding the nonlinear control schemes used in robotic fields.<br>• To analyze and design control system models in the state space approach.<br>• To develop an understanding of robotic control systems and the parameters that influence their stability and performance.<br>• To aware and get exposure on virtual and numerical environments, for designing and verifying nonlinear control schemes. |
| 7. | Course Syllabus | Introduction and overview of robotic systems and their dynamics. Forward and inverse dynamics. Properties of the dynamic model and case studies.<br>Introduction to nonlinear systems and control schemes.<br>System stability and types of stability. Lyapunov stability analysis, both direct and indirect methods. Lemmas and theorems. related to stability analysis.<br>Joint space and task space control schemes: Position control, velocity control, trajectory control and force control.<br>Nonlinear control schemes: Proportional and derivative control with gravity compensation, computed torque control, sliding mode control, adaptive control, observer based control, robust control and optimal control.<br>Observer based on acceleration, velocity and position feedbacks.<br>Numerical simulations using software packages namely MATLAB/MATHEMATICA.<br>Virtual prototype making and inverse dynamic simulation on ADAM.S. (Multibody dynamics software). |

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| 8. | Suggested Books | 1. R. Kelly, D. Santibáñez, L.P. Victor and Julio Antonio, **Control of Robot Manipulators in Joint Space**, Springer, 2005,ISBN 978-1-85233-999-9.<br>2. A. Sabanovic and K. Ohnishi, **Motion Control Systems**, John Wiley & Sons (Asia), 2011, ISBN 978-0-470-82573-0<br>3. R. M. Murray, Z. Li and S.S. Sastry, **A Mathematical Introduction to Robotic Manipulation**, CRC Press, 1994, ISBN 978-0-849-37981-9<br>4. J. J. Craig, **Introduction to Robotics: Mechanics and Control**, Prentice Hall, 2004, ISBN-13 9788131718360.<br>5. J. J. E. Slotine and W. Li,**Applied Nonlinear Control**, Prentice Hall, 1991, ISBN 978-0-130-40890-7.<br>6. M.W. Spong, Seth Hutchinson and M. Vidyasagar, **Robot Modeling and Control**, John Wiley & Sons, 2006, ISBN 978-0-471-64990-8. |

| **Course code** | **ME 632/ ME 432** |
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| **Title of the course** | **Vibrations and Noise Control** |
| Credit Structure | L-T-P–Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | With the increasing demand of noise and vibration engineers in industry, this course is designed to know theoretical and practical aspects of noise and vibration. This course covers basics of noise and vibration, measurement and analysis of noise and vibration, control of noise and vibration and industrial case studies. |
| Course Syllabus | **Introduction:** Basic vibration theory, vibration of one degree, two degrees, and multi-degrees of freedom systems.<br>**Transient vibrations**, vibration of beams.<br>**Measurement and Analysis of Vibrations:** Lagrange's equation, vibration measuring and analyzing instruments. Various types of transducers, data acquisition system, vibration analysis techniques<br>**Design for vibration control**: Vibration absorbers, viscoelastic damping, active vibration control.<br>**Fundamentals of Noise**: One dimensional wave equation, Sound propagation in 3-D space, some important acoustic quantities and relations, additive effects of sound.<br>**Measurement of sound:** Various types of transducers, measurement of sound pressure, sound intensity and sound power.<br>**Noise Control:** Principles of passive noise control, sound absorption, noise barriers.<br>**Case studies:** Source identification and fault detection from noise and vibration signals in mechanical systems such as bearings, gears, fans, blower and pumps, electrical equipment etc. |
| Suggested Books | 1. W.T. Thomson, **Theory of Vibration and Applications**, Prentice Hall, 1979, ISBN-13: 978-0136510680<br>2. R.F. Steidel, **An Introduction to Mechanical Vibration**, John Wiley and Sons, 1979, ISBN-13: 978-0471845454<br>3. J.S. Rao, and K. Gupta, **Theory and Practice of Mechanical Vibrations**, New Age International (Pvt ) Ltd. New Delhi, 1999, ISBN-13: 978-8122412154<br>4. Brandt, Anders, **Noise and vibration analysis : signal analysis and experimental procedures,** John Wiley & Sons, West Sussex, 2011, ISBN-13: 978-0470746448<br>5. Cheremisinoff, Nicholas, **Noise control in industry : a practical guide,** Noyes Publications, New Jersey, 2003, ISBN-13: 978-0815513995<br>6. Fahy, Frank and Walker, John, **Fundamentals of noise and vibration**, Taylor and Francis, London, 1998, ISBN-13: 978-0419227007<br>7. Norton, M.P and Karczub, D.G**, Fundamentals of noise and vibrations analysis for engineers**, Cambridge University press , New York , 2003, ISBN-13: 978-0521499132 |

| **Course code** | **ME 634/ ME 434** |
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| **Title of the course** | **Principles of Product Design** |
| Credit Structure | L-T-P–Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | The scope of the course is to integrate the design, marketing, engineering, and business functions of the firm in creating a new product. The course is intended to provide the following benefits: •Competence with a set of tools and methods for product design and development. • Describe an engineering design and development process •Ability to coordinate multiple, interdisciplinary tasks to achieve a common objective. •Employ engineering, scientific, and mathematical principles to execute a design from concept to finished product. •Reinforcement of specific knowledge from other courses through practice and reflection in an action-oriented setting. |
| Course Syllabus | Overview of the Design Process – Philosophy of Engineering Design, Steps involved in the Design Process S curves, Communications during design process. Understanding the customer need – Steps involved in developing Engineering Design Specifications. The technique of Quality Function Deployment (QFD). Case studies in QFD. Functional Design – Functions in engineering Design. Basics of Function Structure – Functional Basis, Functional decomposition and flow. Product Concept – Various methods of concept generation. The method of theory of the resolution of invention-related tasks (TRIZ). Concept Selection and methods of evaluation. Embodiment design-product architecture, configuration, parametric design, systems approach and other consideration of embodiment design. An introduction to product metrics. Product evaluation techniques. |
| Suggested Books | 1. K. Otto and K. Wood, **Product Design: Techniques in Reverse Engineering and New Product Development**, Pearson, New Jersey, 2001, ISBN 978-0130212719<br>2. D.G. Ullman, **The Mechanical Design Process**, McGraw-Hill, New York, 2009, ISBN 978-0072975741<br>3. G. Dieter and L. Schmidt, **Engineering Design (Mechanical Engineering)**, McGraw-Hill, New York, 2012, ISBN 978-0073398143<br>4. K.T. Ulrich and S.D. Eppinger, **Product Design and Development**, McGraw-Hill, New York, 2007, ISBN 978-0073101422 |

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| **Course code** | **ME 637/ ME 437** |
| **Title of the course** | **Fracture Mechanics** |
| Credit Structure | L - T - P – Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | Theory of elasticity |
| Scope of the course | This course introduces the fundamental concepts of the fracture mechanics useful in designing high risk products such as nuclear plants, airplanes, space vehicles, submarines, etc. This course will not only provide enough background to work in industries but also build foundation to start research in the area of fracture mechanics, computational fracture mechanics and mechanical behaviour of materials. |
| Course Syllabus | Introduction and overview, Energy concepts in fracture mechanics: atomistic view of fracture, Griffith energy balance, Irwin-Orowan extension, Energy release rate G and R curve; Linear elastic fracture mechanics: stress and displacement fields near crack tip for mode-I, II and III fracture, stress intensity factor K, relation between G and K, small scale yielding conditions, Irwin's plastic zone correction, Dugdale model, Fracture toughness Kc, Westergaard method, Principle of superposition, Non Linear fracture mechanics; J Integral, Plastic crack tip (HRR) fields, Ductile fracture criterion, J Integral Testing, J-controlled crack growth and stability, Engineering approach to Plastic Fracture; Fatigue Failure. |
| Suggested Books | 1. T. L. Anderson, **Fracture Mechanics – Fundamentals & Applications**, CRC press, 3rd Ed., 2005, ISBN-10: 0849316561.<br>2. M. F. Kanninen and C.H.Popelar, **Advanced Fracture Mechanics**, Oxford press, 1985, ISBN-10: 0195035321<br>3. D. Broek, **Elementary Engineering Fracture Mechanics**, Martinus Nijhoff publishers, 1982, ISBN-13:- 978-90-247-2580-9<br>4. Kare Hellan, **Introduction to Fracture Mechanics**, McGraw Hill, 1984, ISBN-10: 0070280487 |

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| **Course code** | **ME 639/ ME 439** |
| **Title of the course** | **Mechanical Behavior of Materials** |
| Credit Structure | L-T-P–Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course will discuss crystal structure, basic mechanism of plastic deformation and their influence on the mechanical behavior of metallic materials. In addition, it will provide an understanding of the atomistic modelling of solid materials to characterize their mechanical behavior. |
| Course Syllabus | Introduction and overview, Elastic deformation, Crystal structure, Theory of dislocation (edge, screw and mixed dislocations, cross slip, Peirls-Nabarro stress, Peach-Koehler equation, Frank-Read source), Twining, Plastic deformation in single and polycrystal, Strengthening mechanisms, Hardening mechanisms, Atomic/molecular structure of nanomaterials and their synthesis, overview of nanomechanical testing methods, atomistic modelling tools (DFT, tight-binding modelling, MD with their advantages and limitations), Functionalization, Size-scale strength, Nano-biomechanics and nanocomposites |
| Suggested Books | 1. William F. Hosford, **Mechanical behavior of materials**, Cambridge University Press, 2 edition, New York, 2009, ISBN 978-0521195690<br>2. G.E. Dieter, **Mechanical Metallurgy**, McGraw-Hill, London, 1988, ISBN 0–07–016893–8<br>3. Andrew Leach, **Molecular Modelling: Principles and Applications,** Pearson, London, 2001, ISBN 978-0582382107<br>4. Alan Hinchliffe, **Molecular Modelling for Beginners**, John Wiley & Sons Ltd., United Kingdom, 2008, ISBN 978-0470513149 |

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| 1. | Course Code | **ME 640/ ME 440** |
| 2. | Title of the Course | **Smart Materials and Structures** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The main objective of the course is to show a clear picture on the development and application of smart materials and structures |
| 7. | Course Syllabus | **Intelligent materials:** Primitive functions of intelligent materials; Intelligence inherent in materials; Materials intelligently harmonizing with humanity; Intelligent biological materials.<br>**Smart Materials and Structural Systems:** Actuator materials; Sensing technologies; Micro-sensors; Intelligent systems; Hybrid smart materials; Passive sensory smart structures; Reactive actuator-based smart structures; Active sensing and reactive smart structures; Smart skins<br>**Electro-Rheological (ER) Fluids:** Suspensions and electro-rheological fluids; The electro-rheological phenomenon; Charge migration mechanism for the dispersed phase; Electro-rheological fluid actuators.<br>**Piezoelectric Materials:** Background; Piezoelectricity; Industrial piezoelectric materials; Smart materials featuring piezoelectric elements.<br>**Shape Memory Materials (SMM):** Background on shape-memory-alloys; Applications of shape-memory-alloys; Continuum applications: structures and machine systems; Discrete applications; Impediments to applications of shape-memory-alloys; Shape-memory-plastics.<br>**Fiber-optics:** an overview; Advantages of fiber-optics; Light propagation in an optical fiber; Embedding optical fibers in fibrous polymeric thermosets; Fiber-optic strain sensors.<br>**The piezoelectric Vibrations Absorber Systems:** Introduction; The single mode absorber, theory, design solution, extension including viscous modal damping, the electromechanical coupling coefficient, inductance, experimental results; The multimode absorber, derivation of transfer function, design solution, self-tuning absorber, performance function, control scheme. |
| 8. | Suggested Books | 1. M.V. Gandhi, and B.S. Thompson, **Smart Materials and structures** (2nd edition), Chapman & Hall, 1992, ISBN: 0412370107, 9780412370106<br>2. A. Guran, H.S. Tzou, G.L. Anderson, and M. Natori, **Structure Systems: Smart Structures, Devices and System** (Part 1), and **Materials and Structures** (Part 2), World Scientific Publications, 1998, ISBN: 9780340719206 |

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| | | 3. U. Gabbert, and H.S. Tzou, **Smart Structures and Structuronic System**, Kluwer Academic Publishers, 2001, ISBN: 978-0-470-04192-5<br>4. H.T. Banks, R.C. Smith, and Y.W. Qang, **Smart Material structures: Modeling, Estimation and Control** (6th edition), John Wiley & Sons, 1997. |

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| **Course code** | **ME 641/ ME 441** |
| **Title of the course** | Design of Laminated Composite Structures |
| Credit Structure | L-T-P–Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | Solid Mechanics, Strength of Materials, Composite Materials |
| Scope of the course | This course introduces various aspects of composite structural design based on different applications. This course is intended to educate the students in basics, advantages, design, fabrication, and applications of composite materials in various advanced structures. |
| Course Syllabus | Introduction to different thermo-set and thermo-plastic composites, manufacturing process of thermo-set and thermo-plastic composites, application of thermo-set and thermo-plastic composites based on the design requirement, Design of composite beams, review of laminate strength and failure theories , experimental testing of the composites for stiffness and strength parameters, Introduction to fatigue of composite materials, design and analysis of composite beams, shear flow and shear center calculation in thin walled closed sections, analysis of loads and load paths in the advanced industrial composite structures such as wind turbine rotor blade and gas turbine compressor fan blade, Selection of ply angles based on the load paths. |
| Suggested Books | 1. Isaac M. Daniel , Ori Ishai, **Engineering mechanics of composite materials**, Oxford university press, New Delhi, 2011, ISBN 019568580-6<br>2. Carl T. Herakovich: **Mechanics of fibrous composites,** Wiley Publications, Newyork, 1998, ISBN: 978-0-471-10636-4<br>3. Louis C. Dorworth, Ginger L. Gardiner, Greg M. Mellema, **Essentials of advanced composite fabrication & repair**, Aviation supplies & Academics, Inc., Newyork, 2009, ISBN 978-1-61954-229-7<br>4. Christos Kassapoglou, **Design and analysis of composite structures with applications to aerospace structures**, Wiley publications, The Netherlands, 2011, ISBN9781118401606 |

| **Course code** | **ME 643/ ME 443** |
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| **Title of the course** | **Micromechanics and Nanomechanics** |
| Credit Structure | L - T - P – Credits 2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course is designed for students from diverse fields of study. This course provides a single window for students to comprehend wide range of subjects/research topics of advanced micro- and nano-materials and prepare them to characterize multifunctional behavior of advanced material systems. The first part of the subject includes modules of fundamentals of micromechanics. The second part of the subject includes modules on useful concepts in molecular modeling. A partial focus of the subject is to provide a hands-on training in the application of computer modeling of SOLID materials at the atomic scale. |
| Course Syllabus | Introduction to micromechanics and nanomechanics. Preliminaries of continuum mechanics, micromechanical homogenization theory: Ergodicity principle, representative volume element, eigenstrains and eigenstress, inclusions and inhomogeneities; Effective moduli of heterogeneous materials (single and multi-inclusion approaches), Hill's bounds, Voigt and Reuss bounds, Hashin-shtrikman variational principles Micromechanical damage theory. Basics of atomistic, interatomic potentials, lattice defects; Molecular statics and dynamics: time integration, temperature and pressure control, statistical ensembles, potential field, Virial stress; Bohr's correspondence principle; Multiscale modeling; Structural mechanics of carbon-based and boron nitride-based nanomaterials. |
| Suggested Books | 1. S. Nemat-Nasser and M. Hori, **Micromechanics: Overall Properties of Heterogeneous Materials**, North Holland, Amsterdam, 1998, ISBN 978-0444500847<br>2. Shaofan Li and Xin-Lin Gao, **Handbook of Micromechanics and Nanomechanics**, Taylor & Francis Group, LLC, Boca Raton, 2013, ISBN 978-981-4411-24-0<br>3. Jianmin Qu and Mohammed Cherkaoui: **Fundamentals of Micromechanics of Solids,** John Wiley & Sons Inc., New Jersey, 2006 ISBN 978-0-471-46451-8<br>4. Alan Hinchliffe, **Molecular Modelling for Beginners**, John Wiley & Sons Ltd., United Kingdom, 2008 ISBN 978-0470513149 |

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| 1. | Course Code | **ME 644 / ME 444** |
| 2. | Title of the Course | **Robotics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The main objective of the course is to show a clear picture on the development and application of robotics systems |
| 7. | Course Syllabus | **Introduction:** Introduction to robots – Robot manipulators – Mobile robots – Robot anatomy – Coordinate systems, Work envelope – Types and classification – Specifications – Sensors – Actuators and drives.<br>**Forward and Inverse Kinematics:** Introduction – Representation of position and orientation of a rigid body – Homogeneous transformations – Forward and inverse kinematics problems – Denavit-Hartenberg (D-H) notations and parameters – Representation of joints, link representation using D-H parameters – Closed-form solutions – Geometric and Numerical methods.<br>**Velocity and Statics analysis:** Linear and angular velocity of links – Velocity propagation – Jacobians for robotic manipulators – Statics and force transformation of robotic manipulators – Singularity analysis.<br>**Robot Dynamic analysis:** Introduction – Forward and inverse dynamics – Mass and inertia of links - Lagrangian formulation for equations of motion for robotic manipulators – Newton-Euler formulation method – Dynamic modelling – State space representation of dynamic equations of robotic manipulators.<br>**Trajectory Planning and Control:** Joint and Cartesian space trajectory planning and generation – Classical control concepts using the example of control of a single link – Independent joint PID control – Control of a multi-link manipulator – Nonlinear model based control schemes – Simulation and experimental case studies on robotic manipulators. |
| 8. | Suggested Books | 1. J.J. Craig, **Introduction to Robotics: Mechanics and Control**, John Wiley & Sons Inc., 2004, ISBN: 0201151987.<br>2. M.W. Spong, Seth Hutchinson, M. Vidyasagar, **Robot Modeling and Control**, John Wiley & Sons Inc., 2006, ISBN: 10: 0471649902.<br>3. J.R. Schilling, **Fundamentals of Robotics: Analysis and Control**, Prentice Hall India, 1992, ISBN: 9788120310476.<br>4. K. Fu, R. Gonzalez, and C.S.G. Lee, **Robotics: Control,** |

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| | | **Sensing, Vision and Intelligence**, McGraw - Hill, 1987, ISBN: 9780070226258.<br>5. A. Ghosal, **Robotics: Fundamental Concepts and Analysis**, Oxford University Press, 2008, ISBN: 9780070669000. |

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| **Course code** | **ME 645/ ME 445** |
| **Title of the course** | **Mobile Robotics** |
| Credit Structure | L - T - P - Credits<br>2-0-2-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course provides an introduction to mobile robotic systems and motion control methods with such systems from a computational and real-time perspective. Students will understand the algorithmic approach towards designing intelligent and autonomous mobile robotic systems. Students will learn about a variety of mobile robotic platforms, their applications and uses. Students will learn the basics mechanical and electrical systems of these mobile robots, including sensors, locomotion and manipulation hardware. |
| Course Syllabus | Introduction to Mobile Robots - Tasks of mobile robots, robot_s manufacturers, type of obstacles and challenges, tele-robotics, philosophy of robotics, service robotics, types of environment representation. Ground Robots: Wheeled and Legged Robots, Aerial Robots, Underwater Robots and Surface Robots. Kinematics and Dynamics of Wheeled Mobile Robots (two, three, four - wheeled robots, omni-directional and macanum wheeled robots). Sensors for localization: magnetic and optic position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, GNSS and Sensors for navigation: tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual system, Kinect. Localization and Mapping in mobile robotics. Motion Control of Mobile Robots (Model and Motion based Controllers): Lyapunov-based Motion Control Designs and Case Studies. Understand the current application and limitations of Mobile Robots. Introduction to Mobile Manipulators and Cooperative Mobile Robots. |
| Suggested Books | 1. R Siegwart, IR Nourbakhsh, D Scaramuzza, ***Introduction to Autonomous Mobile Robots***, The MIT Press, USA , 2011, 9780262015356<br>2. SG Tzafestas, ***Introduction to Mobile Robot Control***, Elsevier, USA, 2014, 9780124170490<br>3. A Kelly, ***Mobile Robotics***, Mathematics, Models, and Methods, Cambridge University Press, USA, 2013, 9781107031159<br>4. G Dudek, M Jenkin, ***Computational Principles of Mobile Robotics,*** Cambridge University Press, USA, 2010, 9780521692120 |

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|---|---|---|
| 1. | Course Code | **ME 646 / ME 446** |
| 2. | Title of the Course | **Dynamics and Control Systems** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Kinematics & Dynamics |
| 6. | Scope of the Course | The objectives of this course are to develop in mechanical engineering students the knowledge and skills required<br>• To establish the fundamental techniques for modelling dynamic systems.<br>• To analyse and manipulate system models in the time and frequency domain.<br>• To develop an understanding of feedback control systems and the parameters that influence their stability and performance. |
| 7. | Course Syllabus | **Dynamic Modelling of Systems:** Introduction to Dynamics, Systems and Control. Dynamic modelling of systems. Lumped system. Modelling of translational and rotational mechanical spring-mass-damper systems. Nonlinear systems and Linearization of nonlinear systems. Numerical computations and simulations with MATLAB / MATHEMATICA, and simulations in M.SC. ADAM.S..<br>**Analysis of Linear Systems:** Introduction, Laplace transform, Transfer functions, System response, Stability analysis, Routh-Hurwitz criteria. Time domain analysis: Root locus method. Frequency domain analysis: Bode plot and Nyquist plot. Numerical computations with MATLAB.<br>**Linear Feedback Control Systems:** Lead and Lag compensator, Design and analysis of linear feedback control systems using time and frequency domain techniques. Numerical computations with MATLAB.<br>Proportional (P), proportional-derivative (PD), proportional-integral (PI) and proportional-integral-derivative (PID) controller, Gain tuning methods and modifications. Case studies on PID Controller and its applications.<br>**Analysis of Systems in State Space:** Concept of state and state variables. State space representation of dynamic systems. State models of linear time invariant systems, State transition matrix, and Solution of state equations. Controllability and Observability. Numerical computations with MATLAB.<br>**State Space Controllers and Observers for Linear systems:** Full state feedback controller and Pole placement technique. Design of full state feedback controller. State observer and design of state observer with controller. Numerical computations and simulations with MATLAB. |
| 8. | Suggested Books | 1. K. Ogata, **Modern Control Engineering** (5$^{th}$ edition), Prentice Hall India, 2003, ISBN-13: 978-0136156734.<br>2. B.C. Kuo, **Automatic Control Systems** (7$^{th}$ edition), Prentice Hall |

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| | | India, 2003, ISBN: 9788126513710.<br>3. N.S. Nise, **Control Systems Engineering** (4th edition), John Wiley, 2003, ISBN: 0471366064.<br>4. M. Gopal, **Control Systems, 2/e**, Tata McGraw-Hill, 2000, ISBN: 9780070482890.<br>5. G. F. Franklin, **Feedback Control of Dynamic Systems** (6th edition), Pearson Edition, 2009, ISBN: 9788131721421.<br>6. R.C. Dorf and R.H. Bishop, **Modern Control Systems** (12th edition), Prentice Hall India, 2011, ISBN: 9780132270281.<br>7. C.L. Phillips, and R.D. Harbour, **Feedback Control Systems** (2nd edition), Prentice Hall, 1991, ISBN: 9780133134469.<br>8. I.J. Nagrath and M. Gopal, **Control System Engineering** (2nd edition), Wiley Eastern, 1982, ISBN: 9788122405033. |

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| **Course code** | **ME 647** |
| **Title of the course** | **Dynamics and Control Systems Lab** |
| Credit Structure | L-T-P–Credits<br>0-0-3-1.5 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | It provides a platform for understanding the basic concepts of linear control theory and its application to practical systems. |
| Course Syllabus | Dynamic model development and simulation of simple mechanical systems using Matlab and Mathematica. Numerical simulation of simple mechanical systems. Stability analysis of simple mechanical systems using linear system theory namely root locus and Bode plot. Linear controller (P,PI,PD and PID) design for simple position control of mechanical systems. State space model development and dynamic simulation using Simulink. Full state feedback controller and Pole placement technique. Design of full state feedback controller. State observer and design of state observer with controller. |
| Suggested Books | 1. K. Ogata, **Modern Control Engineering**, Pearson, New Jersey, 2010, ISBN 978-0136156734<br>2. N.S. Nise, **Control Systems Engineering**, Wiley, New Delhi, 2014, ISBN 978-8126537280<br>3. M. Gopal, **Control Systems**, :McGraw Hill, New Delhi, 2012, ISBN 978-0071333269<br>4. B.C.Kuo, **Automatic Control Systems**, Wiley, New Jersey, 2014, ISBN 978-8126552337 |

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| 1. | Course Code | **ME 648 / ME 448** |
| 2. | Title of the Course | **MEMS and Micro-system Design** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering Discipline |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Introduction to MEMS and Micro-systems:** Micro-electro-mechanical- systems (MEMS) and micro-system products, the multidisciplinary nature of micro-systems, scaling laws in miniaturization, application of micro system in other industries, intrinsic characteristics of MEMS.<br><br>**Micro-actuators and Micro-sensors:** Micro-sensors, acoustic wave sensors, biomedical and nano-sensors, chemical sensors, optical sensors, pressure sensors, thermal sensors, micro-actuation through thermal forces, SMA-Piezo electric crystals, and electrostatic forces, magnetic actuation, micro-grippers, micro-motors, micro-valves, micropumps, micro-accelerometers.<br><br>**Materials, Mechanics and design of micro-systems:** Silicon as a substrate, compounds, piezo-resisitors, polymers and packaging materials, micro-fabrication and micro-etching: static bending of thin plates, thermo mechanics and thin film mechanics.<br><br>**Case studies of MEM.S. Products:** Micro-fluidic devices, micro/nano transducers, blood pressure sensor, microphone-acceleration sensors, gyroscope, an overview of micro-system packaging. |
| 8. | Suggested Books | 1. Tai-Ran Hsu, **MEMS and Micro system Design and Manufacturing**, Tata McGraw Hill, ISBN 07-239391-2.<br>2. Chang Liu, **Foundation of MEM.S.**, Pearson Education, ISBN (978-81-317-6475-6)<br>3. Guozhong Cao,Ying, **Nanostructure and Nano materials, synthesis, properties and applications**, World Scientific Publishing Co. 2011<br>4. Robert Kelsall, Ian W.Hamley, Mark Geoghegan, **NanoScale Science and Technology**, ISBN 13:978047085086<br>5. Lifeng Chi, **Nano technology-Volume 8: Nanostructured surfaces**, Wiley Publication, ISBN13:9783527317394. |

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| 1. | Course Code | **ME 650** |
| 2. | Title of the Course | **Materials Characterization Techniques** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The main objective of the course is to show a clear picture on the material characterization techniques |
| 7. | Course Syllabus | **Introduction:** Requirement of different techniques of material characterization for different situations; Mechanical and physical characterization.<br>**Optical Metallographic Techniques:** Observation of microstructure; Preparation of samples (polishing, etching etc.)<br>**Mechanical Characterization Processes:** Measurement of hardness; Measurement of fracture toughness through nano-indentation; Adhesion test; Surface profilometry; Tribological studies of materials.<br>**Physical Characterization Processes:** Introduction to different methods and their applications; Diffraction methods for phase; residual stresses; texture analysis etc. Electro-optical and related techniques like SEM, TEM, EDS, WDS/EPMA etc. Surface analysis and related techniques like XPS, AFM etc. Spectroscopic techniques. |
| 8. | Suggested Books | 1. C. R. Brundle, C. A. Evans, S. Wilson, **Encyclopedia of materials characterization: surfaces, interfaces, thin films, Material Characterization Series, Surfaces, Interfaces, Thin Films**, Butterworth-Heinemann, ISBN: 9780750691680.<br>2. B.D. Cullity, **Elements of X-Ray Diffraction** (3rd edition), Prentice Hall, ISBN: 9781178511420.<br>3. S. Jahanmir, **Friction and Wear of Ceramics**, CRC Press, ISBN: 9780824791155.<br>4. P. J. Goodhew, J. Humphreys, R. Beanland, **Electron Microscopy and Analysis** (3rd edition), Taylor and Francis, London, ISBN: 9780748409686. |

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| 1. | Course Code | **ME 651 / IME 451** |
| 2. | Title of the Course | **Mechatronics System Design** |
| 3. | Credit Structure | L-T-P-Credit<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Mechatronics System design:**<br>Introduction to Mechatronics-Integrated design issues- Key elements and design processes- Physical system modelling - Electrical systems- Micro processor based controller and micro electronics- Mechanical translation and rotational systems-Electromechanical coupling-Fluid system<br>**Actuating devices:**<br>Direct current motor, Permanent magnet stepper motor, Mechanical actuation, Hydraulic and pneumatic power actuation devices, Linear and latching linear actuators, Rotatory actuators, Piezo electric actuators, Actuator parameters and characteristics.<br>**Sensors and Transducers:**<br>An introduction to sensors and transducers, sensors for motion and position, Force torque and tactile sensors, Flow sensors, Temperature sensing devices, Ultrasonic sensors, Range sensors, Active vibration control using magnetostructive transducers, Lasers and Opto-mechatronics based devices.<br>**Software and Hardware components in Mechatronics systems:**<br>Signals, system and controls, system representation, Signal conditioning and devices, PLC, system representation, linearization of nonlinear systems, Time delays and measurement of system performance, Elements of Data acquisition and control systems, real time interfacing.<br>**MEM.S. and Microsystems:**<br>Microsystems and miniaturization- lithography technique- Micro actuators- actuation using shape memory alloys, piezo electric crystals and electrostatic forces- micro valves and pumps- micro sensors- Overview on applications of Robotics in automobiles and other industries. |
| 8. | Suggested Books | **Text books:**<br>1. W. Bolton, Mechatronics, Pearson publications (ISBN 978-81-3176253-3)<br>2. Devdas Shett, Richard A. Kolk, Mechatronics System Design, Brooks/Cole, Thomson learning (ISBN 0-534-95285-2).<br><br>**Reference Books:**<br>1. John Watton, Fundamentals of Fluid power and control, Cambridge university press (ISBN 9780521762502)<br>2. Andrejz M. Pawlak, Sensor and Actuators in Mechatronics Design, Taylor and Francis (ISBN-13:978-0-8493-9013-5)<br>3. Tai-Ran Hsu, MEM.S. and Microsystems design and manufacture, Tata McGraw-Hill (ISBN0-07-048709-X) |

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| | | 4. Stephen A. Campbell, The Science and Engineering of microelectronic fabrication, Oxford university press (ISBN 0-19-568144-4) |

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| 1. | Course Code | **ME 653 / ME 453** |
| 2. | Title of the Course | **Computer Aided Manufacturing** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The main objective of the course is to bring the detail application of CAD |
| 7. | Course Syllabus | **Introduction:** Introduction to manufacturing systems and their performance analysis; Introduction to Automation; Introduction to Computer Integrated Manufacturing (CIM).<br>**Numerical Control (NC):** Introduction, Numerical Control – its growth and development, Components of NC system, Input devices, Control systems – point to point, straight cut, and continuous path NC, Open loop and closed loop NC systems, NC interpolations – linear, circular, helical, parabolic and cubic interpolation, Applications of NC systems, Merits and demerits.<br>**Extensions of NC:** Concepts of Computer Numerical Control (CNC), Machining Center, and Direct Numerical Control (DNC), and their advantages.<br>**Robotics:** Robot anatomy and related attributes, Robot control systems – limited sequence, playback with point to point, playback with continuous and intelligent control, End effectors – gripper, tools, Sensors in Robotics – tactile sensors, proximity, optical sensors and machine vision, Applications of industrial robots, Robot programming.<br>**Material Handling and Storage:** Overview of Material Handling Equipments, Automated material handling equipments – AGVs, Conveyor systems, Performance analysis of material handling systems, Automated material storage systems – ASRS and Carousel storage, Analysis of automated storage systems.<br>**Manufacturing Support Functions:** Introduction to Group Technology (GT), Computer Aided Process Planning (CAPP), Material Requirement Planning MRP (MRP), Capacity Planning, Scheduling etc. |
| 8. | Suggested Books | 1. M.P. Groover, **Automation, Production systems and Computer Integrated Manufacturing**, Prentice-Hall Inc. Englewood Cliffs 1987, ISBN: 087692-618-7.<br>2. N. Singh, **Systems Approach to Computer Integrated Design and Manufacturing**, John Wiley & Sons, 1996, ISBN: 0-471-58517-3.<br>3. T.C. Chang, R.A. Wysk, and H.P. Wang, **Computer Aided Manufacturing**, Prentice Hall Inc. New Jersey, 1991, ISBN: 0-13-161571-8.<br>4. Y. Koren, **Computer Control of Manufacturing Systems**, McGraw Hill Inc., 1983, ISBN: 007-035-3417.<br>5. M. Lynch**, Computer Numerical Control for Machining**, McGraw-Hill |

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| | | Inc. 1992, ISBN: 0-07-039223-4.<br>6. M. Sava, and J. Pusztai, **Computer Numerical Control Programming**, Prentice Hall, 1990, ISBN: 0-13-156084-0. |

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| 1. | Course Code | **ME 654/ ME 454** |
| 2. | Title of the Course | **Rapid Product Manufacturing** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To introduce various concepts of involved in rapid product manufacturing starting from product modeling, reverse engineering, product data exchange, concurrent engineering, rapid prototyping, and rapid tooling |
| 6. | Course Syllabus | **Product Modeling and Reverse Engineering:** Wireframe modeling; Surface modeling – Boundary representation; Solid modeling: CSG; Concept of reverse engineering.<br>**Product Data Exchange:** Neutral file formats for product data exchange- DXF, IGES, STEP.<br>**Concurrent Engineering:** Concept of concurrent engineering; Design for X; Design for manufacturability (DFM); design for assemblability (DFA); Design for reliability (DFR); Design for quality (DFQ).<br>**Rapid Prototyping (RP) Methods:** Various RP process such as Liquid based RP methods – Stereolithography apparatus (SLA), Solid Ground Curing (SGC), Solid Creation System (SCS), etc.; Solid based RP methods: Fused Deposition Modeling (FDM), Laminated Object Manufacturing (LOM), etc. Powder based RP methods– Selective Laser Sintering (SLS), 3D printing (3DP), Ballistic Particle Manufacturing (BPM), etc.<br>**Rapid Tooling (RT):** Introduction, various techniques of RT. |
| 7. | Suggested Books | 1. M.M. Anderson, and L. Hein, **Integrated Product Development**, IFS Publication, Springer Verlag, Berlin, 1987, ISBN: 9781852338039.<br>2. I. Zeid, **CAD/CAM: Theory and Practice**, Tata McGraw Hill, New Delhi, 1998, ISBN: 0-07-463126-8.<br>3. M. E. Mortenson, **Geometric Modeling**, John Wiley & Sons, New York, 1985, ISBN: 0-471-88279-8,<br>4. G.Q. Huang, **Design for X: Concurrent Engineering Imperatives**, Chapman and Hall, London, 1996, ISBN: 0-412-78750-4.<br>5. G. Boothroyd, P. Dewhurst, and W. Knight, **Product Design for Manufacture and Assembly** (2nd Edition), Marcel Dekker, New York, 2002, ISBN: 0-08247-0584-7. |

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| | | 6. C.K. Chua, and K.F. Leong, **Rapid Prototyping: Principles and Applications in Manufacturing**, John Wiley & Sons. Inc. Singapore, 1997, ISBN: 9789812381200. |

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| 1. | Course Code | **ME 655** |
| 2. | Title of the Course | **Advanced Manufacturing Processes** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Basic course on manufacturing processes |
| 6. | Scope of the Course | To expose the students to the various advanced manufacturing processes, their need, evolution, capabilities, and applications. |
| 7. | Course Syllabus | **Advanced Casting Processes:** Non-ferrous mould casting, continuous casting, squeeze casting, vacuum mould casting, evaporative pattern casting, ceramic shell casting, etc.<br>**Advanced Joining Processes:** Details of electron beam welding (EBW); laser beam welding (LBW), ultrasonic welding (USW), Explosive welding, Plasma arc welding (PAW), Infrared welding, microwave welding, etc.<br>**Advanced Forming Processes:** Details of high energy rate forming (HERF) processes such electro-magnetic forming, explosive forming, electro-hydraulic forming; Stretch forming; Contour roll forming; Laser bending, etc.<br>**Additive Manufacturing Processes:** Concept of reverse engineering (RE), rapid prototyping (RP), and rapid tooling (RT); Various RP process such as Liquid based RP methods – Stereolithography apparatus (SLA), Solid Ground Curing (SGC), Solid Creation System (SCS), etc. Solid based RP methods: Fused Deposition Modeling (FDM), Laminated Object Manufacturing (LOM), etc. Powder based RP methods– Selective Laser Sintering (SLS), 3D printing (3DP), Ballistic Particle Manufacturing (BPM), etc.<br>**Advanced Machining Processes:** Introduction of non-conventional machining such as AJM, USM, WJM, AWJM, ECM, EDM, EBM, LBM, and Hybrid Machining Processes such as ECDM/ECAM, AEDG/AEDM, AHM/AECG, etc. |
| 8. | Suggested Books | 1. G. F. Benedict, **Nontraditional Manufacturing Processes**, Marcel Dekker, Inc. New York, 1987, ISBN: 9780470924679.<br>2. Heine and Roshenthal, **Principles of Metal casting**, Tata McGraw-Hill Publishing Company Ltd, New Delhi, 1983, ISBN 007-099-3483.<br>3. C. K. Chua, and K. F. Leong, **Rapid Prototyping: Principles and Applications in Manufacturing**", John Wiley & Sons. Inc. Singapore, 1997, ISBN: 9789812381200.<br>4. E. P. DeGarmo, J. T Black, R. A. Kohser, **Materials and Processes in Manufacturing** (8th Edition), Prentice Hall of India, New Delhi, 1997, ISBN: 0-02-978760. |

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| | | 5. P. C. Pandey, and H.S. Shan, **Modern Machining Processes**, Tata McGraw-Hill Publishing Company Ltd, New Delhi, 1980, ISBN: 0-07-096553-6.<br>6. V. K. Jain, **Advanced Machining Processes**, Allied Publishers, New Delhi, 2002, ISBN: 81-7764-294-4. |

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| **Course code** | **ME 656** |
| **Title of the course** | **Vibrations and Noise Control Lab** |
| Credit Structure | L-T-P–Credits<br>0-0-3-1.5 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | To learn noise and vibration measurement and their analysis using most advanced instruments and software on machinery fault simulator and other machines |
| Course Syllabus | 1. Measurement of natural frequency of various systems<br>2. Measurement of Sound pressure level of various machines.<br>3. Noise source identification using sound intensity measurement.<br>4. Measurement of sound transmission loss.<br>5. Measurement of reflection and absorption coefficients<br>6. Fault detection of mechanical systems such as bearings, gears, fans, blowers, pumps etc. using vibration analysis. |
| Suggested Books | 1. Brandt, Anders, **Noise and vibration analysis : signal analysis and experimental procedures**, John Wiley & Sons, West Sussex, 2011, ISBN 978-0-470-74644-8<br>2. Schmitz, Tony L and Smith, K. Scott, **Mechanical vibrations : modeling and measurement**, Springer, New York, 2012, ISBN 978-1-4614-0460-6<br>3. Cheremisinoff, Nicholas, **Noise control in industry : a practical guide**, Noyes Publications, New Jersey, 2003, ISBN 0815513992<br>4. Robert Bond Randall, **Vibration-based Condition Monitoring: Industrial, Aerospace and Automotive Applications,** Wiley, Chichester, 2011, ISBN 978-0-470-74785-8 |

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| 1. | Course Code | **ME 657** |
| 2. | Title of the Course | **Mechatronics and Metrology** |
| 3. | Credit Structure | L-T- P-Credits<br>3-0-2-4 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose the students to the various mechatronics systems and metrological techniques. |
| 7. | Course Syllabus | **Mechatronics and Metrology:** Mechatronics system elements characteristics of a measuring instrument, different errors in the measurement Types of inspection, principles of inspection, different inspection methods.<br>**Limits and Fits:** Limits, fits, dimensional tolerances, various geometrical/form tolerances, computer vision system based measurement, coordinate measuring machines (CMM).<br>**Sensors and Transducers:** Types of sensors, types of transducers and their characteristics. Measurement of displacement and angular velocity. Measurement of pressure: Gravitational, direct acting, elastic and indirect type pressure transducers. Measurement of very low pressures.<br>**Linear and angular measurement:** line and end standards, gauge blocks, comparators, dial gauge, angular measurement: gauge block, clinometer, sine-bar, Measurement of radius and taper.<br>**Opto-Mechatronics:** optical Instruments-scanning optical technique-Triangulation instruments- Confocal instruments Optical projectors, tool maker's microscope, autocollimators. Interferometry: principle and uses of interferometry, optical flat and interferometers, laser interferometers<br>**Metrology of form tolerances, screw threads, gears, and machine tools:** Measurement of various form/geometric tolerances; Different measurement methods for various parameters of screw threads; Measurement of different parameters of various types of gears; Metrology of machine tools and various tests.<br>**Evaluation of surface roughness:** surface roughness terminology, different standards and methods of surface roughness evaluation. |
| 8. | Suggested Books | 1. J. F. W. Gayler, and C.R. Shotbolt, **Metrology for Engineers**, ELBS, 1990, ISBN: 9780304318445.<br>2. R.K. Leach, **Fundamental Principles of Engineering Nanometrology**, Elesevier Publication James, ISBN: 9780080964546<br>3. W. Dally, W.F. Riley, **Instrumentation for Engineering Measurements**, Wiley India edition, ISBN: 978-81-265-2801-1. |

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| | | 4. E.O. Doebelin, D.N. Manik, **Measurement Systems**, Tata McGraw Hill, ISBN: 978-0-07-061672-8.<br>5. A.K. Bewoor, and V.A. Kulkarni, **Metrology and Measurement**, Tata McGraw Hill Education Pvt. Ltd. New Delhi, 2009, ISBN: 978-0-07-014000-4.<br>6. I.C. Gupta, **Text Book of Engineering Metrology,** Dhanpat Rai Publishing Co. New Delhi, 2003. |

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| 1 | Course Code | **ME 658 / ME 458** |
| 2 | Title of the course | **Laser based Measurements and Micro-manufacturing** |
| 3 | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Mechanical Engineering |
| 5 | Pre-Requisite, if any | None |
| 6. | Scope of the Course | Expose students towards various manufacturing applications of lasers. |
| 7 | Course Syllabus | **Thermal Processes in laser-materials interaction:** Introduction to working of Lasers- Absorption of laser radiation-optical properties of materials-Macroscopic transport-conductive heat transfer; Thermal effects of using lasers: Laser heating- melting- vapor expansion and recoil pressure-Plasma formation-Hydrodynamic stability of transient melts-modelling of laser ablation and plume prorogation<br>**Laser based micro-manufacturing:** Laser based micro-manufacturing-casting-forming/shaping-joining-micro-drilling- Laser micromachining mechanism-laser cutting of various materials- -Three dimensional machining- laser micro-machining mechanism-laser ablation-laser assisted chemical etching.<br>**Laser based surface processing:** Laser based hardening, Laser cladding Laser ablation-Laser assisted chemical etching-laser micromachining-direct writing technique-mask projection-laser based interference processing and combined techniques. Laser shock processing, laser dressing of grinding wheels, Laser marking, laser direct writing, Laser micro-stereo lithography, and Laser tissue interaction –(Photochemical- photo disruptive interactions)<br>**Ultra-fast laser interaction and dynamics of laser based micro-fabrication:** Femto-second laser interaction with metals- Femto-second laser interaction with semiconductor materials-Laser induced periodic surface structure formation(LIPSS) formation by Femto second laser-second laser- Laser processing of organic materials, Ultrafast phase explosion-nonlinear absorption and breakdown in dielectric materials-generation of highly energetic particle-vapour kinetics-Pico-second laser plasma’s<br>**Characterization and diagnosis using lasers:** In-situ and ex-situ diagnostics measurements- Surface topographical measurements using-optical Instruments-scanning optical technique-Triangulation instruments-Confocal instruments-Laser’s in AFM. Surface composition and property diagnosis using, in-situ measurement techniques- Laser Induced Break down Spectroscopy (LIBS)- Shadow graphic techniques, ex-situ measurements-Raman Spectroscopy analysis. Surface evaluation using Holographic techniques. |
| 6 | Suggested books | 1) J. C. Ion, **Laser Processing of Engineering Materials-Principal, Procedures and Industrial Applications**, Elsevier Butterworth-Heinemann, ISBN: 0750660791.<br>2) N. B. Dahotre, S. P. Harimkar, **Laser Fabrication and Machining of Materials**, ISBN: 978-0-387-7234-3.<br>3) J. Perriere, E. Million, E. F. Garassy, **Recent advances in Laser processing of materials**, European Material research Society, Elsevier |

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| | | Publictaions, ISBN: 9780080447278<br>4) K. Ding and L. Ye, **Laser Shock Peening Performance and Processes Simulations**, Woodhead publishing in materials, ISBN: 9780849334443.<br>5) R. K. Leach, **Fundamental Principles of Engineering Nanometrology**, Elesevier Publication, ISBN: 9780080964546.<br>6) R. Hull, R.M. Osgood, J. Parisi, H. Warlimont, **The Theory of Laser Material Processing, Heat and Mass Transfer in Modern Technology**, Springer series in material science, ISBN: 9781402093395. |

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| 1. | Course Code | **ME 659 / ME 459** |
| 2. | Title of the Course | **Micro and Precision Manufacturing** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Basic courses related to manufacturing engineering |
| 6. | Scope of the Course | To expose the students about the concepts of micro and precision manufacturing, the various processes involved in it and, the metrology of the micro and precision manufactured components |
| 7. | Course Syllabus | **Micro-manufacturing:** Introduction to micromachining, milling-machining and nanotechnology, different fabrication and other processes involved and related process parameters, application of miniaturized components.<br>**Micro-machines:** Mesoscopic domain of micromachines - introduction, biological systems, cells as machines, role of proteins, physics of micromechanism, future prospects.<br>**Precision manufacturing:** Introduction, concept of accuracy, tolerance and fits, influence of different factors on the maintainability of accuracy of the machine tools and the product, compensation of thermal errors and location errors, effects of vibration and tool wear, dimensioning and dimensional chains, microfinishing processes. Characterization techniques for products manufactured out of micro and precision manufacturing.<br>**Metrology and Characterization Techniques for Micro and Precision Manufactured Products:** – Profilometric, Microscopic and diffractometric techniques.<br>**Scales in Tribology,** micromechanical mechanisms involved, tribochemical reactions, measurement of hardness and wear resistance at micro and nano-scale. |

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| 8. | Suggested Books | 1. I. Fujimasa, **Micromachines: A New Era in Mechanical Engineering**, Oxford Science Publications, ISBN: 9780198565284.<br>2. J. P. Davim, M. J. Jackson, **Nano and Micromachining**, Wiley-ISTE, ISBN: 9781848211032.<br>3. N.P. Mahalik, **Micromanufacturing and Nanotechnology**, Springer, ISBN: 9783540253778.<br>4. P.C. Pandey and H.S. Shan, **Modern Machining Processes**, Tata McGraw Hill Publication, ISBN: 9780070965539.<br>5. V.K. Jain, **Introduction to Micromachining**, Narosa Publishing House, New Delhi, 2010.<br>6. Y. Qin, **Micromanufacturing Engineering and Technology**, Elsevier, 2010, ISBN-13: 978-0-8155-1545-6.<br>7. R. L. Murty, **Precision Engineering in Manufacturing**, New Age International Publishers, ISBN: 9788122407501.<br>8. C. R. Brundle, C. A. Evans, Shaun Wilson, **Encyclopedia of Materials Characterization: Surfaces, Interfaces, Thin Films, Material Characterization Series, Surfaces, Interfaces, Thin Films,** Butterworth-Heinemann, ISBN: 9780750691680. |

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| 1. | Course Code | **ME 660 / ME 460** |
| 2. | Title of the Course | **Technology of Surface coatings** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards different surface coating techniques |
| 7. | Course Syllabus | Significance of surface engineered materials in modern engineering applications. Role of surface coating and surface modification technologies in obtaining required surface characteristics of a product.<br><br>Different surface coating technologies: chemical vapour deposition, physical vapour deposition, electro deposition, electroless deposition, thermal spray processes, coating deposition by wetting. Principle of various coating processes. Various process parameters controlling the yield of coating and various surface properties of the coating.<br><br>Criteria for selection of a surface coating technology. Product oriented surface coating technology. Different coating systems and function of various elements of coating systems. Substrate technology and its significance in obtaining high performance coating. Physical and mechanical characterization of coating. Various methods for evaluating the performance of the coating. |
| 8. | Suggested Books | 1. A. A. Tracton, **Coatings Technology: Fundamentals, Testing, and Processing Techniques**, CRC Press Inc., ISBN-13: 9781420044065.<br>2. A. A. Tracton, **Coatings Materials and Surface Coatings**, CRC Press, ISBN-13: 9781420044041.<br>3. R. F. Bunshah, **Handbook of Hard Coatings: Deposition Technologies, Properties and Applications,** ISBN-13: 9780815514381, ISBN-10: 0815514387.<br>4. M. Cartier, **Handbook of Surface Treatment and Coatings**, ISBN-13: 9781860583759, ISBN-10: 186058375X.<br>5. T. Provder, J. Baghdachi, **Smart Coatings Vol.-2**, ISBN-13: 9780841272187, ISBN 10: 0841272182.<br>6. G. Franz, **Low Pressure Plasmas and Microstructuring Technology**, ISBN-13: 9783540858485 ISBN-10: 3540858482 |

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| 1. | Course Code | **MM 661** (from AY 2016-17 onward as ME 661 till AY 2015-16) |
| 2. | Title of the Course | **Materials Science and Engineering** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science (from AY 2016-17 onward)<br>Mechanical Engineering (till AY 2015-16) |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To develop understanding of behavior of materials for engineering design |
| 7. | Course Syllabus | **Review of basics of materials science:** Types of materials, atomic structure, inter-atomic bonds and their effect on properties; Crystal structure of metal, ceramic and polymers, Lattice, crystal structure determination, Grain structure, Imperfections in solids, Polymorphism and allotropy, Phase rule, Lever rule**,** binary alloys, Microstructure development in some engineering alloys<br>**Strengthening mechanisms:** Grain boundaries and deformation, strengthening from grain boundaries, strain aging, strengthening from fine particles, Fiber strengthening, Strengtheing due to point defects, Martensitic strengthening, cold worked structure, Strain hardening, annealing of cold worked metal, Bauschinger effect, Recrystallization recover and grain growth, Preferred orientation<br>**Alloy design:** Hume-Rothery rules, Equilibrium and non-equilibrium phases in engineering alloys, Role of alloying elements in ferrous and non-ferrous alloys, Isothermal and continuous cooling transformation diagrams, Heat treatment of alloys; annealing, normalising, quenching, austempering, martempering etc.<br>**Mechanical properties of materials**: Elastic and plastic deformation, Hardness, Fundamentals of fracture; ductile and brittle fracture. cohesive strength of metals, Fatigue; cyclic stresses; fatigue life methods, cyclic stress-strain curve, low and high cycle fatigue, fatigue crack propagation, design for fatigue, Creep; Creep curve, structural changes during creep, creep deformation mechanism, high temperature alloys<br>**Degradation of materials**: Corrosion; electrochemical consideratons, forms of corrosion, types of corrosion, corrosion prevention, Wear; abrasive, adhesive, sliding, etc., design of wear and corrosion resistant alloys<br>**Specific engineering materials**: Ferrous and non-ferrous alloys, Polymers, ceramics, composites<br>**Materials selection and design:** Some case studies<br>**Economic, Environmental and societal issues in materials engineering;** Materials and manufacturing techniques, recycling issues in materials, Life cycle analysis |
| 8. | Suggested Books | 1. G. E. Dieter, **Mechanical Metallurgy**, McGraw-Hill Book company, ISBN: 9780070168930.<br>2. V. Raghavan, **Materials Science and Engineering**, PHI Learning Private Limited, New Delhi, 2009, ISBN: 9788120330122.<br>*3.* W. D. Callister, **Materials Science and Engineering**, Wiley India (P) Ltd, ISBN: 9788126510764. |

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| | | 4. 4) W. F. Smith, **Principles of Materials Science and Engineering**, McGraw Hill International editions, ISBN: 9780072921946. |

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| 1. | Course Code | **ME 663** |
| 2. | Title of the Course | **Theory of Conventional Machining** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | UG level course on machining science. |
| 6. | Scope of the Course | To make the students understand the various aspects of practical machining operations with the help of theory of oblique machining, tool wear, heat generations, cutting force measurement, etc. |
| 7. | Course Syllabus | **Review of Orthogonal Machining:** Concept of orthogonal and oblique machining, single point cutting tool geometry and its specification in different standards, selection of cutting tool angles; Chip formation mechanism, chip types, chip control; Mechanics of single point orthogonal machining; Merchant's force circle, cutting forces, velocity, shear angle, and power consumption relations.<br>**Theory of Oblique Machining:** Cutting geometry with a single edge; Shear angle and chip flow directions; Relations for coefficient of friction, stress, strain, and strain rate; Forces, chip flow and shear angle; Machining with two cutting edges; Analysis of practical machining operations such as turning, drilling, milling, and grinding operations.<br>**Tool Wear and Tool life:** Types and mechanisms of cutting tool wear, tool wear criterion, extended tool life equation, determination of constants of tool life equation, variables affecting the tool life; Machinability and its measures; Cutting tool materials.<br>**Thermal aspects and Cutting Fluids:** Heat generated during machining; Cutting fluids: cooling effect, reduction of friction and shear strength of materials, their relative significance, Selection of cutting fluids.<br>**Dynamometry:** Measurement of various cutting forces in different machining operations.<br>**Advanced Topics:** Machining of advanced materials such as various types of composites polymers, ceramics, and non-ferrous materials and alloys. |
| 8. | Suggested Books | 1. M. C. Shaw, **Metal Cutting Principles**, Oxford University Press, USA, 2004, ISBN: 0195142063, 9780195142068.<br>2. E. J. A. Armarego and R. H. Brown, **Machining of Metals**, Prentice Hall Inc. Englewood Cliffs, New Jersey, 1969, ISBN: 421571501.<br>3. E. P. DeGarmo, J. T Black, R. A. Kohser, **Materials and Processes in Manufacturing** (8$^{th}$ Edition), Prentice Hall of India, 1997, New Delhi, ISBN: 0-02-978760.<br>4. G. Boothroyd, and W.A. Knight**, Fundamentals of Machining and Machine Tools**, Marcel Dekker, 1989, ISBN: 9780824778521. |

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| | | 5. A. Bhattacharya, **Metal Cutting: Theory and Practices** (2nd Edition), New Central Book Agency, 1984, ISBN 0-85312-432-6. |

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| 1. | Course Code | **ME 671 / ME 471/ MA 671** |
| 2. | Title of the Course | **Operations Research** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Disciplines | Mechanical Engineering and Mathematics |
| 5. | Pre–requisite, if any | Basic course in probability and statistics |
| 6. | Scope of the Course | To develop analytical problem solving and decision-making capability through methods of Operations Research. Relate the course material to some of the research problems. |
| 7. | Course Syllabus | **Introduction:** Origin and development of operations research, general methodology of OR, applications of OR to industrial problems.<br>**Linear Programming Problems:** Different types of models, formulation of linear programming problems (LPPs), product-mix problems, deterministic models, graphical solution.<br>**Simplex Method:** Simplex algorithm, computational procedure in simplex method, applications of simplex technique to industrial problems.<br>**Duality and Sensitivity:** Duality and its concept, dual linear programming, application of elementary sensitivity analysis.<br>**Linear Optimization Techniques:** Integer programming problems (IPPs), assignment models: mathematical formulation, methods of solutions, transportation problems: methods of obtaining optimal solution degeneracy in transportation problems, transshipment problems.<br>**Game Problems:** Introduction and scope of game problems in business and industry, min-max criterion and optimal strategy, solution of two-person zero-sum game, game problem as a special case of linear programming.<br>**Queuing Problems.:** Queuing systems and concepts, classification of queuing situations; Kendall's notation, solution of queuing problems, single channel, single stage, finite and infinite queues with Poisson arrival and exponential service time, applications to industrial problems. |
| 8. | Suggested Books | 1. H.A. Taha, **An Introduction to Operations Research** (6th edition), Prentice Hall of India, 2001.<br>2. F.J. Hillier, G.J. Lieberman, **Introduction to Operations Research** (7th edition), Holden Day Inc., 2001.<br>3. H.M. Wagner, **Principles of Operations Research**, Prentice Hall of India, 1980, ISBN:9788120301627.<br>4. D. Gross, and C.M. Harris, **Fundamentals of Queuing Theory** (2nd edition), John Wiley & sons, New York, 1985, ISBN: 9780471890676. |
| 9. | Lab | Apply readily available software packages for solution of management |

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| | | problems.<br>Summarize and present analysis of results in a clear and a coherent manner. |

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| 1. | Course Code | **ME 672 / ME 472** |
| 2. | Title of the Course | **Reliability Engineering** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of probability and statistics |
| 6. | Scope of the course | To introduce the various concepts of reliability, and its applicability to different products and processes. Also, to introduce the concepts of availability and maintainability. |
| 6. | Course Syllabus | **Fundamentals of reliability:** Scope of reliability engineering, concept of bath tub curve, types of failure data, reliability estimations, constant failure rate models, time dependent failure rate models, concept of failure on demand.<br>**System reliability assessment:** Reliability estimation of series/parallel/mixed/complex system configurations.<br>**Design for reliability:** Capturing user's reliability requirements, reliability and/or redundancy allocation/optimization, design methods, FMEA/FMECA, reliability testing (burn-in testing, reliability assurance testing, reliability growth testing, accelerated life testing), fault tree analysis.<br>**Availability assessment:** Point, mission and steady state availability, Markov modeling approach for availability estimation.<br>**Maintainability and maintenance:** Maintainability assessment, and design for maintainability, concept of maintenance, types of maintenance, maintenance optimization.<br>**Warranty management:** Types of warranty, reliability and warranty.<br>**Practical applications of reliability engineering to systems, products and processes:** Case studies |
| 7. | Suggested Books | 1. C. Ebeling, **An Introduction To Reliability and Maintainability Engineering,** Waveland Prentice Hall Inc. 2009, ISBN: 0070188521.<br>2. I. Bazovsky, **Reliability Theory and Practice,** Dover Publications, October, 2004, ISBN: 9780486438672.<br>3. P. O'Connor, **Practical Reliability Engineering**, John Wiley & Sons Inc., 2002, ISBN: 9781119964094.<br>4. G. K. Hobbs, **Accelerated Reliability Engineering: HALT and HASS,** Wiley, 2000, ISBN: 9780471979661.<br>Suggested web page: www.weibull.com |
| 8. | Lab | It will mainly involve use of computer software (Weibull++, BlockSim, ALTA, RENO, etc.) to solve complex engineering problems/ case studies as well as manually solving some of the basic tutorials and interpreting the results. |

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| | | Test data, industry data, data available in various standards like Lambda Predict, etc., should be used for this purpose. |

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| 1. | Course Code | **ME 675 / MA 675** |
| 2. | Title of the Course | **Probability and Statistical Methods** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Disciplines | Mechanical Engineering and Mathematics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The primary goal is to develop ability as well as awareness of reasoning and decision-making utilizing statistical data. The quality of decision making is decided by the way data and information is handled/interpreted by a researcher. |
| 7. | Course Syllabus | **Introduction to statistics**: definitions and terminology; data classification; data collection techniques, various scales for measurement and their relevance<br>**Descriptive statistics:** frequency distributions; measures of central tendency, Variation<br>**Probability:** basic concepts; multiplication and addition rules, Bayes rule, Discrete probability distributions: basic concepts; Binomial, Poisson, and other discrete distributions, Continuous probability distributions: Exponential, Normal, Weibull, and other continuous distribution.<br>**Normal probability distributions**: introductory concepts; the standard normal Distribution; central limit theorem, applications of normal distributions, approximations to discrete probability distributions<br>**Correlation and Regression analysis:** overview of correlation; linear regression,<br>**Hypothesis Testing:** Null and Alternative Hypothesis, Type I and Type II errors, Confidence intervals: confidence intervals for the mean (large samples and small samples) and for population proportions, p-value, z-test, t-test, F-test, etc. Analysis of Variance<br>**Taguchi Method and Design of Experiments, Non-parametric tests,**<br>**Case studies and applications to managerial decision making** |
| 8. | Suggested Books | 1. P.L. Meyer, **Introductory Probability and Statistical Applications**, Oxford and IBH Publishers, ISBN: 0-201-04710-1.<br>2. I.R. Miller, J.E. Freund, R. Johnson, **Probability and Statistics for Engineers**, Prentice-Hall (I) Ltd, ISBN: 9788177581843.<br>3. R.E. Walpole and R.H. Myers, **Probability & Statistics for Engineers and Scientists**, Macmillan, ISBN: 9788131715529.<br>4. S.M. Ross, **Introduction to Probability and Statistics for Engineers and Scientists**, Academic Press, ISBN: 9780123704832. |
| 9. | Lab | It will mainly involve use of computer software (Minitb, Statistica, etc.) to solve complex engineering problems/ case studies as well as manually solving some of the basic tutorials and interpreting the results for decision making. Following points will be mainly covered.<br>1 General, data representation, Mean, expectations, pdf, cdf<br>2 Chebyshevs' inequality, probability distributions: Poisson, Binomial, Normal, Weibull, etc.<br>3 MGF, |

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| | | 4 Sampling with and without replacement<br>5 Type I , II and Hypothesis testing, Hypothesis testing<br>6 Chi-square test,<br>7 Regression<br>8 RBD, CRD, Factorial, Taguchi |

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| 1. | Course Code | **ME 730** |
| 2. | Title of the Course | **Theory of Elasticity** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Analysis of stress and strain; Equilibrium, Compatibility and constitutive equations; Plane problems; Stress functions; Applications; Complex potentials in two dimensional and axi-symmetric problems; Variation methods; Anisotropic elasticity; Finite deformation elasticity. |
| 8. | Suggested Books | 1. Timoshenko and Goodier, **Theory of Elasticity** (3rd edition), McGraw-Hill International, 1970, ISBN: 978-0070858053.<br>2. I. S. Sokolnikoff, **Mathematical Theory of Elasticity** (2nd edition), McGraw-Hill International, 1957, ISBN: 9780070596290.<br>3. Y. C. Fung, **Foundation of Solid Mechanics**, Prentice Hall Inc., 1965, ISBN: 9780133299120.<br>4. X. Zhilun, **Applied Elasticity**, Willey Eastern Ltd., 1992, ISBN: 657944122. |

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| 1. | Course Code | **ME 736 / ME 436** |
| 2. | Title of the Course | **Finite Element Methods** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards application of FEM |
| 7. | Course Syllabus | **Introduction:** Historical background, basic concept of the finite element method, comparison with finite difference method.<br>**Variation Methods:** Calculus of variation, Rayleigh-Ritz and Galerkin methods.<br>**Finite Element Analysis of 1-D problems:** Formulation by different approaches (direct, potential energy and Galerkin); Derivation of elemental equations and their assembly, solution and its post processing, Applications in heat transfer, fluid mechanics and solid mechanics: bending of beams analysis of truss and frame.<br>**Finite Element Analysis of 2-D problems:** Finite element modelling of single variable problems, triangular and rectangular elements; Applications in heat transfer, fluid mechanics and solid mechanics.<br>**Numerical Considerations:** Numerical integration, error analysis, meshes refinement. Plane stress and plane strain problems; Bending of plates; Eigen value and time-dependent problems.<br>Discussion about pre-processors, post-processors and finite element packages. |
| 8. | Suggested Books | 1. J. N. Reddy, **An introduction to the Finite Element Method**, McGraw-Hill, New York, 1993, ISBN: 9780072466850.<br>2. R. D. Cook, D. S. Malkus and M. E. Plesha, **Concepts and Applications of Finite Element Analysis** (3rd edition), John Wiley, New York, 1989, ISBN: 9780471030508.<br>3. K. J. Bathe, **Finite Element Procedures in Engineering Analysis**, Prentice-Hall, Englewood Cliffs, NJ, 1982, ISBN: 9780133014587.<br>4. T. J. R. Hughes, **Finite Element Method**s, Prentice-Hall, Englewood Cliffs, NJ, 1986, ISBN: 9780486411811.<br>5. O. C. Zienkiewicz and R. L. Taylor, **Finite Element Methods** (3rd edition), McGraw-Hill, 1989, ISBN: 9780750664318. |

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| 1. | Course Code | **ME 738 / ME 438** |
| 2. | Title of the Course | **Composite Materials** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To expose students towards development and application of composite materials |
| 7. | Course Syllabus | **Introduction:** classifications, terminologies, manufacturing processes.<br>**Macro-mechanical analysis of lamina:** Hooke's law for anisotropic, monoclinic, orthotropic, transversely isotropic and isotropic materials–2D Unidirectional and angle ply lamina – Strength theories of lamina.<br>**Micro-mechanical analysis of lamina:** Volume and mass fraction, density and void content – Evaluation of Elastic module, Ultimate strength of unidirectional lamina.<br>**Macro-mechanical analysis of laminates:** Laminate code, Stress strain relations – In-plane and Flexural modulus, Hydrothermal effects.<br>**Failure Analysis and Design:** Special cases of laminates, symmetric, cross ply, angle ply and antisymmetric laminates, failure criteria and failure modes |
| 8. | Suggested Books | 1. R. M. Jones, **Mechanics of Composite Materials**, Scripta Book Co., ISBN: 9781560327127.<br>2. B. D. Agarwal, and J. D. Broutman, **Analysis and Performance of Fiber Composites**, New York, John Willey and Sons, 1990.<br>3. P. K. Mallick, **Fiber Reinforced Composites: Materials, Manufacturing and Design** (2$^{nd}$edition), New York- Marcel and Dekker, 1993, ISBN: 9780824790318.<br>4. Autar, K. Kaw, **Mechanics of Composite Materials**, CRC Press, 1997, ISBN: 9780849313431.<br>5. J. N. Reddy, **Mechanics of Laminated Composite Plates**, CRC Press, ISBN: 9780849315923.<br>6. P. K. Mallick, **Composite Engineering Hand Book** (2$^{nd}$ edition), Marcel and Dekker, New York, 1997, ISBN: 9780824793043. |

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| 1. | Course Code | **ME 751 / ME 451** |
| 2. | Title of the Course | **Theory of Advanced Machining Processes** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | A Basic course on machining processes |
| 6. | Scope of the Course | To expose the students to the various types of advanced or non-traditional machining processes, their capabilities, applications, parametric analysis, modeling, and recent research and development trends. |
| 7. | Course Syllabus | **Introduction:** Types, evolution, and need of advanced machining processes (AMPs).<br>**Theory of Advanced Machining Processes (AMPs):** Process principle, machine details, mechanism and modeling of material removal, parametric analysis, shape and material applications, process capabilities and limitations of (i) **mechanical type AMPs** such as abrasive jet machining (AJM), water jet machining (WJM), abrasive water jet machining (AWJM), ultrasonic machining (USM), abrasive flow machining (AFM), magnetic abrasive finishing (MAF), Magneto Rheological Finishing (MRF), etc. (ii) **chemical type AMPs** such as processes chemical machining (CHM), photo-chemical machining (PCM), and bio-chemical machining (BCM), etc. (iii) **thermal type AMPs** such as electro-discharge machining (EDM), electron beam machining (EBM), laser beam machining (LBM), ion beam machining (IBM), plasma arc machining (PAM), etc.<br>**Theory of Electro Chemical Machining (ECM):** Process principle, mechanism and modeling of material removal; Kinematics and dynamics and dynamics of ECM; Design of Tool for ECM applications; Analysis of process parameters; Surface finish and accuracy.<br>**Advanced Topics in AMPs:** Introduction of hybrid and/or derived AMPs such as rotary ultra sonic machining (RUM), electro stream drilling (ESD), shaped tube electro machining (STEM), wire electro discharge machining (WEDM), electro chemical grinding (ECG), electro chemical honing (ECH), electro chemical deburring (ECD), and electro-chemical spark machining (ECSM), etc. Process selection and parametric optimization of AMPs. |
| 8. | Suggested Books | 1. G. F. Benedict, **Nontraditional Manufacturing Processes**, Marcel Dekker, Inc., 1987, ISBN 0-8247-7352-7.<br>2. A. Ghosh, and A.K. Mallik, **Manufacturing Science**, Affiliated East-West Press Ltd, 1985, ISBN: 9780470203125.<br>3. P.C. Pandey, and H.S. Shan, **Modern Machining Processes**, Tata McGraw-Hill Publishing Co. Ltd, 1977, ISBN: 9780070965539. |

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| | | 4. J. A. McGeough, **Advance Methods of Machining**, Chapman and Hall, 1988, ISBN: 9780412319709.<br>5. V. K. Jain, **Advanced Machining Processes**, Allied Publishers, 2002, ISBN: 9781439852903.<br>6. P. K. Misra, **Nonconventional Machining**, Narosa Publishing House, New Delhi, 1997, ISBN 81-7319-138-7. |

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| 1. | Course Code | **ME 756 / ME 456** |
| 2. | Title of the Course | **Industrial Automation** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards design and development of industrial automations system |
| 7. | Course Syllabus | **Basic Concepts:** Introduction of Mechanization and Automation, Classification and Strategies of Automation, Reasons for and Arguments against Automation. Mechanical, Electrical, Hydraulic, and Pneumatic Devices and Controls<br>**High Volume Manufacturing or Hard Automation:** Automated Flow Lines, Types of Automatic Transfer Mechanisms, Design and Fabrication Considerations, Analysis of Automated Flow Lines.<br>**Assembly Automation:** Assembly Systems and their Types, Manual Assembly Lines and Line Balancing, Automated Assembly Lines and their Types, Automatic Assembly Transfer Systems, Automatic Feeding and Orienting Devices:- Vibratory and Mechanical Feeders and their types, Orientation of Parts, Performance and Economics of Assembly Systems, Feasibility Study for Assembly Automation.<br>**Design for Assembly:** Design for Manual Assembly, Design for High-Speed Automatic Assembly, Design for Robotic Assembly<br>**Programmable Automation:** Brief Introduction of Numerical Control (NC), Computer Numerical Control (CNC), Machining Centers, Programmable Robots, Direct Numerical Control (DNC), and Adaptive Control.<br>**Flexible Automation:** Introduction of Group Technology (GT), Steps in Implementing GT, Part Families and Machine Cell Formation, Introduction of Flexible Manufacturing Systems (FMS). |
| 8. | Suggested Books | 1. M. P. Groover, **Automation, Production systems and Computer Integrated Manufacturing**, Prentice-Hall Inc. Englewood Cliffs, 1987 [Indian Edition from Prentice Hall of India, New Delhi], ISBN: 8178085119<br>2. G. Boothroyd, **Assembly Automation and Product Design**, Marcel Dekker, New York, 1992, ISBN: 9781574446432.<br>3. G. Boothroyd, P. Dewhurst, and W. Knight, **Product Design for Manufacture and Assembly** (2nd Edition), Marcel Dekker, New York, 2002, ISBN: 978-0824791766.<br>4. G. Boothroyd, C. Poli, and L. E. Murch, **Automatic Assembly**, Marcel Dekker Inc. New York, 1982, ISBN: 9780824715311.<br>5. G. Boothroyd, and A. H. Redford, **Mechanized Assembly:** |

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| | | **Fundamentals of Parts Feeding, Orientation and Mechanized Assembly**, McGraw Hill Publishing Co. Ltd., London, 1968, ISBN: 1081471. |

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| **Course code** | **ME 764/ ME 464** |
| **Title of the course** | **Microrobotics** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mechanical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | The main objective of the course is to focus on the fundamentals of the physical laws that predominate at the micro scale for fabricating small device and bio-inspired microrobots |
| Course Syllabus | Scaling laws for designing macro, micro and nano systems: scaling laws in fluids, electo-magnetism, thermodynamics, optics and quantum effect. Micro-mechanics, design and selection of materials for micro- robotics systems, control for surface walkers. Introduction to different micro-fabrication techniques. Micro actuators and micro sensors: micro force sensors and tactile sensors, Magnetic actuation, electrostatic actuation, piezo electric actuation, shape memory alloy and conducting polymer based actuation, stick slip, comb drive actuator, micro-pumps, micro engines, magnetic helical micro machines, haptic interface and sensory skin for robotic systems Micro-manipulation: Mechanics of micro-manipulation, Atomic force microscope as micro/Nano robot, micro manipulation in particle assembly, 3D micro/Nano fiber pulling, integrated nano tool carrier, micro-assembly, micro air vehicles (MAVS) and multi robot systems. Bio- inspired micro-mechanics: Microscale propulsion, locomotion in liquids, modeling of propulsion systems, micro mechanical flying insect, Gecko inspired climbing robots, bio-inspired fibrillar adhesive, lizard inspired water runner robot, water strider inspired water walker robot, Magnetic swimming micro-robot for bio-medical application, medical micro-robots for endoscopy and other applications. |
| Suggested Books | 1. N. Chaillet, S. Regnier, **Microrobotics for Micromanipulation**, Wiley, IST, 2010, ISBN 978-1-84821-186-5<br>2. Y. Bellouard, **Microrobotics, methods and applications**, CRC Press, 2009, ISBN 9781420061956<br>3. Fatikow, Sergej, Rembold, Ulrich, **Microsystem technology and microrobotics,** Spirnger publication, 2000, ISBN 978-3-662-03450-7<br>4. Ananthasuresh, **Micro and Smart Systems: Technology and Modelling**, Wiley, 2012, India, ISBN:9780470919392 |

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| 1. | Course Code | **ME 698** |
| 2. | Title of the Course | **PG Seminar Course** |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Course Syllabus | In this course a PG student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her PG Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 7. | Other references | Books and research publications in various relevant journals/conference proceeding, etc. |

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| 1. | Course Code | **ME 797 (Autumn Semester)**<br>**ME 798 (Spring Semester)** |
| 2. | Title of the Course | Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various relevant journals. |

# Course Structure of Ph.D. Program

# in

# Civil Engineering

# and

# Syllabi of Courses

## Course Structure for Ph.D. Program in Civil Engineering

### (A) Semester-I (autumn / spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III + | x-x-x-3 |
| 4 | CE 797* / CE 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (spring / autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective- IV + | x-x-x-3 |
| 2 | ZZ xxx | Elective-V + | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI + | x-x-x-3 |
| 4 | CE 798* / CE 797* | Ph.D. Seminar Course | 0-2-0-2 |

Note

1. A Ph.D. student having **M.Tech./M.E./M.Phil.** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.

2. A Ph.D. student having **B.Tech./ B.E. / M.Sc. or equivalent qualification** admitted to Ph.D. Program in an **Engineering discipline** shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 20 credits).*

   * Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

**Electrical Engineering courses for Electives-I to VI**

*(in addition to these courses, students can also take courses from other disciplines)*

| S. No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1. | CE 612/ CE 412 | Sustainable Construction | 2-1-0-3 |
| 2. | CE 634/ CE 434 | Numerical Methods in Civil Engineering | 2-1-0-3 |
| 3. | CE 635 | Water and climate, sustainability and policies | 2-1-0-3 |
| 4. | CE 684/ CE 484 | Advanced Concrete Technology | 2-1-0-3 |
| 5. | CE 694/ CE 494 | Earthquake Engineering | 2-1-0-3 |
| 6. | CE 696/ CE 496 | Safety of Dams and Reservoirs | 2-1-0-3 |

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|---|---|
| **Course code** | **CE 612/ CE 412** |
| **Title of the course** | **Sustainable Construction** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Civil Engineering |
| Pre-requisite, if any | Basic understanding of Building Materials and Building Construction |
| Scope of the course | This course aims to expose the students to the environmental challenges associated with the construction industry, and their management through the use of sustainable construction practices. This course will cover the use of alternate/green materials and the benefits associated with it. Students will also be exposed to emerging concepts like Life Cycle Assessment, Circular Economy, and Building Information Modelling. It is expected by the end of this course students will be able to understand and appreciate the concept of Sustainability in Construction Practices. |
| Course Syllabus | Sustainability in Construction: Concept of sustainability in construction, Carbon footprint, Embodied energy, Resource Management, Zero waste, 3R concept in construction<br><br>Waste Utilization in Construction: Circular Economy, Value addition, local materials, Supplementary Cementitious Materials, Blended Cements, Recycled Aggregates, Refuse Derived Fuel<br><br>Building Products: Fly Ash Bricks, Hollow Blocks, Precast Walls, Products for modular construction<br><br>Biomaterials: Bamboo, Straw Bale, Bio Cementing, Plant-based Natural Fibers, Durability of Bio-Based Building Materials<br><br>Green Building Design: Introduction to Green Building, Low Energy/ Energy Efficient Building Units, Landscape Management, Building Information Modelling (BIM)<br><br>Assessment Methods: Life Cycle Assessment (LCA), Leadership in Energy & Environmental Design (LEED), Green Rating for Integrated Habitat Assessment (GRIHA). |
| Suggested Books | 1. C. J. Kibert, ***Sustainable Construction, Green Building Design and Delivery****,* John Wiley & Sons, Inc, New Jersey, 2016, 9781119055174.<br>2. F. Dodds, L. Beg, K. Hardcastle, M. Campbell, R. Fairclough and T. Callanan, ***Eco-efficient construction and building materials,*** Woodhead Publishing India Private Limited, New Delhi, 2014,9780857097675<br>3. G. M. Sabnis, ***Green Building with Concrete, Sustainable Design and Construction,*** CRC Press, Florida, 2015, 9781498704113<br>4. BIS, ***Coarse and Fine Aggregate for Concrete,*** *Specification,* Bureau of Indian Standards, New Delhi, 2016 |

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| **Course code** | **CE 634/ CE 434** |
| **Title of the course** | **Numerical Methods in Civil Engineering** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Civil Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course is designed for mainly engineering students to enhance their numerical techniques. In engineering, many complex problems do not have explicit analytical solutions, and in these cases, numerical techniques are extremely beneficial. In addition to providing basic numerical strategies, this course introduces some advanced concepts for solving non-linear differential and integral equations, which are expected to be helpful in B.Tech., M.Tech., and Ph.D. thesis works. |
| Course Syllabus | Computer applications in Civil Engineering, typical problem categories, techniques for linear problems, techniques for nonlinear problems. Iterative solutions for linear and non-linear systems. Algorithms in time domain using Runge - Kutta methods. Newmark B-method and finite-difference approaches, concept of stability of algorithm, propagation of errors in different algorithms. Numerical Differentiation, Difference operators (forward, backward and central difference). Stability and accuracy of solutions. Application of finite difference operators to solve initial and boundary value problems. Numerical solutions of integral equations, Types of integral equations. Fredholm integral equations of the first and second kind. Fredholm_s Alternative theorem. Collocation and Galerkin methods for solving integral equations. Use of commercial software for Civil Engineering Problems. |
| Suggested Books | 1. A. Jennujs, ***Matrix computations for Engineers and Scientists***, John Wiley & Sons, Rumford, ME, USA, 1977, 978-0471994213<br>2. S.D. Conte and C-de Boor, ***Elementary Numerical Analysis***, **An algorithmic approach**, McGraw Hill, New York, USA , 1980 , 978-0070662285<br>3. G. Dahlquist and Å. Bjorck, ***Numerical Methods***, Dover Books, NY, USA , 2003 , 978-0486428079<br>4. S.Guha and R. Srivastava, ***Numerical Methods,*** *O*xford University Press, 2010, 019-569348-5 |

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|---|---|
| **Course code** | **CE 635** |
| **Title of the course** | **Water and climate, sustainability and policies** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Civil Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | The course aims to provide an overview of global water and climate change including socioeconomic issues. The course will provide an introduction to the global challenges of achieving water security in the context of sustainable development and policies, illustrated through case studies. The course is designed for undergraduate and graduate students interested in water management and climate changes issues. |
| Course Syllabus | Review of climate change aspects, Introduction to ecosystem services, importance of water availability for crop water production, basic principles of irrigation under climate change, water- climate-energy nexus, importance of groundwater management, Drought-types and index used, significance and roles of sustainability, Sustainability of river and ground water resources, resilience of hydrologic systems, simulation and modeling through case studies, socio- economic consideration, adaptation, Review of water policies, Framework of water policies in consideration of supply and demand. |
| Suggested Books | 1. E. Kolokytha, Soishi and R. S.V. Teegavarapu, ***Sustainable Water Resources Planning and Management Under Climate Change***, Springer, Heidelberg, 2016, 978-9811020513<br>2. S. Shrestha, M. S. Babel and V. P. Pandey, ***Climate Change and Water Resources***, CRC Press,Taylor and Francis Group, Boca Raton, 2014, 978-1466594661<br>3. C. F. Fung, A. Lopez and M. New, ***Modelling the Impact of Climate Change on Water Resources***, Wiley-Blackwell, West Sussex, 2010, 978-1405196710 |

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|---|---|
| Course Code | **CE 684/ CE 484** |
| Title of the Course | **Advanced Concrete Technology** |
| Credit Structure | L-T- P-Credits<br>2-0-1-3 |
| Name of the Concerned Discipline | Civil Engineering |
| Pre–requisite, if any | Basic knowledge of Building Materials and Concrete |
| Scope of the course | This course aims to develop the understanding of properties, advances and findings in the field of multifunctional concretes, focusing on the principles, design and fabrication, test and characterization, performance and mechanism, and their applications in infrastructures. It's designed to discuss the challenges in the development and application of multifunctional concretes, providing useful theory, ideas and principles. |
| Course Syllabus | <u>**Durability of Concrete**</u>**:** Early-age and the long-term performance of concrete, including issues such as its ability to be placed and compacted, properties and performance characteristics, structural movements, strength development, fire resistance and durability performance.<br><u>**Testing, Quality Assurance, Repair and Maintenance of Concrete**</u>**:** Quality concepts and quality control of concretes, and test methods used both in laboratories and on site for measuring physical and chemical properties of concrete in fresh and hardened states.<br>**Multifunctional** <u>**Concrete Production**</u>**:** Types of concretes that can be used for different applications. Concepts for self-compacting concrete, functionally graded concrete, self-healing concrete, 3-D printed concrete, high performance concrete, fibre reinforced concrete, geopolymer concrete. |
| Suggested Books | 1. Zongjin Li, ***Advanced Concrete Technology*****,** John Wiley and Sons, 2011, 9780470437438<br>2. Mark Alexander, Arnon Bentur and Sidney Mindess, ***Durability of Concrete: Design and Construction***, CRC Press, 2011, 9781138746749<br>3. John Newman and B S Choo ***Advanced Concrete Technology 4*****,** Butterworth-Heinemann, 2003, 9780080489995 |

| Course code | CE 694/ CE 494 |
|---|---|
| **Title of the course** | **Earthquake Engineering** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Civil Engineering |
| Pre-requisite, if any | Basic Knowledge of Structural Dynamics and Soil Mechanics |
| Scope of the course | This course introduces the fundamental concepts of earthquake engineering. |
| Course Syllabus | Importance of Earthquake Engineering, Fundamentals of Earthquake Engineering, Introduction to geotechnical earthquake engineering, Damaging Effects of Earthquakes, Earthquake Ground Motions, Seismic hazard analysis: probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA), Seismic Regions of the World, Earthquake Genesis, Characterization of Strong Ground Motions, Seismic Vulnerability Assessment of Building, Geotechnical Earthquake Engineering. |
| Suggested Books | 1. R. Villaverde, ***Fundamental Concepts of Earthquake Engineering,*** Taylor & Francis, New York, 2009, 978-1-4200-6495-7<br>2. S. L. Kramer, ***Geotechnical Earthquake Engineering,*** Prentice Hall, United States of America, 1996, 978-0133749434<br>3. Sucuoğlu, Halûk, Akkar, Sinan, ***Basic Earthquake Engineering,*** Springer, Switzerland, 2014, 978-3-319-01026-7<br>4. M. Beer, I. A. Kougioumtzoglou, E. Patelli, I. Siu-Kui Au, ***Encyclopedia of Earthquake Engineering,*** Springer, Brazil, 2015 : 978-3-642-35345-1 |

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| **Course code** | **CE 496/ CE 696** |
| **Title of the course** | **Safety of Dams and Reservoirs** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Civil Engineering |
| Pre-requisite, if any | Basic knowledge of water resources engineering |
| Scope of the course | The non-availability of water in the right place at the right time has lead the civilization to store surplus water in man-made reservoirs by constructing dams-large barriers in the flow path of rivers. Historically, these reservoirs have been used to supply water for drinking purposes, agriculture, and to generate hydroelectricity. Although vital assets, the management of such large water resources systems remains challenging.<br><br>Dam failures pose significant threats to life, environment, and the local economy. Such failures may result from multiple reasons, large-magnitude floods being the most common and perhaps the least predictable. Over the last few decades, studies have found increasing trends in the frequency and magnitude of floods over the globe. The situation is expected to exacerbate with the changing climate over the next few decades.<br><br>The aim of the course is to provide basic knowledge to manage and safeguard dams and reservoirs. This course provides introductory technical aspects of planning, design, operation, and maintenance of dams and reservoirs. In addition, topics covering risk management under a changing climate are introduced. |
| Course Syllabus | Introduction to planning, design, operation and maintenance of dams and reservoirs.<br><br>Types of dams; causes of dam failures, flood failures and overtopping, backwater flooding, breaching, slope failure, internal erosion and shear stress in foundations.<br><br>Principles of design of dams: Design flood, probable maximum floods, geologic and seismological considerations, stability analyses, environmental considerations.<br><br>Uncertainty, risk, reliability, and resilience analyses of dams and reservoirs.<br><br>Operation of dams: Modelling dam and reservoir systems. Rule curves and forecast-based policies, a brief introduction to optimization models. Design and operational challenges under a non-stationarity climate.<br><br>Maintenance of dams: Silt and scouring, monitoring and instrumentation; Repair, rehabilitation, and removal of dams. |

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|---|---|
| Suggested Books | • D. P. Loucks, E. V. Beek, ***Water Resources Systems Planning and Management: An introduction to methods, models, and applications***, Springer International Publishing, Gewerbestrasse, Switzerland, 2017, 978-3-319-44232-7<br><br>• A. Pepper, ***Maintaining the Safety of our Dams and Reservoirs***, ICE Publishing, London, United Kingdom, 2014, 9780727760340.<br><br>• Committee on the Safety of Existing Dams Water Science and Technology Board Commission on Engineering and Technical Systems National Research Council, ***Safety of Existing Dams: Evaluation and Improvement***, Washington, D.C., USA, 1983, 978-0-309-03387-9 |

# Course Structure of
# PG and Ph.D. Program in
# Metallurgy Engineering and Material Science
**(Earlier referred as *Surface Engineering*)**
# and Syllabi of Courses

# Course Structure for M.Tech. / M.Tech. + Ph.D. Dual Degree Program in Materials Science and Engineering (from AY 2015-16 to AY 2018-19)

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) either in Mechanical/ Electrical/ Electronics/ Chemical/ Metallurgy/ Materials Science/ Automobile Engineering or M.Sc. in Chemistry/ Physics/ Material Science or Applied Electronics/ equivalent. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE
**(b) Indian Students:** Valid GATE/ CSIR-JRF qualification in relevant areas.

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regula institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***
**Duration of Program:** 2 years on full-time basis.

**Course Structure of M. Tech. Program**

**1st Year: Semester-I**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MSE 601 | Surface Science and Engineering | 2-1-0 | 3 |
| MSE 605 | Computational Techniques in Materials Engineering | 3-1-0 | 4 |
| MSE 607 | Materials for Devices | 2-1-2 | 4 |
| MM 661 | Material Science and Engineering | 2-1-0 | 3 |
| ZZ XXX | Elective –I | x-x-x | 3 |
| | | **Total minimum credits during the semester** | **17** |
| **Additional course (as per requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| ME 650 | Materials Characterization Techniques | 2-0-2 | 3 |
| ME 660/ ME 460 | Technology of Surface Coatings | 2-1-0 | 3 |
| MSE 698 | PG Seminar Course | 0-2-0 | 2 |
| ZZ XXX | Elective-II | x-x-x | 3 |
| ZZ XXX | Elective-III | x-x-x | 3 |
| ZZ XXX | Elective-IV | x-x-x | 3 |
| | | **Total minimum credits during the semester** | **17** |

2nd Year: Semester- III

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MSE 799 | M.Tech. Research Project (Stage-I) | 0-0-36 | **18** |

2nd Year: Semester-IV

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MSE 800 | M.Tech. Research Project (Stage-II) | 0-0-36 | **18** |
| **Total minimum credits during the program** | | | **70** |

| **Courses for Elective-I @** | | | |
|---|---|---|---|
| EE 605 | Nanotechnology | 3-0-0 | 3 |
| MSE 641 | High Temperature Oxidation & Corrosion | 2-1-0 | 3 |
| EE631 | Organic Electronics | 3-0-0 | 3 |
| EE 629 | Nanotechnology and Nanoelectronics | 3-0-0 | 3 |
| PH 725 | Characterization of surfaces and interfaces of materials | 2-0-2 | 3 |
| PH613 | Developments in early 20th century in Physics | 2-1-0 | 3 |
| PH721 | Advance Materials | 2-1-0 | 3 |
| **Courses for Elective II-IV@** | | | |
| MSE 610 | Design of Materials for Surface Protection and Corrosion Control | 2-1-0 | 3 |
| MSE 612 | Laser Based Surface Processing and Characterization | 2-1-0 | 3 |
| MSE 614 | Micro/Nano Fabrication of Nanostructures | 2-1-0 | 3 |
| MSE 616 | High Temperature Materials and Coatings | 2-1-0 | 3 |
| MSE 618 | Organic Paint Coatings | 2-1-0 | 3 |
| MSE 620 | Modeling and Management of Corrosion | 2-1-0 | 3 |
| MSE 622 | Tribology and Wear | 2-1-0 | 3 |
| MSE 624 | Interface Effect in Electronic Devices | 2-1-0 | 3 |
| MSE 626 | Surface Metrology | 2-1-0 | 3 |
| MSE 628 | Wear friction and abrasion of surface | 2-1-0 | 3 |
| ME 738 | Composite Materials | 2-1-0 | 3 |
| ME 640/ ME 440 | Smart Materials and Structures | 2-1-0 | 3 |
| ME 648/ ME 448 | MEM.S. and micro-systems | 2-1-0 | 3 |
| ME 658 | Laser based Measurements and micro-manufacturing | 2-1-0 | 3 |
| ME 738 | Composite Material | 2-1-0 | 3 |
| EE 634 | Semiconductor based sensors | 2-1-0 | 3 |
| EE 628 | Advance Memory Technologies | 3-0-0 | 3 |
| PH 722 | X-Ray Spectroscopy | 1-2-0 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by other disciplines.
**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivating PG students at the end of the **third semester of their program.**
2. If the student moves to the Dual Degree Program, but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.
3.The enhancement in the scholarship from M.Tech. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled, whichever is later.

## Course Structure of M.Tech. / M.Tech. + Ph.D. Dual Degree Program in Materials Science and Engineering (from AY 2019-20 onwards)

**Minimum Educational Qualification:** *"Four-year bachelor's degree or five-years integrated degree (with the first division as defined by the awarding Institute/University for Indian applicants and equivalent to International applicants, as assessed by the institute) in Materials Science/ Physics/ Chemistry/ Nanoscience/ Nanotechnology/ Engineering Science/ Engineering Physics/ Metallurgy Engineering or two years master's degree in Chemistry/ Physics/ Material Science/ Nanoscience/ Nanotechnology."*

Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE
**(b) Indian Students:** Valid GATE/ CSIR-JRF qualification in relevant areas.

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regula institute staff **(IS)** of IIT Indore on part-time basis only.
**Candidates of SW, DF and IS categories will not be provided any scholarship.**

**Duration of Program:** 2 years on full-time basis.

### Course Structure of M. Tech. Program

### 1st Year: Semester-I

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MSE 603 | Applied Surface Science | 2-1-0 | 3 |
| MSE 605* | Computational Techniques in Materials Engineering | 3-1-0 | 4 |
| MSE 607* | Materials for Devices | 2-1-2 | 4 |
| MM 661* | Material Science and Engineering | 2-1-0 | 3 |
| ZZ XXX | Elective –I | x-x-x | 3 |
| | | **Total minimum credits during the semester** | **17** |
| **Additional course (as per requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MM 604 | Transport Phenomena | 2-1-0 | 3 |
| MM 606 | Energy Materials | 2-1-0 | 3 |
| MM 656 * | Experimental Techniques in Materials | 2-0-2 | 3 |
| MSE 724* | Thin film and devices | 2-1-2 | 4 |
| MSE 698 | PG Seminar Course | 0-2-0 | 2 |
| ZZ XXX | Elective-II | x-x-x | 3 |
| **Total minimum credits during the semester** | | | **18** |

**2nd Year: Semester- III**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MSE 799 | M.Tech. Research Project (Stage-I) | 0-0-36 | **18** |

**2nd Year: Semester-IV**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MSE 800 | M.Tech. Research Project (Stage-II) | 0-0-36 | **18** |
| **Total minimum credits during the program** | | | **71** |

**Courses for Elective-I@ and Elective-II @**

| Course Code | Course Name | Credit hours (L-T-P) | Credits |
|---|---|---|---|
| MM 657/MM 457* | Advances in Energy Storage Materials | 2-1-0 | 3 |
| MM 659* | Introduction to Soft Materials | 2-1-0 | 3 |
| MM 669* | Crystallographic Texture of Materials | 2-1-0 | 3 |
| MM 673* | Science of Ceramics | 2-1-0 | 3 |
| MM 674/MM 474* | Fluorescence Phenomenon | 2-0-2 | 3 |
| MM 676 * | Advance Computational Methods for Materials | 2-1-2 | 4 |
| MM 679/MM 479* | Fundamentals and Engineering of solar energy devices | 2-1-0 | 3 |
| MM 686/MM 486* | Applied Photoelectrochemistry | 2-1-0 | 3 |
| MM 688/MM 488* | Electroceramics | 2-1-0 | 3 |
| MM 730* | Two Dimensional Materials and Electronic Devices | 2-1-0 | 3 |

*** Existing course;**

@In addition to this course list, a student can also opt from the PG courses being offered by other disciplines.

***NOTE:***

1. Request for conversion from MTech to MTech + PhD dual degree will be considered after evaluating the research potential of the promising and motivating PG students at the end of the **third semester of their program**

2. If the student moves to the Dual Degree Programme, but cannot complete the requirements of a PhD, an **exit option** with the MTech degree can be earned at the end of the final semester of the normal MTech Programme by getting the MTech Research Project examined in the standard manner as per the requirements for the award of an MTech degree.

3. The enhancement in the scholarship from MTech to PhD will be from the beginning of the fifth semester or from the date on which all requirements for the award of MTech degree are fulfilled, whichever is later.

| | | |
|---|---|---|
| 1. | Course Code | **MM 603** |
| 2. | Title of the Course | **Applied Surface Science** |
| 3. | Credit Structure | L - T - P – Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course intends to provide the students with an overview and theoretical description of concepts related to the surfaces. Recent advances in the interface engineering and surface characterization techniques will also be covered. |
| 7. | Course Syllabus | Basic concepts & definitions; Surface free energy; Surface tension; Wettability, Surface adhesion; Thermodynamics and kinetics of adsorption & desorption; Surface diffusion kinetics; Atomic and electronic structure of surfaces; Non-thermal excitations of surfaces, catalysis and surface reactions; Vibrational and optical properties of surfaces; Liquid interfaces; Growth and Epitaxy; Methods for determining composition and structure of surfaces and near-surface layers of materials |
| 8. | Suggested Books | 1. John B. Hudson, Surface Science: An Introduction, Elsevier Science & Technology, Oxford, United Kingdom, 1992, ISBN: 978-0-471-25239-9<br>2. H. Luth, Surfaces and Interfaces of Solids (2nd Ed.), Springer-Verlag Berlin Heidelberg, New York (USA), 1993, ISBN: 978-3-662-10159-9<br>3. Andrew Zangwill, Physics at Surfaces, Cambridge University Press, Cambridge (UK), 1988, ISBN: 978-0-521-34752-5<br>4. M. Prutton, Introduction to Surface Physics, Clarendon Press, Gloucestershire (UK), 1994, ISBN: 978-0-198-53476-1<br>5. D. P. Woodruff and T. A. Delchar, Modern Techniques of Surface Science, 2nd Edition, Cambridge University Press, Cambridge (UK), 1994, ISBN: 978-0-521-42498-1<br>6. D. Brune, R. Hellborg, H. J. Whitlow, O. Hunderi, Surface Characterization: A User's Sourcebook, Wiley-VCH Verlag GmbH, Germany, 2007, ISBN: 978-3-527-61245-1 |

| | | |
|---|---|---|
| 1. | Course Code | **MM 604** |
| 2. | Title of the Course | **Transport Phenomena** |
| 3. | Credit Structure | L - T - P – Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | |
| 6. | Scope of the Course | The course provides a comprehensive treatment of fundamental aspects of transport phenomena in solids. Emphasis is on understanding the mechanisms behind electrical, thermal, and magnetic transport properties of technologically important materials. |
| 7. | Course Syllabus | **Review of energy dispersion relations & energy bands in solids** and **Effective mass theorem**;<br>**Electrical transport phenomena:** The Boltzmann equation; Electrical conductivity of metals, semiconductors, and insulators; Matthiessen's rule;<br>**Thermal transport**: Thermal conductivity for Metals, Semiconductors, and Insulators, Thermoelectricity, Thermopower, Seebeck, Peltier, and Thomson Effects, Phonon drag effect, Wiedemann–Franz law;<br>**Scattering processes in solids:** Electron-phonon, phonon-phonon, defect-phonon, boundary-phonon, and other scattering mechanisms;<br>**Magneto-transport Phenomena**: Hall effect, Magneto-resistance (including GMR), Two carrier model, Cyclotron effective mass, Effective masses for ellipsoidal Fermi surfaces;<br>**Transport phenomenon in low-dimensional systems**: Quantum Dots, Landauer Formula, One dimensional transport, Ballistic transport in 1D. |
| 8. | Suggested Books | 1. Charles Kittle, Introduction to Solid State Physics, 8th Edition, Wiley, 2012<br>2. Smith, Janak, and Adler, Electron Conduction in Solids, McGraw-Hill, 1967<br>3. Ashcroft and Mermin, Solid State Physics, Brooks/Cole, 1976<br>4. Pippard, Magnetoresistance in Metals, Cambridge University Press, 1989<br>5. Supriyo Datta, Electronic transport in mesoscopic systems, Cambridge University Press, 1995.<br>6. J. M. Ziman, Principles of the Theory of Solids, Cambridge University Press, 1979 |

| | | |
|---|---|---|
| 1. | Course Code | **MM-606** |
| 2. | Title of the Course | **Energy Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Fundamental knowledge of materials science and characterization |
| 6. | Scope of the Course | To present an overview of energy materials for efficient energy harvesting, conversion, storage, and saving. |
| 7. | Course Syllabus | **Energy and environment**: The global energy landscape and energy security<br>**Materials energy fundamentals**: Production, processing, and sustainability. Economics of energy materials.<br>Global materials flow.<br>**Energy Sources**: Non-renewable and renewable energy sources.<br>**Materials for energy harvesting**: Solar cells, nuclear materials, composites for wind energy, thermo-electrics.<br>**Materials for energy conversion & storage**: batteries, supercapacitors, hydrogen storage, photo-conversion,<br>fuel cells, piezoelectrics, phase change materials<br>**Materials for energy saving:** Energy efficient transportation and housing applications (thermal insulation,<br>transformers, actuators, generators, magnetocaloric/electrocaloric materials)<br>Aging, damage, and failure of materials in energy harvesting, conversion, storage, and saving applications. |
| 8. | Suggested Books | 1. D. S. Ginley, D. Cahen, Fundamentals of Materials for Energy and Environmental Sustainability.: Cambridge University Press, Cambridge, 2011, ISBN 9781107000230.<br>2. R.C. Neville, Solar Energy Conversion, Elsevier, 1995, ISBN: 9780444898180<br>3. C C Sorrell, J. Nowotny, S Sugihara, Materials for Energy Conversion Devices, Woodhead Publishing, 2005, ISBN: 9781855739321<br>4. L. M. Fraas, and L.D. Partain, Solar Cells and Their Applications, John Wiley & Sons, 2010, ISBN: 97804704463314 |

**Course Structure of M.Tech. program with specialization in Metallurgy Engineering (with an option to convert M.Tech. + Ph.D. dual degree Program)**

**Minimum Educational Qualification:** Four-year Bachelor's degree or five-year integrated degree (with first division as defined by the awarding Institute/ University for Indian applicants and equivalent to International applicants, as assessed by the Institute) in either in Metallurgy/ Materials Science and Engineering/ Mechanical/ Manufacturing/ Production Engineering. *Relaxation of 5% in qualifying degree is applicable for SC and ST category applicants.*

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE.
**(b) Indian Students:** valid GATE qualification in Metallurgical Engineering/ Mechanical Engineering/ Production and Industrial Engineering.

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Teaching Assistantship **(TA)**; (ii) Highly motivated sponsored candidate **(SW)** on full-time basis from highly reputed R & D organizations such as DRDO, ISRO, BHEL, C-DAC, ADE, ADA, etc. and highly reputed Industries; (iii) Defense Forces **(DF)**: Candidates sponsored by the Defense Forces; (iv) Regular institute staff **(IS)** of IIT Indore on part-time basis only.
***Candidates of SW, DF and IS categories will not be provided any scholarship.***

**Duration of Program:** 2 years on full-time basis.

**1$^{st}$ Year: Semester-I**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MM 641 | Advanced Physical Metallurgy | 2-0-2 | 3 |
| MM 643 | Advanced Mechanical Metallurgy | 2-0-2 | 3 |
| MM 645 | Multiphysics Modelling | 2-0-2 | 3 |
| MM 647/ MM 447 | Metallurgical Thermodynamics and Phase Transformations | 2-1-0 | 3 |
| MSE 605 | Computational Techniques in Materials Engineering | 2-1-0 | 3 |
| ZZ XXX | Elective–I | x-x-x | 3 |
| | | **Total minimum credits during the semester** | **18** |
| **Additional course (as per requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1$^{st}$ Year: Semester-II**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MM 642/ MM 442 | Quality Assurance in Metallurgy | 2-0-2 | 3 |
| MM 644 | Integrated Computational Materials Engineering (ICME) | 2-0-2 | 3 |
| MM 646 | Advances in Iron and Steel Metallurgy | 2-1-0 | 3 |
| MM 698 | PG Seminar Course | 0-2-0 | 2 |
| ZZ XXX | Elective-II | x-x-x | 3 |
| ZZ XXX | Elective-III | x-x-x | 3 |
| | | **Total minimum credits during the semester** | **17** |

**2nd Year: Semester-III**

| Course Code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MM 799 | M. Tech. Research Project (Stage-I) | 0-0-36 | **18** |
| **Additional mandatory course** | | | |
| MM 672 | Visit to Industrial/Research organizations | 0-0-4 | PP/NP |

**2nd Year: Semester-IV**

| Course code | Course Title | Contact hours (L-T-P) | Credits |
|---|---|---|---|
| MM 800 | M.Tech. Research Project (Stage-II) | 0-0-36 | **18** |
| | | **Total minimum credits during the program** | **71** |

**Courses for Elective-I @**

| | | | |
|---|---|---|---|
| ME 655 | Advanced Manufacturing Processes | 2-1-0 | 3 |
| ME 659/ ME 459 | Micro and Precision Manufacturing | 2-0-2 | 3 |
| MM 602/ MM 402 | Design and Selection of Materials | 2-1-0 | 3 |
| MM 649/ MM 449 | Advance Welding Technology | 2-0-2 | 3 |
| MM 651/ MM 451 | Non-Destructive Evaluation | 2-0-2 | 3 |
| MM 653/ MM 453 | Non-equilibrium Processing of Materials | 2-1-0 | 3 |
| MM 657/ MM 457 | Advances in Energy Storage Materials | 2-1-0 | 3 |
| MM 659 | Introduction to Soft Materials | 2-1-0 | 3 |

**Courses for Elective-II and Elective-III @**

| | | | |
|---|---|---|---|
| MM 648/ MM 448 | Solidification and Phase Field Modeling | 2-0-2 | 3 |
| MM 650/ MM 450 | Ferrous and Non-Ferrous Alloys | 2-1-0 | 3 |
| MM 652/ MM 452 | Thermomechanical Processing | 2-0-2 | 3 |
| MM 654/ MM 454 | Advanced Foundry Technology | 2-0-2 | 3 |
| MM 656 | Experimental Techniques in Materials | 2-0-2 | 3 |
| MM 663 | Failure Analysis and Life Assessment | 2-1-0 | 3 |
| MM 665 | Surface Engineering of Metallic Materials | 2-1-0 | 3 |
| MM 667 | Advanced Composites | 2-1-0 | 3 |
| MM 669 | Crystallographic Texture of Materials | 2-1-0 | 3 |
| MM 671 | Dynamic Behavior of Materials | 2-1-0 | 3 |
| MM 673 | Science of Ceramics | 2-1-0 | 3 |
| MM 674/ MM 474 | Fluorescence Phenomenon | 2-1-2 | 4 |
| MM 675/ MM 475 | Advanced Fracture Mechanics | 2-1-0 | 3 |
| MM 676 | Advance Computational Methods for Materials | 2-1-0 | 3 |
| MM 677/ MM 477 | High Temperature Deformation of Materials | 2-1-0 | 3 |
| MM 679/ MM 479 | Fundamentals and Engineering of solar energy devices. | 2-1-0 | 3 |
| MM 681/ MM 481 | High Pressure Materials Processing | 2-1-0 | 3 |
| MM 683/ MM 483 | Analysis and Modelling of Welding | 2-0-2 | 3 |
| MM 685/ MM 485 | Materials Degradation | 2-0-2 | 3 |
| MM 686/ MM 486 | Applied Photoelectrochemistry | 2-1-0 | 3 |
| MM 688/ MM 488 | Electroceremics | 2-1-0 | 3 |
| MSE 622 | Tribology and Wear | 2-1-0 | 3 |

@In addition to this course list, a student can also opt from the PG courses being offered by other disciplines.

**NOTE:** 1. Request for conversion from M.Tech. to M.Tech. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.**

2. If the student moves to the Dual Degree Program, but cannot complete the requirements of a Ph.D., an **exit option** with the M.Tech. degree can be earned at the end of the final semester of the normal M.Tech. Program by getting the M.Tech. Research Project examined in the standard manner as per the requirements for the award of an M.Tech. degree.

3.The enhancement in the scholarship from M.Tech. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Tech. degree are fulfilled, whichever is later.

## Course Structure for Ph.D. Program in MEMS (w.e.f. AY 2017-18)
## (from AY 2014-15 to 2016-17 referred as Material Science and Engineering)

1. **(A) Semester-I (Autumn / Spring)**

**2.**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective- III | x-x-x-3 |
| 4 | MSE 797 / MSE 798* | Ph.D. Seminar Course | 0-2-0-2 |

**(B) Semester-II (spring / autumn)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI | x-x-x-3 |
| 4 | MSE 798 / MSE 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Courses for the Electives-I to VI** (In addition to this course list, a student can also opt from the PG courses being offered by other disciplines.)

| S. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | MSE 601 | Surface Science and Engineering | 2-1-0-3 |
| 2. | MSE 605 | Computational Techniques in Materials Engineering | 3-1-0-3 |
| 3. | MSE 607 | Materials for Devices | 2-1-2-4 |
| 4. | MM 661 | Material Science and Engineering | 2-1-0-3 |
| 5. | ME 650 | Materials Characterization Techniques | 2-0-2-3 |
| 6. | ME 660/ ME 460 | Technology of Surface Coatings | 2-1-0-3 |
| 7. | MSE 607 | Materials for Devices | 2-1-2-3 |
| 8. | MSE 610 | Design of Materials for Surface Protection and Corrosion Control | 2-1-0-3 |
| 9. | MSE 612 | Laser Based Surface Processing and Characterization | 2-1-0-3 |
| 10. | MSE 614 | Micro/Nano Fabrication of Nanostructures | 2-1-0-3 |
| 11. | MSE 616 | High Temperature Materials and Coatings | 2-1-0-3 |
| 12. | MSE 618 | Organic Paint Coatings | 2-1-0-3 |
| 13. | MSE 620 | Modeling and Management of Corrosion | 2-1-0-3 |
| 14. | MSE 622 | Tribology and Wear | 2-1-0-3 |
| 15. | MSE 624 | Interface Effect in Electronic Devices | 2-1-0-3 |
| 16. | MSE 626 | Surface Metrology | 2-1-0-3 |
| 17. | MSE 628 | Wear friction and abrasion of surface | 2-1-0-3 |
| 18. | ME 738 | Composite Materials | 2-1-0-3 |
| 19. | ME 640/ ME 440 | Smart Materials and Structures | 2-1-0-3 |

| | | | |
|---|---|---|---|
| 20. | ME 648/ ME 448 | MEM.S. and micro-systems | 2-1-0-3 |
| 21. | ME 658 | Laser based Measurements and micro-manufacturing | 2-1-0-3 |
| 22. | MSE 610 | Design of Materials for Surface Protection and Corrosion Control | 2-1-0-3 |
| 23. | MSE 612 | Laser Based Surface Processing and Characterization | 2-1-0-3 |
| 24. | MSE 614 | Micro/Nano Fabrication of Nanostructures | 2-1-0-3 |
| 25. | EE631 | Organic Electronics | 3-0-0-3 |
| 26. | EE 629 | Nanotechnology and Nanoelectronics | 3-0-0-3 |
| 27. | EE 605 | Nanotechnology | 3-0-0-3 |
| 28. | PH 725 | Characterization of surfaces and interfaces of materials | 2-0-2-3 |
| 29. | PH613 | Developments in early 20th century in Physics | 2-1-0-3 |
| 30. | PH721 | Advance Materials | 2-1-0-3 |
| 31. | ME 640/ ME 440 | Smart Materials and Structures | 2-1-0-3 |
| 32. | ME 648/ ME 448 | MEMS and micro-systems | 3-0-1-3 |
| 33. | ME 658 | Laser based Measurements and micro-manufacturing | 2-1-0-3 |
| 34. | MSE 724 | Thin Films and Devices Fabrication | 2-1-2-4 |
| 35 | MSE 725 | Single Crystal Growth Techniques | 2-1-2-4 |

**NOTE:**

- A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses) Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.
- A Ph.D. student having **M.Sc./ B.Tech./ BE** or equivalent qualification has to do 6 to 8 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 20 credits).*

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

| | | |
|---|---|---|
| 1. | Course Code | **MM 602/ MM 402** |
| 2. | Title of the Course | **Design and Selection of Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To develop a systematic procedure for selecting materials and processes that best matches the requirements of industries. |
| 7. | Course Syllabus | Materials and Design, Evolution of Engineering Materials, Material Resource in Indian Context, Classification of Materials, Materials Selection for automotive and aerospace. Material Properties; The Role of Crystal Structure. Metals and Metallic Structure, metallic alloys, ceramics & glasses, Introduction to Polymeric Materials, Phases and microstructure of Polymers, Polymers for Mechanical Design, Material Selection using Ashby Method, Case Studies, Multiple Constraints in material selection, Multiple Objectives, Role of Materials in Shaping the Product Character. |
| 8. | Suggested Books | 1. M.F. Ashby, **Materials Selection in Mechanical Design**, 4th Edition, Elsevier, San Francisco, 2011; ISBN: 978-1-85617- 663-7.<br>2. Cambridge Engineering Selector (CES EduPack), Granta Design Limited, Cambridge, UK, 2010, www.grantadesign.com. Cases studies provided by the instructor.<br>3. W.D. Callister**, Materials Science for Engineering: An Introduction**, 7th Edition, Wiley, 2007. ISBN: 978-0-471-73696- 7. |

| | | |
|---|---|---|
| 1. | Course Code | **MM 641** |
| 2. | Title of the Course | **Advanced Physical Metallurgy** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course teaches advanced concepts in crystallography, crystal defects, advanced heat-treatments, and related phase transformations. |
| 7. | Course Syllabus | Lattices and symmetries, Reciprocal lattice, Crystal symmetry, Point groups, Plane groups and space group, Determining crystal structures; Crystal imperfections; Crystal interfaces and microstructure: Interfacial free energy, Boundaries in single-phase solids, Interphase interfaces in solids, Interface migration; Solid solutions; Basics of metallurgical thermodynamics; Phase diagrams of ferrous and non-ferrous systems; Advanced Heat-treatments of ferrous and non-ferrous alloys; Concept of diffusion; Diffusional transformations; Diffusionless transformations: Martensite crystallography, Theory of martensite nucleation and growth, Tempering of ferrous Martensite, Deformation induced phase transformations, Martensite transformation in shape-memory alloys; Concept of hardenability. |
| 8. | Suggested Books | 1. C. Hammond, **The Basics of Crystallography and Diffraction**, Oxford University Press, 2009, ISBN-13: 978-0199546459.<br>2. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, **Physical Metallurgy Principles**, 4th Edition, Cengage Learning, 2003,ISBN-13: 978-0495082545.<br>3. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Inc. New York, 1988, ISBN-13: 978-1259064791.<br>4. D. A. Porter, E. E. Kenneth, M. Sherif, **Phase Transformations in Metals and Alloys**, CRC press, 2009,ISBN-13: 978-1420062106.<br>5. R. E. Smallman, A. H. W. Ngan, **Physical Metallurgy and Advanced Materials**, 7th Edition, Elsevier, 2007,ISBN: 9780750669061. |

| | | |
|---|---|---|
| 1. | Course Code | **MM 642/ MM 442** |
| 2. | Title of the Course | **Quality Assurance in Metallurgy** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To inculcate quality management and analytical industrial problem solving skills in our students so that readymade technical manpower will be available for industries. |
| 7. | Course Syllabus | Inventory management; Colour code system; Heat number; Metallurgical parameters; Relevant materials testing standards (ASTM, ISO, DIN, etc.) for inclusion rating; C2R2S2, grain size and other specific customer requirement; Laboratory quality system (ISO17025, NADCAP, NABL accreditation); Process flow chart; Six sigma; 5S; PDCA, root cause analysis, Kaizen and other relevant lean manufacturing quality tools for continuous improvement in materials processing; Idea and talent management; various quality standard for quality control, such as ISO9000:2008; TS16949, etc.; Non-destructive testing; Introduction to Environmental management standards, such as ISO 14000 family; Statistical quality control tools; Total quality management (TQM); GATE review criteria; Process and product oriented research for sustainable development; Case studies and practical exposure to industries. |
| 8. | Suggested Books | 1. W. M. Fed, **Lean Manufacturing: Tools, Techniques, and How to Use Them,** 1st Edition, CRC Press Series on Resource management, 2000, ISBN: 978-1574442977.<br>2. ASTM International: **https://www.astm.org/Standard/standards-and-publications.html**<br>3. A. J. Duncan**, Quality Control and Industrial Statistics**, Richard D. Irwin, Inc,1974, ASIN: B01LQEKJ2M. |

| | | |
|---|---|---|
| 1 | Course Code | **MM 643** |
| 2 | Title of the Course | **Advanced Mechanical Metallurgy** |
| 3 | Contact Hours | L-T-P-Credits<br>2-0-2-3 |
| 4 | Name of the Concerned Discipline/School | Metallurgy Engineering and Materials Science |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | This course provides base to understand the advanced metal processing. It provides advanced understanding on deformation processes, creep, fracture, advances in metal forming processes and additive manufacturing processes. |
| 7 | Course Syllabus | Stress-strain relationships for Elastic behavior; Theory of plasticity; Dislocations and slip phenomena; Sharp yield point, Lueders bands, Stain-aging; Recovery and recrystallization; Fracture: The Griffith theory, Ductile and Brittle fracture, Low-cycle and high-cycle Fatigue; Creep: Superplasticity, Creep mechanisms, Creep curve, Creep resistant alloys.<br>Deformation processing: Mechanics of Forming, Deformation mechanism maps.<br>Conventional metal forming processes (Rolling, extrusion, drawing, forging, sheet metal forming).<br>Advances in conventional forming techniques.<br>**Advanced Metal Forming Processes:** High energy rate forming (HERF) process, Electro-magnetic forming, explosive forming, Electro-hydraulic forming, Stretch forming, super plastic forming, Contour roll forming.<br>Powder processing – mechanism of sintering, spark plasma sintering, microwave processing of materials<br>Additive Manufacturing processes: Laser-Sintering and industrial 3D printing. |
| 8 | Suggested books | 1. K. Sindo,**Transport Phenomena and Materials Processing**, Wiley-Interscience, 1996, ISBN: 9780471076674.<br>2. H. Tschätsch, **Metal Forming Practice: Processes - Machines – Tools**, Springer, 2005, ISBN-10: 3642069770.<br>3. I. Gibson, D. Rosen, B. Stucker, **Additive Manufacturing Technologies**, Springer, 2014, ISBN-10: 1493921126.<br>4. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Inc. New York, 1988, ISBN-13: 978-1259064791. |

| | | |
|---|---|---|
| 1. | Course Code | **MM 644** |
| 2. | Title of the Course | **Integrated Computational Materials Engineering (ICME)** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Computational techniques in Materials Engineering |
| 6. | Scope of the Course | The scope of this course is introduce the student the multiscale aspects (both in space and temporal) of an engineering problem. Students will be exposed to the computational techniques and the ways to bridge the results obtained at different scales. |
| 7. | Course Syllabus | **Introduction:** ICME history and overview, Multiscale aspects of materials, Creating new materials/structure/component, case studies. Introduction to numerical techniques, Different boundary conditions: Dirichlet, Neuman and Periodic Boundary conditions, Stability criterion; **First Principle method**: Electronic structure method: Quantum mechanics of multi-electron systems, Early density functional theories, The Hohenberg-Kohn theorem, Kohn-Sham method, Exchange-correlation functional, wave functions, Pseudopotentials, Use of density functional theory; **Molecular Dynamics (MD):**Molecular dynamics of soft spheres: Interaction potentials and forces, Integrating the equations of motion: Verlet algorithm, Molecular dynamics in materials research; **Monte-Carlo (MC) method**: Ensemble averages, The Metropolis algorithm, The Ising model, Monte Carlo for atomic systems, Other ensembles, Time in Monte Carlo simulation, Assessment of the Monte Carlo method, Uses of the Monte Carlo method in materials research; **Dislocation Dynamics (DD):** Introduction to dislocation dynamics theory: bridging from MD; **Crystal Plasticity (CP):** Crystal plasticity theory: Introduction, Crystal plasticity: Kinetics, bridging from DD and model correlation, Running rate dependent single and poly crystalline CP; **Phase Field Modeling:** Introduction: Phase-Field Method and Its Formalisms, Classical diffusion equation and its Failure, Analytical and Numerical solution of Diffusion equation, Cahn-Hilliard equation: Simulation of the spinodal decomposition, Allen-Cahn Equation: Order-Disorder phase transformation, Phase Field Modelling of Solidification: dendritic solidification, Multiple Phase Fields and Order Parameters: Case studies, Outlook on various aspects of phase-field modeling; **Finite element method**: Introduction: Heat transfer problem, Fluid flow problem, Stress analysis. Stress-strain relation, Constitutive equation, deformation behavior of materials: temperature, strain field distribution. |
| 8. | Suggested Books | 1. N. Provatas, K. Elder, **Phase-Field Methods in Material Science and Engineering**, Wiley-VCH, 2010, ISBN: 9783527407477.<br>2. J.G. Lee, **Computational Materials Science: An Introduction**, CRC Press, Taylor and Francis group, 2012, ISBN: 9781439836163.<br>3. D. Raabe, **Computational materials science: the simulation of materials microstructures and properties**, Wiley-VCH, 1998, ISBN: 9783527295418.<br>4. R. Lesar, **Introduction to computational materials science: Fundamentals to Applications**, Cambridge University Press, 2013, ISBN-10: 0521845874.<br>5. W.A. Stauss, **Partial Differential equation: An Introduction**, Wiley Publications, 2007, ISBN: 9780470473184.<br>6. M.F. Horstemeyer, **Integrated Computational Materials Engineering (ICME) for Metals**, Wiley Publications, 2012, ISBN: 9781118022528. |

| | | |
|---|---|---|
| 1. | Course Code | **MM 645** |
| 2. | Title of the Course | **Multiphysics Modelling** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Computational techniques in Materials Engineering, Advanced structural and mechanical metallurgy |
| 6. | Scope of the Course | The course is intended to discuss the Multiphysics aspects of an engineering problem. The coupling phenomena such thermos-mechanical, electro-mechanical and electro-thermal problems will be discussed in detail. |
| 7. | Course Syllabus | Introduction to continuum mechanics: REV; Cauchy Stress tensor; Strain tensor, strain rate, material and spatial derivatives; General principles, continuity equation, momentum and energy principles, mass-momentum and energy transport theorems;<br>Thermo-Elasticity: Classical elasticity, Generalized Hooke's law, isotropy, thermal stresses and strain, stress concentration, Boundary value problems, Introduction to thermo-Electromagneto-mechanical coupling: Joule effect, linear piezoelectricity, Maxwell stress tensor;<br>Heat Transfer: The three modes of heat transfer: conduction, radiation, convection. Phenomenological approach to the heat transfer coefficient: coupling between conduction and convection. Steady-state heat conduction. Fin approximation. Ideal and infinite fins. Unsteady conduction. Characteristic times and lengths, dimensional analysis, Fourier and Biot numbers. Convective heat transfer: Dimensional approach to forced convection. Notions of mechanical and thermal boundary layers. Reynolds, Prandtl and Nusselt numbers. Laminar-turbulent transition. Standard cases (tube, flat plate) of internal and external convection in the fully developed regime. |
| 8. | Suggested Books | 1. J.N. Reddy, **Principles of Continuum Mechanics**, Cambridge University Press; 1stEdition, 2010, ISBN: 0521513693<br>2. J.G. Simmonds**, A brief on Tensor Analysis**, Springer, 1982, ISBN: 978-1-4419-8522-4<br>3. M. Kaviany, **Principles of Heat Transfer**, 2002,ISBN: 9781468404128.<br>4. COM.S.OL Multiphysics Manual. |

| | | |
|---|---|---|
| 1. | Course Code | **MM 646** |
| 2. | Title of the Course | **Advances in Iron and Steel Metallurgy** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | There are various types of steels which are evolved through the requirements of the engineering components. Steel production is expected to grow significantly in India. Therefore, the country needs manpower having good knowledge in iron and steel-making. This course deals with technological and physical-chemical aspects of various iron and steel making processes. |
| 7. | Course Syllabus | Treatment of iron ores: Agglomeration, sintering and pelletization. Coke making. Dissection of quenched blast furnace and its study in detail, flow of gas, liquid and solid in the various parts of the blast furnace. Physical chemistry of blast furnace reactions, thermodynamic equilibria, chemical and thermal reactions zones, Reactions in stack, bosh and hearth, thermal efficiency, mass and enthalpy balances, gas flow, burden distribution and cohesive zone formation in BF. Kinetics of iron oxide reduction and carbon gasification. Silicon transfer mechanism to hot metal, slagless steelmaking. Alternative iron making processes: Mini-blast furnace, COREX process, low shaft furnace, electro thermal processes, Directly reduced iron (DRI). Primary steel making. Thermodynamics and kinetics of steel making reactions, Theoretical analysis of refining reactions. Gas injection in steel making vessels. Theory of steel making slags. Arc Furnace practices for Carbon and Low Alloy Steels. Secondary steel making and its application to production of special and alloy steel. Fundamental and practical aspects of Injection Metallurgy. Advanced features of Continuous Casting. Application of modeling and simulation in steel making. |
| 8. | Suggested Books | 1. R. H. Tupkary, V. R. Tupkary, **Modern Iron Making**, Khanna Publications, Delhi, 2004, ISBN-13: 9788174090215.<br>2. A. Ghosh, A. Chatterjee, **Ironmaking and Steelmaking**, PHI Pvt. Ltd., 2008,ISBN-13: 978-8120332898.<br>3. V. Kudrin, **Steel Making**, Mir Publisher, Moscow, 1985. ISBN: 5030008594 9785030008592.<br>4. Bashforth, **Manufacture of Iron and Steel**. Vol I and II, Asia Publishing House, 1996, ISBN: 9781504122511. |

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|---|---|---|
| 1. | Course Code | **MM 647/ MM 447** |
| 2. | Title of the Course | **Metallurgical Thermodynamics and Phase Transformations** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To develop critical thinking and analytical problem solving skills related to macroscopic thermodynamics and kinetics in Metallurgy and Materials Engineering. |
| 7. | Course Syllabus | Introduction to metallurgical thermodynamics and concept of equilibrium; Clausius–Clapeyron equation; Phase diagram for unary system; Pressure-temperature-volume surface; Free energy of solution; Free energy–composition diagram; Evolution of Phase diagram; Phase rule and binary phase diagram; Fe-C equilibrium phase diagram; Introduction to ternary phase diagram; Free energy of intermediate phase; Metastable phase diagram; Miscibility gap in phase diagram; Kauzmann paradox and the glass transition; Free energy of undercooled liquid; Stability criteria for phase formation; Solid state phase transformations; Order of transformation; Thermodynamics of homogeneous and heterogeneous nucleation; Diffusion: Self-diffusion, Inter-diffusion, The Kirkendall effect, Capillarity-Driven diffusion, Stress-driven diffusion; Atomistic mechanisms of diffusion, Interphase layer Growth in inter-diffusion, Role of micro structure in diffusion: Short-circuits, Rate of reaction; Kinetics of phase changes; Kinetics in the diffusion-controlled regime, Sintering, Process of nucleation and growth; Gibbs-Thomson Effect; Grain-growth kinetics in two and three dimensions; Time-Temperature-Transformation diagrams; Continuous cooling transformation curves. |
| 8. | Suggested Books | 1. D. R. Gaskell and D. E. Laughlin, **Introduction to thermodynamics of materials,** Sixth Edition, CRC Press, 2017, ISBN-13: 978-1498757003.<br>2. D. A. Porter, and K. E. Eastering, Phase Transformations in Metals and Alloys, Chapman & Hall, London, New York, 1992, ISBN: 0442316380.<br>3. R. W. Balluffi, S. M. Allen, W. C. Carter, **Kinetics of Materials**, Wiley, New York, 2005, ISBN: 9780471246893.<br>4. D. V. Ragone, **Thermodynamics of Materials**, Vol 1-2, Wiley, New York, 1994, ISBN: 978-0-471-30885-0.<br>5. Bashforth, **Manufacture of Iron and Steel**. Vol I and II, Asia Publishing House, 1996, ISBN: 9781504122511. |

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|---|---|---|
| 1. | Course Code | **MM 648/ MM 448** |
| 2. | Title of the Course | **Solidification and Phase Field Modeling** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Discipline of Metallurgy Engineering and Materials Science |
| 5. | Pre-requisite, if any | None |
| 6. | Scope of the Course | Solidification processing is considered as one the most important processing technique used by engineers to manufacture structural and functional components in automobile and electronic industries. More than 90% of all metallic materials used in daily human life are synthesized from the liquid state as their parent phase. This course is intended to make the students familiar with the science and technology of solidification processing of materials, undercooled metallic melts, as well as phase field modelling of microstructure development. |
| 7. | Course Syllabus | Heat transfer in solidification, continuous and ingot casting processes, structure of castings and ingots, defects in casting, macro- and micro-segregation and homogenization, design of risering and gating in castings. Thermodynamics of solidification, nucleation and growth, Gibbs-Thomson effect, anisotropy and faceting, directional solidification-growth of single crystals. Alloy solidification, mathematical analysis of solute redistribution during solidification: Solidification at equilibrium and non-equilibrium condition. Scheil and Flemings solidification model, Stability of interface and constitutional undercooling, Mullins-Sekerka criterion, Cellular and dendrite growth. Physics of dendritic growth: Ivantsov's transport model and solution, Marginal stability hypothesis, Free dendritic theories: Lipton-Glicksman-Kurz (LGK) theory, Lipton-Kurz-Trivedi (LKT) theory, Microscopic solvability (M.S.) theory. primary and secondary dendrite arm spacing, Rayleigh instability. Solidification microstructures of multiphase alloys such as eutectic, peritectic and monotectic alloys, coupled growth and phase selection, rapid solidification processing, phase selection kinetics in undercooled metallic melt. Phase field modeling for microstructure evolution during solidification. |
| 8. | Suggested Books | 1. G. J. Davies, **Solidification and Casting**, Applied Science Publishers Ltd, London, 1973, ISBN: 0-853345562.<br>2. W. Kurz, D.J. Fisher, **Fundamental of Solidification**, Trans Tech Publications, Switzerland, 1992, ISBN: 0-878495223.<br>3. M.E. Glicksman, **Principles of Solidification**, Springer, New York, 2010, ISBN: 9781441973436.<br>4. J.A. Dantzig, M. Rappaz, **Solidification**, EPFL Press, Switzerland, 2016, ISBN: 9780849382383.<br>5. D. M. Herlach, D.M. Matson, **Solidification of Containerless Undercooled Melts**, Wiley-VCH, 2012, ISBN:9783527331222.<br>6. S. BulentBiner, **Programming Phase-Field Modeling**, Springer, 2017,ISBN: 9783319411941. |

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| 1 | Course Code | **MM 649/ MM 449** |
| 2 | Title of the Course | **Advance Welding Technology** |
| 3 | Contact Hours | L-T-P-Credits<br>2-0-2-3 |
| 4 | Name of the Concerned Discipline/School | Metallurgy Engineering and Materials Science |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | In this course students learn briefly on joining of materials basics and extensively on advanced joining techniques, process selection and design of weld joint |
| 7 | Course Syllabus | Introduction to joining of materials, Advances in joining of materials Solid State Joining Processes (Pressure welding, friction welding, explosive welding, ultrasonic welding, diffusion bonding, resistance welding); Brazing and Soldering (Filler materials and fluxes, heating methods, wetability, joint design); Adhesive bonding (Types of adhesive, wetability, surface preparation, joint design)<br>Fusion welding fundamentals, Fusion welding processes (Oxyacetylene torch welding, Manual metal arc welding, MIG and TIG welding, submerged arc welding, electron beam and laser welding), recent trends in fusion welding.<br>Welding specific materials - Plain carbon, low alloy steels, stainless steels, copper and copper alloys, nickel and nickel alloys, aluminum and aluminum alloys (similar and dissimilar materials joining).<br>Modern welding techniques (Pulsed TIG, Pulsed electron beam, Laser welding, plasma and friction stir welding); Welding defects; Quality Assurance of Welding Operations (Non-destructive testing, safety, measurement, control and recording); Process selection and joint deign with case studies |
| 8 | Suggested books | 1. M. Robert, **Joining of Materials and Structures**, 1st Edition, Elsevier, 2004,**ISBN:** 9780750677578.<br>2. S. Kou, **Welding Metallurgy**, 2nd Edition, Wiley, 2002, ISBN: 9780471434917.<br>3. H. Granjon**, Fundamentals of Welding Metallurgy**, 1st Edition, Elsevier, 1991, ISBN: 9781855730199. |

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| **Course code** | **MM 650/ MM 450** |
| **Title of the course** | **Ferrous and Non-Ferrous Alloys** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| Pre-requisite, if any | Fundamentals of materials science |
| Scope of the course | This course introduces students to the advanced alloys and develops literacy about the technologically important alloy-systems used in automotive, aerospace and nuclear industries. This course implicates the fundamental concepts in the metallurgy of the advanced alloys. |
| Course Syllabus | Ferrous alloys: Alloy Steels – General Introduction, Maraging Steels (Heat-treatment Cycle, Aging behavior), High-Strength Low-Alloy Steels (Role of Microalloying of Steels), Ultra-High Strength Steels (Role of Alloying Elements), Dual-Phase Steels, Stainless Steels (Fe-Cr-Ni System, Schaeffler Diagram, Precipitation of Carbides/Nitrides, Microstructural Aspects of Various Types of SS, Ni-free Duplex SS, Embrittlement Phenomena), Tool Steels (Secondary Hardening, Types of Carbides), TRIP-assisted Steels (Microstructural evolution, Stress induced transformation, Role of alloying elements, Factors affecting performance, Concept of &#948_-TRIP Steel), Bearing Steels (Metallurgical & Engineering Requirements of Steel, Microstructural Aspects, Microcracking, Spheroidise Annealing, Inclusions, Aerospace Bearings), IF Steels. Non-ferrous alloys: Nickel-Based Superalloys (Microstructural features, Role of Alloying Elements, Strengthening Mechanisms, Heat-Treatments, Dispersion-Hardened Superalloys), Titanium Alloys (Deformation Modes, Effect of Alloy Addition on Phase Diagrams, Alloy Classification, Phase Transformations, Microstructures, Hardening Mechanisms of Alfa- & Beta- Phases, Microstructure in Dependent of Processing, Basic Correlation between Microstructure & Mechanical Properties, Ti-based Intermetallic Compounds), Aluminum Alloys (Microstructures of Al-Si Alloys, Modified/Unmodified Al-Si Alloys, Aging Process in Al-4%Cu alloy), Brass, Bronze. Special alloys: Bulk Nanostructured Steels – the Latest Development in Steels, Mechanically Alloyed Metals, Shape Memory Alloys, Metallic-glass Forming Alloys, Nuclear Power Plant Alloys (Irradiation Damages in Microstructure, Irradiation Hardening, Concepts of ODS Steels). |
| Suggested Books | 1. H. K. D. H. Bhadeshia, R. W. K. Honeycombe, ***Steels* , Microstructure and Properties**, Butterworth-Heinemann Publications, Elsevier, UK, 2006, ISBN, 9780750680844<br>2. R. E. Smallman, A. H. W. Ngan, ***Physical Metallurgy and Advanced Materials***, Elsevier, USA, 2007, ISBN, 9780750669061<br>3. G. Lutjering, J.C. Williams, ***Titanium***, Springer-Verlag, Berlin, 2003, ISBN, 9783540713975<br>4. R.C. Reed, ***The Superalloys, Fundamentals and Applications***, Cambridge University Press, UK, 2006, ISBN-13, 978-0521070119 |

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| 1. | Course Code | **MM 651/ MM 451** |
| 2. | Title of the Course | **Non-destructive Evaluation** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | Student will understand the basic principles of various methods used for nondestructive evaluation, fundamentals, and discontinuities in different product forms, importance of NDE, applications, and limitations of nondestructive testing (NDT) methods. Students will be able to cultivate in-depth understanding on the importance of NDT in the relevant industries. |
| 7. | Course Syllabus | **Introduction**: Need for inspection, types of inspection system, Quality of inspection, Reliability of defect detection and benefits of NDE.<br>**Visual Inspection**: Basic principles and applications, borescope; rigid chamber scopes; endoscope; videoscope; robotic crawlers.<br>**Liquid Penetrant Inspection**: Physical principles, procedures of testing, penetrant testing materials, applications and limitations.<br>**Magnetic Particle Testing**: Principle of MPT, Magnetization techniques, procedure used for testing a component, equipment used for MPT, applications and limitations.<br>**Ultrasonic Testing**: Basic principles of sound beam, ultrasonic transducers, type of display, inspection methods, identification of defects, immersion testing, applications and limitations.<br>**Acoustic Emission Testing (AET)**: Principles, technique, Instrumentation and applications.<br>**Techniques used for Eddy Current Testing:** Basic principles, various probes, pulsed eddy current testing; low frequency eddy current testing; SQUID-based eddy current testing; and mechanical impedance analysis; Applications and limitations.<br>**X-ray and Neutron Radiography**: Basic principles, electromagnetic radiation sources, effect of radiation in film, radiographic imaging, inspection techniques, applications and limitations.<br>Shearography, Vibrothermography, Thermography, Laser Interferrometry, Acoustic microscopy, Microwave Testing: Working principles and applications.<br>Case study; Statistical methods for quality control. |
| 8. | Suggested Books | 1. B. Raj, T. Jayakumar, M. Thavasimuthu, **Practical Non-destructive Testing**, 3rd Edition, Narosa, New Delhi, 2007, ISBN: 9788173197970.<br>2. ASM handbook committee, **Nondestructive Evaluation and Quality Control**, Metals Handbook, Vol. 17, ASM International, ISBN: 0871700077.<br>3. J. Prasad, C. G. Nair, **Nondestructive Test and Evaluation of Materials,** McGraw-Hill Education, 2008, ISBN: 9780070077461. |

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| **1.** | **Course Code** | **MM 652/ MM 452** |
| **2.** | **Title of the Course** | **Thermomechanical Processing** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Discipline of Metallurgy Engineering and Materials Science |
| 5. | Pre-requisite, if any | None |
| 6. | Scope of the Course | This course deals with advanced thermomechanical processing to understand the development of unique microstructure. |
| 7 | Course Syllabus | General Introduction, Microstructure and Properties, Plasticity, Work Hardening, Softening mechanisms, Deformation mechanism, Phase transformations, Textural developments during thermomechanical processing, Residual stress, Processing maps and constitutive Modelling, Forming techniques: Forging, Rolling, Deep drawing, Sheet metal forming, Defects in thermomechanical processing, Physical simulation of properties, Case studies: Aluminum alloys, Steels, Hexagonal alloys, High entropy alloys. |
| 8. | Suggested Books | 1. B. Verlinden, J. Driver, I. Samajdar, R. D. Doherty, Edited by R. W. Cahn, Thermo-Mechanical Processing of Metallic Materials, Elsevier, 2007,ISBN: 9780080444970<br>2. B.S. Altan, Severe Plastic Deformation: Towards Bulk Production of Nanostructured Materials, Nova Publishers, New York, 2006, ISBN: 1-59454-508-1.<br>3. M.J. Zehetbauer, R.Z. Valiev, Nanomaterials by Severe Plastic Deformation, Wiley-VCH, Germany, 2004, ISBN: 9783527604944.<br>4. A. Rosochowski, Severe Plastic Deformation Technology, Whittles Publishing, UK, 2017, ISBN: 9781849950916.<br>5. Y. T. Zhu, V. Varyukhin, Nanostructured Materials by High-Pressure Severe Plastic Deformation, Springer, Netherlands, 2006, ISBN-10: 1402039212.<br>6. T. C. Lowe, R. Z. Valiev, Investigations and Applications of Severe Plastic Deformation, Springer, Netherlands, 2000, ISBN: 9780792362814. |

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| 1. | Course Code | **MM 653/ MM 453** |
| 2. | Title of the Course | **Non-equilibrium Processing of Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre-requisite, if any | None |
| 6. | Scope of the Course | This course is intended to make the students familiar with the different non-equilibrium processing techniques and various novel materials and its possible applications. |
| 7. | Course Syllabus | **Introduction:** Thermodynamics and kinetics of metastable phase formation.<br>**Non-equilibrium processing methods (NEPM)**: Rapid solidification, Mechanical alloying, Laser processing, Thermal plasma processing, Spray forming, Ion-mixing, Physical vapor deposition, Chemical vapor deposition, Combustion synthesis.<br>**Nanostructured materials:** Classification, preparation, structure, stability, properties, application and future direction.<br>**Special alloys:** Introduction, properties, applications and future aspects. Case studies: Bulk amorphous alloys, Quasi-crystalline alloys, Shape memory alloys, Superalloys, Heusler alloys, High entropy alloys. |
| 8. | Suggested Books | 1. C. Suryanarayana, **Non-equilibrium Processing of Materials**, Elsevier, 1999, ISBN: 0080426972.<br>2. B.S. Murty, J.W. Yeh, S. Ranganathan, **High Entropy Alloys**, Elsevier, UK, 2014, ISBN: 9780128002513.<br>3. R. E. Smallman, A. H. W. Ngan, **Physical Metallurgy and Advanced Materials**, 7th Edition, Elsevier, 2007, ISBN: 9780080552866.<br>4. R.C. Reed, **The superalloys: fundamentals and applications**, Cambridge University Press, 2006, ISBN-13: 9780511245466.<br>5. Dimitris C. **Lagoudas**, **Shape Memory Alloys Modeling and Engineering Applications**, Springer, 2008, ISBN: 9780387476841. |

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| 1. | **Course Code** | **MM 654/ MM 454** |
| 2. | **Title of the Course** | **Advanced Foundry Technology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Discipline of Metallurgy Engineering and Materials Science |
| 5. | Pre-requisite, if any | None |
| 6. | Scope of the Course | This course introduces students to different foundry techniques, different alloy systems by casting routes, casting defects. |
| 7 | Course Syllabus | Introduction to Casting technology, Solidification analysis for metals and alloys, Technology of patternmaking, Study of molding sands and their testing methods, Technology of mould making and core making, Special sand moulding processes, Principles of gating design for castings, Principles of risering design for castings, Special casting methods, Melting furnaces, Melting and pouring practices for production of Cast Iron family, steel and non-ferrous metals and alloys, Fettling and Heat treatment of castings, Casting defect and its diagnostic methods. |
| 8. | Suggested Books | 1. R.W. Heine, C.R. Loper, P.C. Rosenthal, **Principles of Metal Casting**, McGraw Hill Education, New York, USA, 1976, ISBN: 9780070993488.<br>2. A. Ghosh, A.K. Mallik, **Manufacturing Science**, Affiliated East-West Press Pvt. Ltd., India, 2010, ISBN-10: 8176710636.<br>3. P.L. Jain, **Principles of Foundry Technology,** 5th Edition, Mcgraw Hill Education, 2009, ISBN: 9780070151291.<br>4. A.K. Chakrabarti, **Casting Technology and Cast Alloys**, PHI Learning Pvt. Ltd., 2005, ISBN: 9788120327795.<br>5. B. Ravi, **Metal Casting: Computer - Aided Design and Analysis**, Phi Learning Pvt. Ltd, 2010, ISBN: 9788120327269, 8120327268.<br>6. D. Kumar, S.K. Jain, **Foundry Technology**, Cbs Publisher, 2007, ISBN: 9788123902906.<br>7. P. Beeley, **Foundry Technology**, Butterworth-Heinemann, 2001, ISBN: 0750645679.<br>8. O.P. Khana, **Foundry Technology**, Dhanpat Rai Publications, 2011, ISBN: ISBN-10: 8189928341.<br>9. K.P. Sinha, D.B. Goel, **Foundry Technology**, Standard Publishers Distributors, 2006, ISBN: 8186308121.<br>10. G. Sutradhar, **Principles of Foundry Process Design**, New Age International Pvt. Ltd, 2010, ISBN 10: 8122434053. |

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| 1. | Course Code | **MM 656** |
| 2. | Title of the Course | **Experimental Techniques in Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The course is intended to teach the students an overview of the various characterization techniques used in metallurgy and materials. |
| 7. | Course Syllabus | Properties of Electromagnetic radiation, interaction of EM radiation with matter, absorption, scattering, diffraction, polarization, excitation and de-excitation. Experimental techniques and analysis of materials through X-ray scattering techniques: powder method, Laue method, crystal structure determination. Phase diagram determination; X-ray stress measurements; X-ray spectroscopy; Scanning probe microscopy techniques (AFM, Surface profile, MFM, STM etc.); Reciprocal lattice, Electron microscopy (SEM, TEM), Optical microscopy; optical and vibrational spectroscopy, Characterization using SIM.S., 3D Atom probe analysis, Elemental analysis (XPS, EDS, WDS, EELS).<br>Experimental methods in materials properties measurements: Mechanical, Electrical, Thermal, Magnetic, and optical. |
| 8. | Suggested Books | 1. C. Suryanarayana, **Experimental Techniques In Materials And Mechanics**, CRC press, 2011, ISBN-10: 1439819041.<br>2. H.H. Willard, L.L. Merritt, J.A. Dean, F.A. Settle, **Instrumental Methods of Analysis**, 6th Edition, C.B.S. Publishers, New Delhi, 1991, ISBN-10: 0534981445.<br>3. **Characterization of Materials**, 10th Edition, Metals Handbook, Vol. 9, American Soc. of Metals, Metals Park, Ohio, 1986, ISBN: 9780871700162.<br>4. M.V. Heimendahl, **Electron Microscopy of Materials-An Introduction**, Academic Press, 1980, ISBN:0127251502.<br>5. B.D. Cullity, **Elements of X-Ray Diffraction,**Pearson, 2001, ISBN:10: 0201610914. |

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| 1. | Course Code | **MM 657/ MM 457** |
| 2. | Title of the Course | **Advances in Energy Storage Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Discipline of Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course is designed for the students of science and engineering disciplines to understand the use of nanomaterials in the advancement of energy storage devices. Potential of nanomaterials will be detailed for the significant enhancement in functionality of electrochemical devices. The basics of electrochemical devices and cutting edge research developments will be covered from various books, research reports, articles and review papers. |
| 7. | Course Syllabus | Introduction to nanomaterials, Overview of the basic characteristic differences between nanomaterials and conventional materials, Overview of the types and architectures of nanomaterials with relevance to the applications in energy storage/conversion devices, Electrochemical interfaces at the nanoscale.<br>**Characteristics and properties**: Effects of crystal structures, orientations, various dimensions, and aspect ratio at nano/micro scales, Morphological and structural stability during operation, Issues of diffusivity, Importance of chemical, physical and mechanical properties.<br>**Devices**: Importance, working principles, characterization, and fabrication of advanced electrochemical energy storage and conversion devices like Electrochromic Smart windows, Supercapacitors, Li/Na-ion batteries, and fuel cells, etc.<br>**Nanomaterials for devices**: Beneficial aspects of nanomaterials to improve device performance, Nanomaterials used and problems associated in electrochemical energy storage and conversion devices, Possible ways to overcome limitations, Potentials of nanostructures/nanomaterials for further significant enhancement in functionality. Present scenario and necessities of efforts on fabricating of nanomaterials for designing aforesaid applications. |
| 8. | Suggested Books | 1. E. R. Leite, **Nanostructured Materials for Electrochemical Energy Production and Storage**, Springer, 2009, ISBN: 978-0-387-49323-7.<br>2. B. E. Conway, **Electrochemical Supercapacitors Scientific Fundamentals and Technological Applications**, Springer, 1999, ISBN: 9781475730586.<br>3. D. Linden, T. B. Reddy, **Handbook of Batteries,** 3rd Edition, McGraw-Hill, 2002, ISBN-13: 9780071359788.<br>4. C. G. Granqvist**, Handbook of Inorganic Electrochromic Materials**, Elsevier, 1995, ISBN: 9780080532905. |

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| 1. | Course Code | **MM 659** |
| 2. | Title of the Course | **Introduction to Soft Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | This course will serve as an introduction to soft materials for students which is highly interdisciplinary area of chemistry, overlapping with topics in physics, biology, materials science and engineering. Soft materials have attracted attention due to wide applicability and importance in the chemical industries, pharmaceuticals, consumer products, food and cosmetics.<br>The course will illustrate the broad overview of design, synthesis, characterization, properties, recent advancements and potential applications of soft materials. |
| 7. | Course Syllabus | Introduction, definition, classifications of soft materials: gels and colloids. Gels: hydrogel, metallogels, organic gel and xerogels. Methods and materials selection for gel synthesis, characterization, multi-responsive behavior with special emphasis on thermal, mechanical, redox, pH and light. Reversible and irreversible physical gels; shape memory gels. Rheology of gels and colloids. Applications of gels in biology, pharmaceuticals, consumer, food, cosmetics and electronics. Colloids: Classification, preparation and purification, properties, DVLO theory, electro kinetic and physical properties. Determination of size of colloidal particles involving microscopy, scattering (ILS, DLS, x-ray, neutron), micelles, emulsions and membranes. Surface tension, adsorption and surface activity, micelles formation and colloids examples and applications. |
| 8. | Suggested Books | 1. I. W. Hamley, **Introduction to Soft Matter: Polymers, Colloids, Amphiphiles and Liquid Crystals**, Willey, 2000, ISBN: 0471899518.<br>2. R. G. Weiss, P. Terech, **Molecular Gels: Materials with Self-Assembled Fibrillar,** Networks, 2006, ISBN: 9781402036897.<br>3. M. Tokita, K. Nishinari, **Progress in Colloid and Polymer Science,** Vol 136, 2009, ISBN: 9783642008658. |

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| 1 | Course Code | **MM 663** |
| 2 | Title of the Course | **Failure Analysis and Life Assessment** |
| 3 | Contact Hours | L-T-P-Credits<br>2-0-2-3 |
| 4 | Name of the Concerned Discipline/School | MEM.S. |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | In this course students learn various failures types, failure mechanisms in materials and about the life assessment of structural components in safety critical industries. |
| 7 | Course Syllabus | Need of failure analysis; Failure analysis tools and procedure (Microscopes, NDT techniques and etc.); Failure analysis examples with case studies: For example, Columbia and challenger disaster, Kanisk failure and preventive measures in design consideration<br>Classification of different types of failures; Description and origin of processing defects: Metal working defects, casting defects, heat treatment defects and weld defects;<br>Basic of fracture, fracture mechanism map, Fatigue failures, Creep failures.<br>Environmental assisted failures (corrosion, stress corrosion cracking, hydrogen embrittlement, failures at elevated temperatures),<br>Failure of coatings, Failure due to wear<br>Life assessment of structural components- Life-limiting factors, the role of the failure analyst in life assessment · The role of non-destructive inspection, Structural health monitoring of aircraft structures · Fatigue life assessment· Elevated-temperature life assessment · Fitness-for-service life assessment · Probabilistic and deterministic approaches.<br>Safety design approaches in safety critical industries (Nuclear, aerospace, automotive industries). |
| 8 | Suggested books | 1. A. J. McEvily, **Metal Failures: Mechanisms, Analysis, Prevention**, John Wiley & Sons, New York, 2002,ISBN: 9781118163962.<br>2. **J.S. Zhang, High Temperature Deformation and Fracture of Materials**, Elsevier,**2010,** ISBN: 9780857090799.<br>3. **Failure Analysis and Prevention,** ASM Handbook Volume 11, 2002, ISBN: 9780871707048. |

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|---|---|---|
| 1 | Course Code | **MM 665** |
| 2 | Title of the Course | **Surface Engineering of Metallic Materials** |
| 3 | Contact Hours | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline/School | Metallurgy Engineering and Materials Science |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | In this course students learn about importance of surface engineering, various surface engineering processes, advances in surface engineering, surface engineering industrial application with case studies. |
| 7 | Course Syllabus | Introduction to surface engineering, Need for engineered surface.<br>Definition and principles of conventional surface hardening methods.<br>Surface hardening methods involving no change in the chemical composition of the surface and methods involving change in chemical composition of the surface.<br>Surface hardening methods involving addition of new material on the surface- Advanced Coatings - Thermal spray, cold spray process, warm spray process high velocity oxy fuel (HVOF) process, detonation gun (D-Gun) coating, diamond-like-carbon coating (DLC)<br>Application of advanced techniques such as ion and electron beam towards creating new engineered surface.<br>Advanced and high quality surface modification processes- chemical vapor deposition (CVD), physical vapor deposition (PVD).<br>Effect of process variables to obtain high quality surface modification.<br>Evaluation of mechanical properties of coatings and surface modified components<br>Recent trends in surface engineering for components in structural and engineering applications – case studies |
| 8 | Suggested books | 1. P. Martin, **Introduction to Surface Engineering and Functionally Engineered Materials**, John Wiley & Sons, 2011, ISBN: 9780470639276.<br>2. T. Burakowski, T. Wierzchon, **Surface Engineering of Metals**, CRC Press,1998, ISBN: 9780849382253.<br>3. H. Dong, **Surface Engineering of Light Alloys**, Woodhead Publishing, 2010, ISBN: 9781845695378.<br>4. J. Takadoum, **Materials and Surface Engineering in Tribology**, John Wiley & Sons, 2007,ISBN: 9781848210677. |

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| 1. | Course Code | **MM 667** |
| 2. | Title of the Course | **Advanced Composites** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The course covers the advanced topics pertaining to the processing of various composites and the mechanics associated with them. |
| 7. | Course Syllabus | Principles of composites, micromechanics of composites. Various types of reinforcements and their properties. Role of interfaces. Fabrication of metal matrix composites: in-situ, dispersion hardened, particle, whisker and fiber reinforced; composite coatings by electrodeposition and spray forming. Fabrication of polymeric and ceramic matrix composites. Mechanical physical properties of composites. Mechanisms. of fracture in composites. Property evaluation and NDT of composites. Wear and environmental effects in composites |
| 8. | Suggested Books | 1. **Composites**, Engineered Materials Handbook, Vol.1, ASM International, Ohio, 1988, ISBN-10: 0871702797.<br>2. K.K. Chawla, **Composite Materials Science & Engineering**, Springer-Verlag, New York, 1987, ISBN: 9781475729665.<br>3. F.L. Matthews, R.D. Rawlings, **Composite Materials: Engineering and Science**, Chapman & Hall, London, 1994, ISBN: 9781855734739.<br>4. **Structure and Properties of Composites, Materials Science and Technology**, Vol.13, Wiley-VCH, Germany, 1993, ISBN 3:527268316. |

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| 1. | Course Code | **MM 669** |
| 2. | Title of the Course | **Crystallographic Texture in Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Advanced structural and Mechanical Metallurgy |
| 6. | Scope of the Course | The course is aimed at acquainting the student with mathematic basis for crystallographic texture, selected set of characterization tools relevant to the quantification of texture and basis for anisotropic properties in various materials. |
| 7. | Course Syllabus | Mathematical basis for crystallographic orientation; Concepts of preferred orientations (texture) in materials, their representation by pole figure and orientation distribution functions; Methods of characterizing crystallographic texture: X-ray diffraction, Electron Back Scattered Diffraction (EBSD), neutron diffraction, synchrotron X-rays; Origin and development of textures during materials processing stages: solidification, deformation, annealing, phase transformation; Deformation microstructure and texture in FCC, BCC and HCP metals and alloys; Modelling of deformation texture and elastic & plastic anisotropy in polycrsytals; Uniform stress models (Sachs), The Taylor, Bishop a& Hill model, Self-consistent models for polycrystal deformation and texture evolution; Annealing phenomenon: Recovery, recrystallization and grain growth, texture evolution during annealing; Solidification and transformation texture; Texture development during coatings and thin film deposition; Influence of texture on mechanical, chemical and physical properties: Yield strength, ductility, fatigue, corrosion, stress corrosion cracking, magnetic and dielectric properties; Texture and formability; Case studies: Texture control in aluminium industry, automotive grade and electrical steels, magnetic and electronic materials. |
| 8. | Suggested Books | 1. U. F. Kocks, C. Tomé, H.-R. Wenk(Eds.),**Texture and Anisotropy,** Cambridge University Press, UK, 1998, ISBN-10: 052179420X.<br>2. V. Randle, O. Engler, **Texture Analysis: Macrotexture, Microtexture& Orientation Mapping**, Gordon & Breach, AM.S.terdam, Holland, 2000, ISBN: 9056992244.<br>3. M. Hatherly, W.B. Hutchinson, **An Introduction to Textures in Metals**, 1979, ISBN:0901462055. |

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| 1. | Course Code | **MM 671** |
| 2. | Title of the Course | **Dynamic Behavior of Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | Advanced structural and Mechanical Metallurgy |
| 6. | Scope of the Course | Many of the engineering components, often undergo dynamic loading condition during their service e.g. car crash, high speed machining, a bullet impacting an armour plate or space debris impacting a satellite. The materials response under dynamic loading conditions is completely different from the quasi-static loading conditions. This course intends to discuss the mechanics and mechanisms of materials under dynamic loading conditions. |
| 7. | Course Syllabus | Introduction to materials and dynamic events; Stress waves in solids: Uniaxial stress and strain waves, three dimensional wave propagation, guides waves; Experimental techniques for high strain rate testing: Impact testing, split-Hopkinson bar testing, plate impact tests, dynamic fracture tests; Plastic deformation under high strain rate loading conditions, Adiabatic shear localization, Constitutive descriptions for polymers, Dynamic fracture; Applications. |
| 8. | Suggested Books | 1. M. Andre,J. Meyers, **Dynamic Behaviour of Materials**, Wiley, 1994, ISBN: 9780471582625.<br>2. W.W. Chen, B. Song, **Split Hopkinson (Kolsky) Bar: Design, Testing and Applications**, Springer, 2011, ISBN: 9781441979827.<br>3. K. T. Ramesh(edited by Sharpe Jr., N. William), **High Strain Rate and Impact Experiments**, Springer Handbook of Experimental Solid Mechanics, 2008, ISBN: 9780387343624. |

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| 1. | Course Code | **MM 673** |
| 2. | Title of the Course | **Science of Ceramics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The objective of the course is to cover the entire spectrum of topics related to ceramics i.e., from crystal structure, defect structure, and processing of the ceramics and various structural and functional propertied of ceramics. |
| 7. | Course Syllabus | Introduction: oxide and non-oxide ceramics, their chemical formulae, crystal and defect structures, non-stoichiometry and typical properties. Powder Preparation: Physical methods (different techniques of grinding), chemical routes - co-precipitation, sol-gel, hydrothermal, combustion synthesis, high temperature reaction (solid state reaction). Basic principles and techniques of consolidation and shaping of ceramics: powder pressing- uniaxial, biaxial and cold isostatic and hot isostatic, injection moulding, slip casting, tape-casting, calendaring, multi-layering. Sintering: different mechanisms and development of microstructure (including microwave sintering); Preparation of single crystal, thick and thin film ceramics; Mechanical behavior: fracture mechanics and tribology; Engineering applications: at room and high temperatures (including armor application); Electrical behavior: insulating (dielectric, ferroelectric, piezoelectric, pyroelectric) semiconducting, conducting, superconducting and ionically conducting, specific materials and their applications; Magnetic behavior: basic principles, materials and their applications; Transparent ceramics, coatings and films: preparation and applications; Porous ceramics and ceramic membrane: fabrication techniques and applications in separation technology; Bio-medical applications of ceramic materials; Ceramics for energy and environment technologies (fuel cell, lithium battery, gas sensor and catalytic support); Ceramics matrix composites: different types, their preparation and properties (including nano-composites); Exotic ceramics: functionally graded, smart/ Intelligent, bio-mimetic and nano-ceramics - basic principles, preparation and applications |
| 8. | Suggested Books | 1. M. W. Barsoum ,**Fundamental of Ceramics**, McGraw Hill, 1997, ISBN:9780750309028.<br>2. D. W. Richerson, **Modern Ceramic Engineering**, Mercel Dekker, 1992, ISBN: 9781574446937.<br>3. M. N. Rahman, **Ceramic Processing and Sintering**, Mercel Dekker, 2003, ISBN: 9780824709884. |

| Course code | MM 674/ MM 474 |
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| **Title of the course** | **Fluorescence Phenomenon** |
| Credit Structure | L - T - P - Credits<br>2-1-2-4 |
| Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| Pre-requisite, if any | NA |
| Scope of the course | The objective of course will be an asset to build up concept about phenomenon of fluorescence involved in development of materials. The course will illustrate the broad overview of various phenomenon and applications of fluorescence in materials science and engineering. |
| Course Syllabus | Introduction to fluorescent phenomenon, basic concepts and instrumental techniques involved in fluorescence, Time-domain lifetime measurements, Dynamics of solvent and spectral relaxation, Aggregation induced emission (AIE), Chelation induced fluorescence (CHEF), Quenching of fluorescence, Fluorescence resonance energy transfer (FRET), Fluorescence anisotropy, Intramolecular charge transfer (ICT), Twisted intramolecular charge transfer (TICT), Photoinduced electron transfer (PET), Effect of solvent and molecular conformation on emission, Time-resolved energy transfer and conformation distributions of biopolymers, protein fluorescence, fluorescence sensing, Nucleic acids fluorescence, live-cell imaging, applications of fluorescent phenomenon in disease detection. Laboratory Experiment: Demonstration of the fluorescence phenomenon in development of emissive materials. |
| Suggested Books | 1. J. R. Lakowicz, ***Principles of Fluorescence Spectroscopy**, 3rd edition,* Springer Science + Bussines Media, New York, USA, 2006, 780387312781<br>2. J. R. Albani, ***Principles and Applications of Fluorescence Spectroscopy**,* Blackwell Publishing, Lowa, USA, 2007, 9781405138918<br>3. E. Wehry, ***Modern Fluorescence Spectroscopy**,* Plenum Press, New York and London, 1976, 9781468425833<br>4. O. S. Wolfbeis, *Fluorescence Spectroscopy,* New Methods and Applications : Springer-Verlag : Berlin, Heidelberg : 1993 : 9783642773747 |

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| 1 | Course Code | **MM 675/ MM 475** |
| 2 | Title of the Course | **Advanced Fracture Mechanics** |
| 3 | Contact Hours | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline/School | Metallurgy Engineering and Materials Science |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | In this course students can learn about the fracture concepts, fracture mechanics basics, equations governing fracture and fracture mechanics, concept of fracture toughness and experimental measurement of fracture toughness. Advanced topics in fatigue of materials and creep. |
| 7 | Course Syllabus | Introduction to Fracture Mechanics, Theory of Elasticity and Plasticity, Mohr's circle, equivalent stress, stress tensors.<br>Fracture, Theories of brittle and ductile fracture, Theoretical cohesive strength, strain energy release rate, Griffith theory, Stress intensity actor, relation between strain energy release rate and stress intensity factor, Ductile to brittle transition, instability in plastic deformation.<br>Linear elastic fracture mechanics, elastic plastic fracture mechanics, fracture toughness and test methods, J-integral, R-Curve, CTOD.<br>Fatigue of materials, basic terminology in fatigue, mechanism of fatigue, S-N curve, high cycle fatigue, Effect of mean stress on fatigue, good man diagram, low cycle fatigue, factors affecting fatigue of materials, fatigue crack growth, crack closure, thermal fatigue, fretting fatigue, corrosion fatigue, design to mitigate fatigue failure.<br>Creep of materials, mechanisms of creep, creep curve, deformation mechanism maps, and basic equations governing creep. Creep-fatigue interaction, Damage tolerant design. |
| 8 | Suggested books | 1. R. W. Hertzberg, R. P. Vinci, J. L. Hertzberg, **Deformation and Fracture Mechanics of Engineering Materials**, 5th Edition,Wiley,2012, ISBN-10: 0470527803.<br>2. G. E. Dieter, **Mechanical Metallurgy**, 3rd Edition, McGraw-Hill, 2017, ISBN: 0071004068.<br>3. T. L. Anderson, **Fracture Mechanics: Fundamentals and Applications**, 4th Edition, CRC Press, 2017, ISBN-10: 1498728138.<br>4. R. J. Sanford, **Principles of Fracture Mechanics**, 1st Edition, Pearson, 2002, ISBN-10: 0130929921. |

| Course code | MM 676 |
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| **Title of the course** | **Advance Computational Methods for Materials** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| Pre-requisite, if any | Basics of Quantum Mechanics, Statistical Mechanics, Solid State Physics and Material Science. |
| Scope of the course | This course intends to introduce a variety of theoretical and computational methods used in different fields of materials science as well as green energy applications. This course uses the theory and application of atomistic computer simulations to model, understand, and predict the properties of real materials. The course provides the student with deepened knowledge and understanding of computational material science and engineering. |
| Course Syllabus | A brief introduction of quantum theory, Hartree-Fock and post-Hartree-Fock theory, Introduce energy models from classical and first-principles approaches, Local Density Approximation (LDA), Local (Spin) Density Approximation (LSDA), Hybrid Density Functional theory (DFT), Generalized Gradient Approximation (GGA). Advanced theories and Computational methods, Dispersion-corrected DFT (DFT-D), van der Waals forces, Kohn-Sham DFT, Exchange-Correlation parameters, Meta-GGA, Limits of current implementations of DFT, Møller–Plesset perturbation methods, Monte Carlo (MC), quantum Monte Carlo (QMC), and grand canonical Monte Carlo (GCMC) simulations, molecular dynamics (MD), Description of variational Monte Carlo (VMC) and diffusion Monte Carlo (DMC) theories. Introduction of periodic DFT-D methods, Atomistic Modeling of materials, Multiscale Modeling technique, Thermodynamics of crystalline solids and porous materials, Quantum theory of the harmonic crystal and anharmonic effects in crystals, Applications of the periodic DFT-D methods in green energy resources, 2D layer structure materials, Transition Metal Dichalcogenides (TMDs), Graphene, and Renewable Energy Materials. |
| Suggested Books | 1. F. Giustino, ***Materials Modelling Using Density Functional Theory: Properties and Predictions,*** Oxford University Press, 2014, 978-0199662449<br>2. E. G. Lewars, ***Computational Chemistry*** **: Introduction to the Theory and Applications of Molecular and Quantum Mechan**ics, Springer, 3rd edition, 2016, 978-90-481-3862-3<br>3. B. L. Hammond, W. A. Lester, Jr., ***Monte Carlo methods in ab initio quantum chemistry***, World Scientific Lecture and Course Notes in Chemistry, 1994, 978-981-02-0321-4<br>4. C. Kittle, ***Introduction to Solid State Physics***, Wiley, 8th edition, 2012, 978-8126535187 |

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|---|---|---|
| 1 | Course Code | **MM 677/ MM 477** |
| 2 | Title of the Course | **High Temperature Deformation of Materials** |
| 3 | Contact Hours | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline/School | Metallurgy Engineering and Materials Science |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | This course provides basic understanding of d the various deformation mechanisms that take place under given stress and temperature. |
| 7 | Course Syllabus | Creep of materials. Creep curve, mechanisms of creep. structural changes during creep, equations governing creep of metals, stress rupture test. Creep resistance materials, super alloys, dispersion strengthening materials, refractory materials. Fatigue of materials, effect of temperature on fatigue behavior, high temperature fatigue, thermal fatigue, thermo mechanical fatigue. Creep fatigue interaction. Thermal barrier coatings. Deformation Mechanism Maps (Ashby and Langdon-Mohamed). Applications of Deformation Mechanism Maps [turbines, nuclear reactor components, metal forming and shaping, etc. |
| 8 | Suggested books | 1. W. D. Callister, **Materials Science and Engineering: An Introduction**, 7th Edition, John Wiley & Sons, 2014, ISBN: 9781118324578.<br>2. J. S Zhang, **High Temperature Deformation and Fracture of Materials**, 1st Edition, Elsevier,2010, ISBN: 9780857090805.<br>3. M. A. Meyers, K. K. Chawla, **Mechanical Behavior of Materials**, Cambridge University Press, 1999, ISBN: 9780521866750.<br>4. G. E Dieter, **Mechanical Metallurgy**, 1st Edition, McGraw Hill Education, 1976, ISBN: 9780070168916. |

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| 1. | Course Code | **MM 679 / MM 479** |
| 2. | Title of the Course | **Fundamentals and Engineering of Solar Energy Devices** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Discipline of Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course introduces various aspects of the solar energy devices to the students from science and engineering disciplines. This course is intended to educate the students in basics, limitations, advantages, solar cell characteristics, design, fabrication, and applications of solar cells. |
| 7. | Course Syllabus | **Fundamentals and basics concepts**: Working principle of solar cell, fundamental of photoelectric conversions (*charge excitation, conduction, separation, and collection*), Light absorption and reflections, Solar energy conversion (P*hotovoltaic, Solar thermal and photochemical*), Shockley–Queisser Limit (*Efficiency, Recombination time, AM1.5 radiation*), Generation and recombination of electron-hole pairs, recombination processes (*Radiative, Auger, Schokley-Read-Hall, direct/Langevin type, trap assisted, direct, interfacial, geminate, and non-geminate recombination*) and possible losses.<br>**Characteristic:** Equivalent circuits of the solar cell, Physical aspects of efficiency, Irradiation and series/shunt resistances on the open-circuit voltage ($V_{OC}$) and short-circuit current ($I_{SC}$), Dark and illuminated characteristics, Dark current, Light generated current, Effects of shading, Significance of various parameters (O*ut-put parameter, FF, solar cell* $\eta$, $I_{SC}$, $V_{OC}$, *Quantum efficiency, Maximum power point operation*), Antireflections coating, Practical efficiency limit (P*arasitic resistance, Losses in* $I_{SC}$, $V_{OC}$, *and FF, Effects of temperature, Series and shunt resistance, high irradiance*), Theoretical Limits, Challenges, and New Ideas.<br>**Solar Cell Devices**: Basic structure, modeling, advantages, disadvantages and challenges, Generations of solar cells, Si solar cell (*Single- and Poly- Crystalline, Amorphous, and Hybrid*), Thin film solar cells (*Amorphous silicon, Cd-Te, Cd-Se, CZTS, CIGS solar cells*), Grätzel & tandem cell(Metal-Oxide micro/nano-structures; *fabrication, Mechanism, Key efficiency parameters, Substrate effect, Examples of dyes for photosensitization, Electrolytes, Influence of additives on the performance,*), Heterojunction organic, Perovskite, Quantum dots and Hybrid solar cell (*types, materials used, compositions of components, processing, architectures, efficiency limits, stability issues, temperature effect*), Emerging new technologies.<br>Over view of potential hazards, Solar energy storage/utilization (*Batteries, Supercapacitor, Display devices, Emitters, and Generators etc.*), Status and prospective of *PV technology*. |
| 8. | Suggested Books | 1. A. McEvoy, T. Markvart, L. Castaner, **Solar Cells: Materials, Manufacture and Operation,** 2nd Edition, Elsevier, 2013, ISBN: 9780080993799.<br>2. T. Soga, **Nanostructured Materials for Solar Energy Conversion**, Elsevier, 2006, ISBN: 9780444528445.<br>3. D. Yogi Goswami, **Principles of Solar Engineering,** 3rd Edition, CRC Press, 2015, ISBN: 9781466563780.<br>4. A. L. Fahrenbruch, R. Bube, **Fundamentals of Solar Cells**, Elsevier, 1983, ISBN: 9780323145381.<br>5. C. J. Chen, **Physics of Solar Energy,** John Wiley & Sons, Inc., |

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| | | 2011, ISBN: 9780470647806.<br>6. P. Wurfel, **Physics of Solar Cells: From Basic Principles to Advanced Concepts,** 2nd Edition, Wiley-VCH, 2005, ISBN:9783527408573.<br>7. L Fraas, L. Partain, **Solar Cells & Their Applications,** 2nd Edition, John Wiley & Sons, 2010, ISBN: 9780470446331.<br>8. M. A. Green, **Third Generation Photovoltaics: Advanced Solar Energy Conversion**, Springer, 2005, ISBN: 9783540265634. |

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| **Course code** | **MM 681/ MM 481** |
| **Title of the course** | **High Pressure Materials Processing** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| Pre-requisite, if any | NA |
| Scope of the course | This course is designed for the students of science and engineering disciplines to understand the use of High pressure for materials synthesis and properties studies under high pressure. This course provides new insight for basic, applied and industrial applications. |
| Course Syllabus | Introduction to High Pressure Materials Synthesis Technique and basic principles, Pressure effects in material synthesis and physics/science behind it, Comparison of solid-medium and gas-medium pressure techniques, Solid-medium ultra-high-pressure low-temperature O2 annealing, Gas-medium high-pressure synthesis. High Pressure Materials Synthesis Techniques: Encapsulation techniques, Shock-wave methods, Diamond-anvil cells, Cubic Anvil and Belt type. Synthesis of Novel Materials under high pressure: General features of high-pressure processes, calibration of parameters etc., High Pressure synthesis of Mechanical Materials and new layered structures, Polymers etc. Application of high-pressure techniques: magnetic materials, diamonds, gems, Wide band gap semiconductors, Electronic and Optical Materials, etc. |
| Suggested Books | 1. R. S. Bradley, ***High Pressure Physics and Chemistry***, Academic Press, Cambridge, USA, 1963, 0121240029<br>2. K. D. Timmerheld, ***High-Pressure Science and Technology***, Springer, Berlin, Germany, 1979, 9780306400698<br>3. M. I. Eremets, ***High Pressure Experimental Methods***, Oxford University Press, United Kingdom, 1996, 9780198562696<br>4. R. V. Eldic and F. G. Kramer, ***High Pressure Chemistry, Synthetic, Mechanistic, and Supercritical Applications***, Wiley, New York, 2002, 9783527612635 |

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|---|---|---|
| 1 | Course Code | **MM 683/ MM 483** |
| 2 | Title of the Course | **Analysis and Modelling of Welding** |
| 3 | Contact Hours | L-T-P-Credits<br>2-0-2-3 |
| 4 | Name of the Concerned Discipline/School | Metallurgy Engineering and Materials Science |
| 5 | Pre–requisite, if any | None |
| 6 | Scope of the Course | Welding is an important fabrication process in manufacturing industries. This course deals with the detailed analysis and modelling techniques that apply to the different phenomena that take place during welding processes. |
| 7 | Course Syllabus | Introduction to fusion welding processes, Heat sources, Heat removal. Thermal modelling, Analytical solution to weld thermal field, Zones in a weldment, Phase change. Fluid flow in the weld pool, Fusion zone, Conduction mode and Keyhole mode.<br>Introduction to micro-segregation, Solute redistribution, Microscale, Microstructure evolution. Solute transfer at Macroscale.<br>Defects in fusion welds, Effects of dilution, Weld Cladding. Distortion in welding, Dissimilar welding, Solutions to Dissimilar welding.<br>Numerical solutions to thermal field and fluid flow in welding. |
| 8 | Suggested books | 1. S. Kou, **Welding Metallurgy**, 2nd Edition, John Wiley & Sons, 2002, ISBN: 9780471434917.<br>2. R. W. Messler, **Principles of Welding: Processes, Physics, Chemistry and Metallurgy**, Wiley-VCH, 1999, ISBN-13:978-0471253761.<br>3. J. F. Lancaster, **Metallurgy of Welding**, Abington Publishing, England, 1999, ISBN: 1855734281.<br>4. D. R. Gaskell, **An Introduction to Transport Phenomena in Materials Engineering**, 2nd Edition, Momentum Press, New York, 2013, ISBN-13: 978-6065-35-3.<br>5. S. V. Patankar, **Numerical Heat Transfer and Fluid Flow**, McGraw-Hill Book Company, New York,1980, ISBN: 0070487405. |

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|---|---|---|
| 1. | Course Code | **MM 685/ MM 485** |
| 2. | Title of the Course | **Materials Degradation** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To start from the fundamentals and provide an integrated and up-to-date picture of degradation of engineering materials used in the current industry. This course will concentrate on the materials, forms of degradation and their mechanism that are most relevant to the largest number of current industrial applications. |
| 7. | Course Syllabus | Introduction to materials degradation; Corrosion standards; Electrochemical corrosion of metallic materials; General corrosion; Localized corrosion; Introduction to electrochemical impedance spectroscopy (EIS); Metallurgical influenced corrosion; Mechanically assisted corrosion; Environmentally induced cracking; $CO_2$ corrosion of mild steel; materials degradation in nuclear power plant; Corrosion in automotive industry; Corrosion in aerospace industry; Corrosion in Aircraft industry; Corrosion in electronic industry; Degradation issues of concrete and polymer materials; Degradation issues in metallic implants; Electro-chemo-mechanical degradation of high-capacity battery electrode materials; Degradation of dental materials; Corrosion in the Brewery Industry; Biodetoriation of materials. |
| 8. | Suggested Books | 1. ASM committee, **ASM Handbook on Corrosion,** 9$^{th}$ Edition, Vol 13, 1992, ISBN: 9780871707079.<br>2. J. R. David, **Corrosion: understanding the basics,** ASM international, Materials Park, Ohio, 2000,ISBN-10: 0824799178.<br>3. A. M. El-Sherik, **Trends in Oil and Gas Corrosion Research and Technologies,** Woodhead Publishing. 2017, ISBN: 9780081011058. |

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| **Course code** | **MM 686/ MM 486** |
| **Title of the course** | **Applied Photoelectrochemistry** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| Pre-requisite, if any | Basic knowledge of Semiconductors, Optoelectronic Properties and Electrochemistry |
| Scope of the course | The course is designed to provide the fundamentals knowledge of Photoelectrochemistry and its application in solar light harvesting. The student would get comprehensive understanding on phenomenon's that are occurring at the interface of semiconductor and electrolyte. To introduce the nanostructure photoelectrode and their impact as well as recent advancement in semiconductor photoelectrodes. |
| Course Syllabus | 1. Introduction: Electrochemistry and Electrochemical Cells, Electrodes: Anode and Cathode, Equilibrium Potential of Electrode Reactions, Cathodic and Anodic Reactions, Electrode Reactions in Electron Transfer.<br>2. Semiconductor Photoelectrodes: Electron Energy Bands of Semiconductors, Chemical Potential and Electrochemical Potential, Graphical Representation of Energy Levels, Theory of Junction Formation, Metal-Schottky Junction, Semiconductor– Electrolyte Junction, Flow of Carriers Across the Junction, Depth of Charge Separation at the Interface of n- and p-Type Semiconductors, Nature of Potential at the Interface, Width of the Space Charge Region, and Quasi-Fermi Levels (QFLs). Semiconductor–Electrolyte Junction Under Illumination: Open Circuit Potential, Photovoltage and Photocurrent, Photocurrent Conversion Efficiency.<br>3. Nanostructured Semiconductor Photoelectrodes: Band Bending in Nanostructures, Effect of Surface Area, Determination of Quasi-Fermi Level Positions, Surface States and Fermi Level Pinning, Surface Recombination, Charge Separation and Collection, Charge Compensation and Charge Trapping.<br>4. Photoelectrochemical Water Splitting: Concept of Solar Driven Water Splitting and Production of Chemical Fuels/Hydrogen. Prospective Materials for Solar Driven Water Splitting and Associated Challenges. The Advanced Materials Design: Harvesting of Wider Solar Spectrum, Effective Separation and Transportation of Photo Charge Carriers, Earth Abundant Elements based Nanostructures. |
| Suggested Books | 1. Norio Sato, ***Electrochemistry at Metal and Semiconductor Electrodes***, Elsevier, The Netherlands, 2005, 0444828060<br>2. Yurii Pleskov, ***Semiconductor Photoelectrochemistry***, Springer, New York, USA, 2012, 9781468490800<br>3. Mary D Archer and Arthur J Nozik, ***Nanostructured and Photoelectrochemical Systems for Solar Photon Conversion***, World Scientific, London, 2008, 10 1860942555<br>4. R. Krol and M. Grätzel, ***Photoelectrochemical Hydrogen Production***, Springer, USA, 2011, 9781461413806 |

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|---|---|
| **Course code** | **MM 688/ MM 488** |
| **Title** | **Electroceramics** |
| Credit Structure | L - T - P – Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| Pre-requisite, if any | NA |
| Scope of the course | The course provides a comprehensive treatment of fundamental aspects of electroceramics and their applications. |
| Course Syllabus | A brief review of the structure of selected ceramic materials, Defects Equilibria, Diffusion Kinetics, Theory of Ionic Conduction, Applications of Ionic Conductors: Fuel Cells, Batteries, etc. Polarization in Static and Alternating Electric Fields, Clausius–Mossotti Relation, Linear & Nonlinear Dielectrics and their Applications: Capacitors, Sensors, Actuators, Data Storage Devices, Ferroelectric Random Access Memories (Fe-RAM), Magnetoelectric Coupling and Multiferroicity, Electroceramics Fabrication-Technology. |
| Suggested Books | 1. W. D. Kingery, H. K. Bowen, and D. R. Uhlmann, ***Introduction to Ceramics**,* 2nd Edition, Wiley India Pvt. Ltd., New Delhi, India, 2012, 978-8126539994<br>2. L. L. Hench and J. K. West, ***Principles of Electronic Ceramics***, Wiley-Interscience, New Jersey, United States, 1990, 978-0471618218<br>3. A. J. Moulson and J. M. Herbert, ***Electroceramics , Materials, Properties, Applications***, John Wiley & Sons, West Sussex, England, 2003, 978-0470864975<br>4. Anthony R. West, ***Solid State Chemistry and its Applications***,2nd Edition, Wiley, New Delhi, India, 2014, 978-1119942948<br>5. Nava Setter (editor), ***Electroceramic***-Based MEM.S., Springer US, 2005, ISBN: 978-1441936042 |

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| 1 | Course Code | **MM 730/ MM 430** |
| 2 | Title of the Course | **Two Dimensional Materials and Electronic Devices** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Metallurgy Engineering and Materials Science |
| 5 | Pre-requisite, if any | Basic knowledge in nanomaterials fabrication, characterization, devices integration and electronic devices. |
| 6 | Scope of the Course | To gain fundamental knowledge about the world of 2-D materials. The course will develop an understanding on 2-D materials fabrication, classification, and characterization. It will deliver an idea, how 2-D materials can be applied in electronics devices and its importance and advantages. |

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| 7 | Course Syllabus | Introduction to 2-D Materials. Stable 2-D layer: Theoretical Consideration to Experimental Demonstration. Overview of 2-D Materials: Graphene, Silicene, Germanene, Phosphorene, Stanene, Transition-Metal-Chalcogene, MX-enes etc. Graphene: Discovery, Structure, Its Derivatives and Applications. Fabrication and Characterization of Graphene and other 2-D Materials. Electronic Properties of 2-D materials: Band Structure, Mobility, Quantum Hall Effect etc. Surface Functionalization and Modification. Surface Controlled Electrical and Optical Properties of 2-D Materials. 2-D Materials in Electronic Devices, 2-D Transistors – State of The Art; Graphene MOSFET (GFET); GFET for Digital Electronics, 2-D Materials Based Transistors: RF Transistor; Multi-Gate FET, Inter-layer Tunnelling FET. |
| 8 | Suggested Books | 1. M. Aliofkhazraei, and N. Ali, *Two-Dimensional Nanostructures,* CRC Press, 2012, ISBN:9781439866658<br>2. J.H. Warner, F. Schaffel, M. H. Rummeli and A. Bachmatiuk, *Graphene : Fundamentals and Emergent Applications*, Elsevier,2013, ISBN: 9780123945938<br>3. V. Skakalova, A. B. Kaiser, *Graphene: Properties, Preparation, Characterisation and Devices,* Woodhead Publishing, 2014, ISBN: 9780857095084<br>4. F. Iacopi, J. J. Boeckl and C. Jagadish; *2D Materials*, Academic Press, 2016, ISBN:9780128043370<br>5. Kolobov, Alexander V., Tominaga, Junji, *Two-Dimensional Transition-Metal Dichalcogenides* , Springer, 2016, ISBN: 9783319314501<br>6. M. Raghu, *Graphene Nanoelectronics: from Materials to Circuits*, Springer, 2012, ISBN: 9781461405481<br>7. M. Houssa, A. Dimoulas and A. Molle, *2D Materials for Nanoelectronics,* CRC Press , 2016, ISBN: 9781498704175 |

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| 1. | Course Code | **MSE 601** |
| 2. | Title of the Course | **Surface Science and Engineering** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards science and surface engineering |
| 7. | Course Syllabus | Concept of Surfaces, surface reactions, interaction, surface energy, surface tension, surface diffusion.<br><br>Design of surface layers based on mathematical modeling, rational application of surface layers.<br><br>Spontaneous growth-Evaporation (dissolution)-condensation growth-evaporation-condensation growth-dissolution condensation growth-vapor (solution)-Liquid-solid growth(VLS or SLS) growth-VLS growth of various of nanowires-control size of nanowires-Carbon nano tubes-precursors and catalyst-solution-liquid-solid growth-stress induced recrystallization-Template based synthesis-Electrocehmical deposition-electrophoretic deposition-template filling-collidal dispersion filling-melt solution filling-chemical vapour deposition-deposition by centrifugation-electrospinning-lithography<br><br>Significance of the surface function, the surface – physico-chemical concepts, interphase surface – a physical surface, surface energy, surface phenomenon, the superficial surface structure, potential properties.<br><br>Stereometric-physico-chemical parameters types of surface degradation.<br><br>surface modification techniques conventional methods of surface property alteration, functional coatings, advanced methods – basic principles, |
| 8. | Suggested Books | 4. G. Cao, Y. Wang, **Nanostructure and Nano materials, synthesis, properties and applications**, World scientific Publishing Co., 2011, ISBN:978-9814324557.<br>5. Bhusan, **The Handbook on Nanotechnology,** Springer series, ISBN: 978-3-540-29855-7.<br>6. R. Kelsall, I. W. Hamley and M. Geoghegan, **NanoScale Science and Technology,** ISBN :9780470850862.<br>**7.** L. Chi, **Nano Technology-Volume 8: Nanostructured Surfaces**, Wiley Publication, ISBN:9783527317394.<br>**8.** R. K. Leach, **Fundamental Principles of Engineering Nanometrology**, Elesevier publication, ISBN 978-0-08-096454-6. |

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| 1. | **Course Code** | **MSE 605** |
| 2. | **Course Title** | **Computational Techniques in Materials Engineering** |
| 3. | Credit Structure | L-T-P-Credit<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline | Material Science and Engineering |
| 5. | Pre-requisite, if any | Nil |
| 6. | Scope of the course | The main objective of this course is to provide training in few selected topics in numerical techniques that is relevant for a Master's student in MSE. This course can be used as a tool to translate the language of continuous mathematics into discrete calculations that can be easily handled by present day computers. |
| 7. | Course Syllabus | **Numerical methods and Special functions for data analysis:** Iterative methods and their convergence, Newton methods and modifications of newton methods, rank and row echelon form, secant, Eigenvalues and Eigenvectors, Existence and uniqueness of solutions, Elementary Row Operations, Gaussian Elimination, LU decomposition. Fourier analysis, Fourier transform, Bessel Functions, Fourier-Bessel series expansion, Fourier-Bessel transform, Green's function, Spherical harmonics, Cubic splines and Runga-Kutta methods.<br>**Applied statistics and error analysis:** Introduction to Probability Theory, Sample space & events, axioM.S. of Probability, Joint and Conditional Probabilities, Baye's Theorem, random variables, cumulative distribution function, probability density function, reliability and failure rates, MTBF and lifetime prediction. Normal and Gaussian distribution, normal approximation to a binomial distribution, central limit theorem, t-distribution, and introduction of analysis of variance, method of least squares, existence of outliers, chi square test, correlation and regression. Error analysis, propagation of errors, classification and probabilistic estimation of errors<br>**Introduction to numerical simulations and Physical concepts related to materials science:** Computer Simulations at different time scales, electronic structure of materials using Quantum Mechanics, atomic/molecular structure using molecular dynamics/montecarlo methods, segment structure using mesoscale dynamics and material structures using Finite element methods, Finite Difference and Finite volume methods **S**tructure property relationships at different length scales, Stress-strain relations, Deformation process, Phase transitions, Dimensional effects on nanoscale materials, 1 and 2-D numerical simulations of discrete electronic devices. |
| 8. | Suggested Books | ▪ K. E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989.<br>▪ Numerical Methods for Engineers, Steven Chapra and Raymond Canale, McGraw-Hill, 6thedition.<br>▪ S D Conte and C. De Boor, Elementary Numerical Analysis: An Algorithmic Approach, McGraw Hill 1980.<br>▪ J. Stoer and R. Bulirsch, Introduction to Numerical Analysis, 2nd ed., Texts in Applied Mathematics, Vol. 12, Springer Verlag, New York, 1993.<br>▪ D. C. Montgomery and G. C. Runger, "Applied Statistics and Probability for Engineers", 3$^{rd}$ ed., John Wiley & Sons Inc, ISBN 0-471-20454-4.<br>▪ J. W. Barnes, "Statistical Analysis for Engineers and Scientists", McGRAW-HILL, Inc., 2001<br>▪ W.A. Strauss, "Partial Differential equation: An Intrduction", Wiley Publications, Inc., 2007<br>▪ J. G. Lee, "Computational Materials Science: An Introduction" CRC Press, Taylor and Francis group, 2012.<br>▪ M. K. Jain, S. R. K. Iyengar and R. K. Jain, "Numerical Methods" (for scientific |

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| | | and engineering computation), New Age International, sixth edition.<br>▪ S. S. Rao, “Finite Element Method in Engineering”, Elsevier, 2004. |

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| 1 | **Course Code** | **MSE 607** |
| 2 | **Course Title** | **Materials for Devices** |
| 3 | Credit structure | L-T- P-Credits<br>2-1-2-4 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This program introduces important advanced functional materials emphasizing on synthesis techniques, processing, characterization and device fabrication techniques towards development of new generation applications. |
| 7. | Course Syllabus | **Material types and their importance as devices**(Applications in basic science, engineering, energy, biomedical and other applications):<br>Magnetic materials<br>8. Magnetic semiconductors<br>9. Multiferroics<br>10. Superconductors<br>Smart materials<br>Topological insulators<br>Nanomaterials<br>Carbon forM.S.<br>Semiconducting Materials<br>**Materials synthesis methods:**<br>Solid state reaction, sol-gel, hydrothermal, high pressure high temperature, vapor processing, etc.<br>Case study of synthesis for each material: Optimization of the processing parameters<br>**Measurement of Physical Properties**:<br>Sample preparation techniques for different application – device fabrication<br>5. Electrical properties<br>6. Magnetic properties<br>7. Thermoelectric properties<br>8. Magnetoelectric properties<br>9. Themal properties<br>10. Type and density of charge carriers |
| 8. | Suggested Books | Z. L. Wang and Z. C. Kang, **Functional and Smart Materials Structural Evolution and Structure Analysis,** (Plenum Press; 1st edition, January 15, 1998) ISBN: 0306456516 (514 pages).<br>J. A. Harvey, **Smart Materials, in Handbook of Materials Selection**(ed. M. Kutz), (2007) John Wiley & Sons, Inc., New York. ISBN Print ISBN:9780471359241, Online ISBN: 9780470172551<br>M. Schwartz, **Smart Materials** CRC Press, 2008.ISBN 9781420043723.<br>R. C. Dorf, **The Electrical Engineering Handbook, 2nd Edition,** CRC Press, 1997. ISBN:1420049763, 9781420049763.<br>B. Culshaw, **Smart Structures and Materials**, Artech House, 1996. ISBN 0890066817.<br>A.V. V. Srinivasan and D. M. McFarland, **Smart Structures Analysis and Design**, Cambridge University Press, 2000. ISBN:0521650267.<br>M.Tinkham, **Introduction to Superconductivity**, McGraw-Hill, New York, 1996. ISBN:0071147829.<br>S. Brian, **An Introduction to Materials Engineering and Science**, John Wiley & Sons, Inc., New York, 2003. ISBN ISBN:0471436232. |

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|---|---|---|
| 1. | Course Code | **MSE 610** |
| 2. | Title of the Course | **Design of Materials for Surface Protection and Corrosion Control** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards design and protection of structures towards corrosion |
| 7. | Course Syllabus | Basic concepts of interaction free surfaces. Fundamentals of Corrosion modeling, corrosion allowance calculations, life prediction of corroding structures. Design of pitting resistant materials, stress corrosion cracking resistance, and wear resistance. Design of material with free from water/moisture stagnation. Design of protective coatings : coatings for short term protection, 4-6 years, 6-10 years, 10-15 years, more than 25 years and so on. Cathodic protection design, calculation of number anodes, total weight of anodes, anode efficiencies and consumption rate. Design of CP system for storage tanks, underground cross country pipelines, offshore structures. Design of high temperature corrosion resistant materials, life of high temperature materials. |
| 8. | Suggested Books | 1. Fontana, G. Mars, Greene and D. Norbert, **Corrosion Engineering**, McGraw-Hill, New York, 1967, ISBN: 978-0070214637.<br>2. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, Edited, ISBN: 0-87170-705-5.<br>3. M. Cartier, **Handbook of Surface Treatment and Coatings,** Tribology in Practice S. (Hardback), ISBN-13: 9781860583759 ISBN-10: 186058375X.<br>4. J. Baghdachi, T. Provder, **Smart Coatings: Vol-2,** ACS Symposium (Hardback), ISBN-13: 9780841272187, ISBN-10: 0841272182.<br>5. G. Franz, **Low Pressure Plasmas and Microstructuring Technology** (Hardback), ISBN-13: 9783540858485, ISBN-10: 3540858482 |

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|---|---|---|
| 1. | Course Code | **MSE 612** |
| 2. | Title of the Course | **High Temperature Corrosion-Resistant Materials and Coatings** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards design and protection of structures towards high temperature corrosion |
| 7. | Course Syllabus | Importance of high temperature, examples of various industries and components operating at high temperatures, power plants, refineries, petrochemical plants, manufacture of various chemicals, aerospace industry, selection criterion of materials at high temperatures, interaction between mechanical properties such as creep and fatigue with corrosion, materials for moderate temperature applications, steels, low alloy steels, copper and aluminum alloys, stainless steels, superalloys, oxide dispersion strengthened alloys, directionally solidified materials and single crystals. High temperature coatings, CVD, PVD, thermally sprayed coatings, thermal barrier coatings, laser cladding. |
| 8. | Suggested Books | 1. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, ISBN: 0-87170-705-5.<br>2. M. Cartier, **Handbook of Surface Treatment and Coatings,** Tribology in Practice S., (Hardback), ISBN-13: 9781860583759, ISBN: 186058375X.<br>3. A. S. Khanna, **Introduction to High Temperature Corrosion**, ASM Publication, 2002, ISBN: 978-0871707628.<br>4. A. A. Tracton, **Coatings Technology: Fundamentals, Testing, and Processing Techniques** (Hardback) CRC Press Inc., ISBN: 9781420044065.<br>5. A. A. Tracton, **Coatings Materials and Surface Coatings** (Hardback), CRC Press ISBN: 9781420044041. |

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| 1. | Course Code | **MSE 614** |
| 2. | Title of the Course | **Corrosion-Resistant Paints and Coatings** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards coatings on resistance against corrosion |
| 7. | Course Syllabus | Concept of paint coatings, classification of various paint systems based on resin chemistry, their advantages and limitation in specific environments. Constitution of a paint coating, methods of preparation, single and two component paint systems, concept of pot life. High performance coatings, coatings for specific functions, such as hydrophobic and hydrphillic coatings, self cleaning and self healing coatings. Green coatings, concept of VOC, waterborne coatings. Surface preparation techniques and standards used. Paint application by brush, rollers, air spray, airless spray and electrostatic spray. Coating efficiency. Paint failures, reasons and remedial measures. Repair and maintenance of paint coatings. Paint application quality control and inspection. Role of supervisors and inspectors. Application of paint coatings in offshore structures, power plants, refineries and petrochemical plants and concrete structures. |
| 8. | Suggested Books | 1. A. S. Khanna, **High Performance organic Coatings**, CRC, Woodhead Publications, 2008, ISBN 978-1-84569-265-0.<br>2. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, Edited, ISBN: 0-87170-705-5.<br>3. M. Cartier, **Handbook of Surface Treatment and Coatings,** Tribology in Practice S. (Hardback), ISBN-13: 9781860583759, ISBN-10: 186058375X.<br>4. J. Baghdachi, T. Provder, **Smart Coatings Vol.2,** ACS Symposium (Hardback), ISBN-13: 9780841272187, ISBN-10: 0841272182. |

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| 1. | Course Code | **MSE 616** |
| 2. | Title of the Course | **Wear, Friction and Abrasion of Surfaces** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards tribology and wear |
| 7. | Course Syllabus | Principles of friction and wear. Mechanism of adhesive and abrasive wear, oxidation wear, corrosion and erosive wear. Fretting and fatigue, fundamentals of erosion and erosion-corrosion. Wear and friction resistant materials, wear resistant coatings, hard coatings using conventional methods such as carburization, carbonitriding, principles of CVD, PVD, plasma spraying, plasma nitriding, ion implantation, laser surface alloying, life prediction of coated surface, economic consideration and future coatings requirements. |
| 8. | Suggested Books | 1 M. Cartier, **Handbook of Surface Treatment and Coatings**, Tribology in Practice S. (Hardback), ISBN: 9781860583759.<br>2. G. Franz, **Low Pressure Plasmas and Microstructuring Technology**, Hardback, ISBN 13: 9783540858485, ISBN: 3540858482.<br>3. V. Raghavan, **Materials Science and Engineering**, PHI Learning Private Limited, New Delhi, 2009, ISBN: 8120324552.<br>4. W. D. Callister, **Materials Science and Engineering**, Wiley India (P) Ltd. , ISBN: 9788126510764. |

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| 1. | Course Code | **MSE 618** |
| 2. | Title of the Course | **Corrosion in Oil and Gas Industries** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards suitable application of corrosion |
| 7. | Course Syllabus | Household corrosion vs Industrial corrosion, example of corrosion in various industries : power plants, refineries, chemical and petrochemical plants, fertilizers plants, sugar and pulp & paper industry. Corrosion in electrical and electronics industries. Corrosion in concrete and RCC structures. Failure case histories and analysis. How to make industry free from corrosion, better material selection based upon requirement of various industries, corrosion control method, use of corrosion monitoring to monitor the health of an industries, corrosion management approach and KPI concept.<br>Definition of highly aggressive environment, sour and sweet environments, materials requirements for offshore structures, refineries, petrochemical plants, X-40 to X80 steels for pipelines, high corrosion resistant materials such as superaustenitic, superferritic, Duplex stainless steels and special superalloys, design of corrosion resistant storage tanks, tank linings and cathodic protection, transportation of crude and gas, underground cross country pipelines, phenomena of corrosion in crude gas pipelines, complex combination of pH, water cut, oil, carbon dioxide and $H_2S$, external corrosion prevention by coatings and cathodic protection, methods of corrosion monitoring of pipelines, PSP surveys, Pearson surveys, intelligent pigging, ultrasonic and other NDT methods, SCADA system. |
| 8. | Suggested Books | 1. A. S. Khanna, **Introduction to High Temperature Corrosion**, ASM Publication, 2002, ISBN: 978-0871707628.<br>2. Evans, R. Ulick, **An Introduction to Metallic Corrosion**, Edward Arnold, London, UK, 1948, ISBN: 9780713120530.<br>3. Fontana, G. Mars, Greene and D. Norbert, **Corrosion Engineering**, McGraw-Hill, New York, 1967, ISBN: 0070214611.<br>4. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, Edited, ISBN: 0-87170-705-5. |

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| 1. | Course Code | **MSE 620** |
| 2. | Title of the Course | **Modeling and Management of Corrosion** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards modeling of corrosion |
| 7. | Course Syllabus | Modelling tools, mathematics for mdeliling, finite element approach. Examples of the use of modelling in corrosion life predition. Corrosion modelling to predict the effectiveness of corrosion control measures. Computer simulation to predict current and potential distributions under different conditions and strategies to be trialled to find the most effective solution. Modern numerical methods of fracture mechanics, in particular, crack propagation and assess crack-like defects and learn how to use to predict fatigue life and how to model cracks in built up structure to model and assess multiple site damage. Computer modelling of Electrochemical and many processes and coatings to components and structures to predict their performance to learn how modelling can help improve your corrosion control solutions. Corrosion sensor technology with corrosion structural effects modeling to enable the transition from periodic corrosion inspections to an efficient, focused prognostics and health monitoring (PHM) system. Corrosion modeling in oil & gas applications, especially in cathodic protection design, inhibitors feeding. Design of corrosion in concrete. High temperature corrosion life prediction of components<br>General management approach for better organization. Basis of corrosion management. Tools of corrosion management. Organizational policies and their implementation. Corrosion management begins with design, effective corrosion control methodologies and their implementation. Corrosion monitoring and its importance in corrosion management. Periodic health monitoring and maintenance, Risk based design and identification of vulnerable components. Role of failure analysis and its importance in corrosion management by using its input in better design and control policies. |
| 8. | Suggested Books | 1. R. A. Adey, Modelling of Cathodic Protection Systems (Advances in Boundary Elements), ISBN-10: 1853128899, ISBN-13: 9781853128899.<br>2. A. S. Khanna, High Performance Organic Coatings, CRC, Woodhead Publications, 2008, ISBN: 978-1-84569-265-0.<br>3. A. S. Khanna, Introduction to High Temperature Corrosion, ASM Publication, 2002, ISBN: 978-0871707628.<br>4. C. Andrade and G. Mancini, Modelling of Corroding Concrete Structures: Proceedings of the Joint fib-RILEM Workshop held in Madrid, Spain, 22-23 November 2010 (RILEM Bookseries)<br>5. Integrity of Pipelines Transporting Hydrocarbons: Corrosion, MechanisM.S., Control, and Management (NATO Science for Peace and Security Series C: Environmental Security), ISBN-13: 978-9400705876. |

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| 1. | Course Code | **MSE 641** |
| 2. | Title of the Course | **High Temperature Oxidation and Corrosion** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose students towards high temperature corrosion |
| 7. | Course Syllabus | Difference between ambient temperature corrosion and High temperature corrosion, basics of oxidation, thermodynamic criterion, Ellingham diagram, nomographic representation of oxidation potential, oxide layer growth mechanisM.S. and measurement techniques, thermogravimetric techniques, isothermal and cyclic oxidation, concept of activation energy and rate constants, defects in oxides, Wagner hauffe rules, diffusion in oxides, fick's laws, kirkendal diffusion, temperature effect of diffusion, marking studies in oxide layers and oxidation mechanisM.S. using tracer studies. Thin layer oxidation, Cabrera Mott theory, Ely Wilkensin theory and theories based upon ion migration, electron jump and role of oxide structure. Thick layer oxidation, Wagner's Theory. Oxidation of pure metals, Ni, Fe, Co, Ti, Zr, Nb. Multioxide layer theory, oxidation of alloys, internal oxidation, selective oxidation, breakaway oxidation, catastrophic oxidation, oxidation of steels, stainless steels, superalloys. Oxidation in mixed environment, sulphidation, carburization, metal dusting. Hot Corrosion with examples from gas turbines and coal based power plants. Criteria of corrosion protection at high temperatures. Oxide growth stresses, scale spallation. Active element effect. Development of alloys for Gas turbine and aerospace applications, selection of materials for high temperature application. |
| 8. | Suggested Books | • A. S. Khanna, Introduction to High Temperature Corrosion, ASM Publication, 2002, ISBN: 978-0871707628.<br>• Evans, R. Ulick, An Introduction to Metallic Corrosion, Edward Arnold, London, UK, 1948, ISBN: 9780713127584.<br>• Fontana, G. Mars, Greene and D. Norbert, **Corrosion Engineering**, McGraw-Hill, New York, 1967, ISBN: 978-0070214637.<br>• D. Stephen, Cramer, S. Bernard and Jr. Covino, ASM Corrosion Fundamentals and Testing, ASM International, Edited, ISBN: 0-87170-705-5. |

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| 1. | Course Code | **MSE 698** |
| 2. | Title of the Course | **PG Seminar Course** |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Course Syllabus | In this course a PG student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her PG Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 7. | Textbook | None |
| 8. | Other references | Books and research publications in various relevant journals/conference proceeding, etc. |

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| 1 | **Course Code** | **MSE 724** |
| 2 | **Course Title** | **Thin FilM.S. and Devices Fabrication** |
| 3 | Credit structure | L-T- P-Credits<br>2-1-2-4 |
| 4. | Name of the Concerned Discipline | Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course is aimed to provide up-to-date knowledge on the preparation of thin filM.S. and then utilization of the same for device fabrication. to students how thin filM.S. can be prepared, then how can be utilized for the device fabrications. To introduce the current fields of research in this subject. |
| 7. | Course Syllabus | **Introduction and Overview:** Basic Physics, Chemistry and Materials science<br>**Steps in thin film formation:** Thermal accommodation, binding, surface diffusion, nucleation, island growth, coalescence, *etc.*<br>**Thin Controlling Parameters:** Environment, Temperature, Concentration, *etc.*<br>**Film Deposition:** Vacuum and kinetic theory of gasses, Evaporation, Sputtered deposition, Cathodic Arc Deposition, Ion Beam, Molecular Beam, Wet chemical, Electrochemical, Hydrothermal, *etc.*<br>**Thin Film Characterization:** Imaging techniques, structural technique, chemical technique, optical technique, electrical/magnetic technique, mechanical technique.<br>**Chemical Mechanical Polishing/Planarization (CMP):** Chemical process and Mechanical process, Working principals, Usage in semiconductor fabrication, Limitations of CMP, Applications, *etc*.<br>**Wafer processing and Device fabrication:** Wafer fabrication and processing - its importance in device fabrication, Introduction to lithography, Introduction to various electrode pattering and materials involved in electronic devices. Materials related probleM.S. and challenges ahead in microelectronics industry.<br>**Laboratory work:** Thin film deposition by various techniques; Characterizations by -X-ray diffraction pattern (XRD), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Uv-Vis, Raman, etc.; device fabrications like -gas sensors, -Uv sensors, *etc.* |
| 8. | Suggested Books | 1) L I. Maissel and R. Glang, **Handbook of Thin Film Technology,** McGraw-Hill, 1970.<br>2) M. Ohring, **Materials Science of Thin FilM.S.**, Academic Press (2nd Edition) 2001, ISBN-13:978-0125249751.<br>3) J. L. Vossen and W. Kern, **Thin Film Processes,** Academic Press (January 11, 1979) ISBN-13:978-0127282503.<br>**4) M. H. Francombe, Handbook of Thin Film Devices,** Academic Press (Volume-I-V) 2000, ISBN:978-0122653209.<br>5) Z. Cao, **Thin Film Growth: Physics, Materials Science and Applications,** Woodhead Publishing; 1 edition (August 1, 2011) ISBN-13: 978-1845697365.<br>6) F. C. Matacotta and G. Ottaviani**, Science and Technology of Thin FilM.S.,** World Scientific Publishing Co. 1995, ISBN: 978-9810221935.<br>7) S. Wolf**, Silicon processing for the VLSI Era — Vol. IV Deep-submicron Process Technology**, Lattice Press Publisher, 2002, ISBN 978-0-9616721-7-1, Chapter 8 "Chemical mechanical polishing" pp. 313 |

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|---|---|---|
| 1 | **Course Code** | **MSE 725** |
| 2 | **Course Title** | **Single Crystal Growth Techniques** |
| 3 | Credit structure | L-T- P-Credits<br>2-1-2-4 |
| 4. | Name of the Concerned Discipline | Centre for Materials Science and Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To provide basic knowledge about importance of materials synthesis and growth of single crystals to students. |
| 7. | Course Syllabus | Crystal growth from solids: nucleation and crystallization, e.g. in metals and glass ceramics.<br>Crystal growth from liquids: melt growth – Bridgman, Czochralski, Kyropoulos technique, Zone melting technique, Verneuil technique LPE; solution growth – hydrothermal, co-precipitation, sol-gel, polymer precursor processes; spray processes – plasma spray, flame spray techniques; High Pressure High Temperature Synthesis Technique, *etc*. |
| 8. | Suggested Books | 1) G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer Handbook of Crystal Growth, 2010, ISBN: 9783540747611.<br>2) D. T. J. Hurle, Handbook of crystal growth. Vol. 2: Bulk crystal growth. a: Basic techniques; b: Growth mechanisM.S. and dynamics, Elsevier Science Publishers, 1994, ISBN: 0444815546.<br>3) H. K. Henisch, Crystal Growth in Gels, Courier Dover Publications, 1996, ISBN: 9780486689159<br>4) A. Holden and P. Morrison, **Crystals and Crystal Growig, MIT Press, 1982, ISBN:** 9780262580502.<br>5) R. A. Laudise, J. B. Mullin, Boyan Mutaftschiev, **Crystal growth 1971**: **proceedings of the third International Conference on Crystal Growth, Marseille, France, 5-9 July, 1971, Volume 3, ISBN:** 9780720402407. |

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|---|---|---|
| 1. | Course Code | **MSE 797 (Autumn Semester)**<br>**MSE 798 (Srping Semester)** |
| 2. | Title of the Course | Ph.D. Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Materials Science Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various journals |

# Course Structure

# of

# PG and Ph.D. Program in Chemistry

# and

# Syllabi of Courses

# Course Structure for M.Sc. (2 year) and M.Sc. + Ph.D. Dual Degree Program in Chemistry

**Minium Education Qualification (MEQ):** Bachelor's degree with Chemistry as a subject for three years/ six semesters.

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE.
**(b) Indian Students:** Valid JAM qualification in Chemistry.

**Eligibility Requirement (ER):** As per the brochure of Joint Admission test for M.Sc. (JAM).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Not Applicable

**Duration of the Program:** 2 years on full-time basis**.**

**Course Structure for two-year Full-time M.Sc. (Chemistry) Program**

**1st Year: Semester-I**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| CH 601 | Quantum Mechanics and Group Theory | 2-1-0 | 3 |
| CH 621 | Structural Organic Chemistry | 2-1-0 | 3 |
| CH 623 | Synthetic and Mechanistic Aspects of Organic Chemistry | 2-1-0 | 3 |
| CH 641 | Advanced Topics in Inorganic Chemistry | 2-1-0 | 3 |
| CH 643 | Modern Techniques in Inorganic Chemistry | 2-1-0 | 3 |
| | | **Total minimum credits earned during the semester** | **15** |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| CH 602 | Thermodynamics, Kinetics, Electrochemistry | 2-1-0 | 3 |
| CH 604 | Molecular Spectroscopy | 2-1-0 | 3 |
| CH 624 | Total Synthesis and Natural Products Chemistry | 2-1-0 | 3 |
| CH 642 | Applied Inorganic and Nuclear Chemistry | 2-1-0 | 3 |
| CH 698 | PG Seminar Course | 0-2-0 | 2 |
| CH 700 | Advanced Chemistry Lab | 0-0-6 | 3 |
| | | **Total minimum credits earned during the semester** | **17** |

**2 nd Year: Semester-III**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| CH 799 | M.Sc. Research Project (Stage-I) | 0-0-36 | 18 |

**2 nd Year: Semester-IV**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| CH 800 | M.Sc. Research Project (Stage-II) | 0-0-36 | 18 |
| | | **Total minimum credits to be earned during the program** | **68** |

**NOTE:** 1. Request for conversion from M.Sc. to M.Sc. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivating PG students at the end of the **third semester of their program.** The confirmation of conversion of M.Sc. program and to M.Sc. + Ph.D. dual degree program is done during 4th semester with subject to successfully qualifying CSIR/UGC-JRF or equivalent fellowship to enable receiving Ph.D. scholarship.

2. The enhancement in the scholarship from M.Sc. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Sc. degree are fulfilled AND candidate successfully qualifies CSIR/UGC-JRF or equivalent fellowship, whichever is later**.**

**3. If the** student opts for Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Sc. degree can be earned **before the specified date during the 4th semester** of the normal M.Sc. Program by getting the M.Sc. Research Project examined in the standard manner as per the requirements for the award of an M.Sc. degree.

## Course Structure for Ph.D. Program in Chemistry
### (From AY 2010-11 to AY 2012-13)

### (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | CH 701 | Spectroscopic Techniques | 2-1-0-3 |
| 2 | CH XXX | Elective-I | x-x-x-x |
| 3. | CH XXX | Elective-II | x-x-x-x |
| 4 | CH 797 * / CH 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | CH XXX | Elective-III | x-x-x-x |
| 2 | CH XXX | Elective-IV | x-x-x-x |
| 3 | CH XXX | Elective-V | x-x-x-x |
| 4 | CH 798 * / CH 797* | Ph.D. Seminar Course | 0-2-0-2 |

### Elective Courses available from the Discipline of Chemistry

| S.No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | CH 704 | Chemistry at Surfaces and Interfaces | 2-1-0-3 |
| 2. | CH 705 | Materials Chemistry | 2-1-0-3 |
| 3. | CH 706 | Photochemistry | 2-1-0-3 |
| 4. | CH 708 | Catalysis: Approaches and Applications | 2-1-0-3 |
| 5. | CH 709 | Advanced Bioinorganic Chemistry | 2-1-0-3 |
| 6. | CH 710 | Molecular Modeling and Computational Chemistry | 2-1-0-3 |
| 7. | CH 711 | Bio-Organic and Medicinal Chemistry | 2-1-0-3 |
| 8. | CH 720 | Asymmetric Synthesis | 2-1-0-3 |

Note:

1. M.Tech./MPhil qualified candidates have to do one semester coursework (with two-three PG level courses) while M.Sc./B.Tech. qualified candidates have to do two semester course work (with minimum five PG level courses).

2. Core courses are compulsory.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

## Course Structure for Ph.D. Program in Chemistry

### (From AY 2013-14 onwards)

### (A) Semester-I (autumn / spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-x |
| 2 | ZZ xxx | Elective-II | x-x-x-x |
| 3 | ZZ xxx | Elective-III | x-x-x-x |
| 4 | CH 797* / ME 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (spring / autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective- IV | x-x-x-x |
| 2 | ZZ xxx | Elective-V | x-x-x-x |
| 3 | ZZ xxx | Elective-VI | x-x-x-x |
| 4 | CH 798* / ME 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Chemistry Courses for Elective-I to VI** *(in addition to these courses, students can take courses from the other disciplines also)*

| S. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | CH 701 | Spectroscopic Techniques | 2-1-0-3 |
| 2. | CH 704 | Chemistry at Surfaces and Interfaces | 2-1-0-3 |
| 3. | CH 705 | Materials Chemistry | 2-1-0-3 |
| 4. | CH 706 | Photochemistry | 2-1-0-3 |
| 5. | CH 708 | Catalysis: Approaches and Applications | 2-1-0-3 |
| 6. | CH 709 | Advanced Bioinorganic Chemistry | 2-1-0-3 |
| 7. | CH 710 | Molecular Modeling and Computational Chemistry | 2-1-0-3 |
| 8. | CH 711 | Bio-Organic and Medicinal Chemistry | 2-1-0-3 |
| 9. | CH 720 | Asymmetric Synthesis | 2-1-0-3 |

**NOTE:**

1. A Ph.D. student having **M.Sc./ B.Tech./ BE or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*
2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

| | | |
|---|---|---|
| 1. | Course Code | **CH 601** |
| 2. | Title of the Course | **Quantum Mechanics and Group Theory** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | The purpose of this course is to provide an introduction to the quantum chemistry, which uses high-level mathematics as a tool to understand atomic, molecular structure and properties, as well as chemical reactivity. In addition group theory tells us about molecular shapes, symmetry and selection rules used in spectroscopy. |
| 7. | Course Syllabus | **Quantum Chemistry:**<br>Basic concepts of calculus, vectors and matrices, black body radiation, classical wave equation, Schrödinger wave equation, models in quantum chemistry: particle in a box, harmonic oscillator and rigid rotor, theorems in quantum chemistry, spherical harmonics, approximation methods: variation and perturbation methods, multi electron atoms, atomic term symbols, di-atomic molecules, Born-Oppenheimer approximation, LCAO and molecular orbital theory, introduction to Hartree-Fock, computational quantum chemistry.<br>**Group Theory:**<br>Symmetry Operations, Point Groups, Construction of Character tables, Reducible and irreducible representation, Representation of molecular orbitals, Chemical applications: molecular shapes, selection rules in spectroscopy. |
| 8. | Suggested Books | **Text Books**<br>1. P. W. Atkins, **Molecular Quantum Mechanics**, Clarendon Press, Oxford, 1980.<br>2. I. N. Levine, **Quantum Chemistry**, 4th Edn., Prentice Hall of India Pvt. Ltd., New Delhi, 1995.<br>3. D. A. McQuarrie, **Quantum Chemistry**, University Science Books, 1983.<br><br>**Reference Books**<br>1. A. K. Chandra, **Introductory Quantum Chemistry**, Tata McGraw-Hill Publishing Co, New Delhi, 1989.<br>2. E. Merzbacher, **Quantum Mechanics**, John Wiley and Sons, 1970.<br>3. L. Pauling and E. B. Wilson, **Introduction to Quantum Mechanics**, McGraw-Hill, 1939.<br>4. P. C. W. Davies, **Quantum Mechanics**, ELBS, 1985.<br>5. A. Vincent, **Molecular Symmetry and Group Theory**, John Wiley and Sons, New York, 1998.<br>6. Volker Heine, **Group Theory in Quantum Mechanics: An Introduction to Its Present Usage**, Dover Publication, New York, 1991. |

| | | |
|---|---|---|
| 1. | Course Code | **CH 602** |
| 2. | Title of the Course | **Thermodynamics, Kinetics and Electrochemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | The objective of this course involves introduction to concepts of thermodynamics and kinetics and their application to various chemical systems. |
| 7. | Course Syllabus | **Chemical Thermodynamics and Kinetics**: Differential calculus, properties of gases, Vander Waals and Rddlich-Kwong equation, second virial coefficients, Lennard-Jones interatomic potential, kinetic theory of gases, laws of thermodynamics, Helmholtz and Gibbs energies, Maxwell relations, phase equilibrium, chemical potentials, partial molar quantities, Gibbs-Duhems equation, solid-liquid solutions, Debye-Huckel theory, Chemical equilibrium and Van't Hoffs equation. Theories of reaction rates: application to uni-, bi- and intermolecular reactions, thermodynamic formulation of reaction rates, Kinetic isotope effect, reactions in solution-cage effect, diffusion and activation controlled reactions.<br>**Statistical Thermodynamics:** Introduction to statistical methods, Boltzmann factor, partition function, generalized ensembles: micro-canonical, canonical and grand-canonical, applications of statistical methods to evaluate: mean energies, heat capacities, residual entropies and free energies.<br>**Electrochemistry:** Introduction, Ion-solvent interaction, Born model and Born equation. Enthalpy of ion-solvent interaction and its calculation, solvation number, ion association, the rates of electron transfer processes, Theory of electron transfer processes: electron tunnelling, processes at electrode: electrode-solution interface, Butler-Volmer equation, current-overpotential relationship, voltametry, electrolysis. |
| 8. | Suggested Books | **Text Books**<br>1.Peter A. Rock, **Chemical Thermodynamics**, University Science Books, 2003<br>2. T. L. Hill, **An Introduction to Statistical Thermodynamics**, Courier Dover Publications 1960<br>3. D. A. McQuarrie, **Statistical Mechanics**, Harper and Row, 1976.<br>4. K. J. Laidler, **Chemical Kinetics**, TMH Publishing Company Limited, 1988.<br>5. S. Glasstone, **An Introduction to Electrochemistry**, D. Van Nostrand Company, 1962.<br>6. J. O'M. Bockris, A. K. N. Reddy, **Modern Electrochemistry**, Vol. I, Plenum Press, New York, 1970.<br>**Reference Books**<br>1. Irving M. Klotz and Robert M. Rosenberg, **Chemical Thermodynamics: Basic Concepts and Methods**, Wiley, 2008<br>2. D. Chandler, **Introduction to Modern Statistical Mechanics**, Oxford University Press 1987.<br>3. M. R. Wright, **Fundamental Chemical Kinetics**, Horwood Publishing, 1999. |

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|---|---|---|
| 1. | Course Code | **CH 604** |
| 2. | Title of the Course | **Molecular Spectroscopy** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | This course provides theoretical aspects for various spectroscopic techniques such as emission, absorption, scattering and NMR. In addition statistical mechanics provides a probabilistic approach to equilibrium properties of large numbers of degrees of freedom in atoms and molecules. |
| 7. | Course Syllabus | **Molecular spectroscopy:** Introduction to spectral energy domains and measurement of spectra, Implications of discrete energy levels, Population of States–Boltzman Distribution, Interaction of radiation with matter, Electronic spectroscopy (UV-visible, fluorescence and phosphorescence): Simple chromophoric groups, conjugated and aromatic systems. Characteristic absorption and emission of organic and inorganic compounds. origin of line-widths in molecular spectra, Transition dipole moment and Fermi's Golden Rule, Einstein's Coefficients, Lasers and Masers; Rotational (Microwave) spectroscopy, Molecular vibrations - Infrared spectroscopy, Normal mode analysis, Raman Scattering, Selection Rules from Group Theory, Molecular electronic spectra, Photo-physical processes, Non-Linear Spectroscopy, NMR spectra: theory, relaxation process, instrumentation, chemical shift and shielding, factors contributing to magnitude of shielding, spin interactions its origin, equivalent protons, qualitative idea of energy levels of AX and $A_2$ systems, a few representative example. |
| 8. | Suggested Books | **Text Books**<br>1. C. N. Banwell and E. M. McCash, **Fundamentals of Molecular Spectroscopy** (4th edition), Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1994.<br>2. K. K. Rohatgi, Mukkerjee, **Fundamentals of Photochemistry**, Wiley Eastern Ltd., 1992.<br>3. T. L. Hill, **An Introduction to Statistical Thermodynamics**, Courier Dover Publications 1960.<br>**Reference Books**<br>1. D. A. McQuarrie and J. D. Simons, **Physical Chemistry** (1st edition), Viva Books Private Limited, New Delhi, 1998.<br>2. W. Demtroder, **Laser Spectroscopy- Basic Concepts and Instrumentation** (3rd edition)**,** Springer, 2004<br>3. K. Denbigh, **Principles of Chemical Equilibrium**, Cambridge University Press, Cambridge, 1981.<br>4. F. Reif, **Fundamentals of Statistical and Thermal Physics**, McGraw-Hill, 1965.<br>5. L. D. Landall and E. M. Lifshitz, **Statistical Physics** (2nd Revised English edition), Pergamon Press, Oxford, 1977. |

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| 1. | Course Code | **CH 621** |
| 2. | Title of the Course | **Structural Organic Chemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | Students will become familiarized with the modern theories and instrumental techniques employed to understand the fundamentals of structure, bonding and reactivity in organic molecules. |
| 7. | Course Syllabus | MO treatment of acyclic and cyclic conjugated systems, Huckel rule and concept of aromaticity; annulenes, heteroannulens, fullerenes (C60), alternate and non-alternate hydrocarbons, anti-aromaticity, pseudo-aromaticity, homo-aromaticity, Frost diagram, Huckel treatment – applications to ethylene, allyl, cyclopropenyl, butadiene, cyclobutadiene, Importance of antibonding orbitals in organic reactions.<br>**Photochemistry:** Basic principles, Jablonski diagram, photochemistry of olifinic compounds, *Cis-trans* isomerization, Paterno-Buchi reaction, Norrish Type-I and II reactions, Photoreduction of ketons, di-π methane rearrangement, Photochemistry of arenas; Photoreactions in solid state, synthetic applications; cyclization of radicals<br>**Pericyclic reaction:** Classification and stereochemical modes; Thermal and photopericyclic reactions, selection rules and stereochemistry of electrocyclic reactions, 2-component cycloadditions – antarafacial and suprafacial additions; Rationalization based on Frontier M.O. approach, correlation diagram, Dewer-Zimmermann approach, Mobius & Huckel systems; Claisen, Cope, Aza-Cope and Oxy-Cope rearrangements, Sommelet - Hauser, Ene reaction – Applications in Organic synthesis; Fluxional Tautomerism<br>**Stereochemistry:** Effects of conformation on reactivity in acyclic compounds and cyclohexanes Conformation and reactivity of monocyclic systems-3 to 10 membered rings, 6-6, 6-5,6-4, 5-5 bicyclic systems, 6-6-6, 6-5-6, 5-6-5 and 5-5-5 tricyclic systems, enantioselective and diastereoselective synthesis, Addition to carbonyl compounds. Chirooptical properties of organic molecules: Origin, Theory of CD, ORD, their applications, haloketone rules, sector rules, helicity rules, excitation chirality. Chiral analysis by polarimeter, NMR, GC, HPLC and Capillary Electrophoresis (CE) methods, Baldwin's rules.<br>**General Concept of Spectroscopy and their applications:** IR, NMR, M.S. |
| 8. | Suggested Books | **Text Book:**<br>1. E. L. Eliel and S. H. Wilen, **Stereochemistry of Organic Compounds**, John Wiley & Sons, New York, 1994.<br>2. R. M. Silverstein, G. C. Bassler and T. C. Morril, **Spectroscopic Identification of Organic Compounds,** John Wiley, 1991.<br>3. W. Carruthers and I. Coldham, **Modern Methods of Organic Synthesis**, First South Asian Edition 2005, Cambridge University Press.<br>4. S. Sankararaman, **Pericyclic Reactions- A text Book,** Wiley VCH, 2005.<br>**References**<br>1. F. A. Carey and R. A. Sundberg, **Advanced Organic Chemistry, Part A: Structure and Mechanisms** ($5^{th}$ edition), Springer, New York, 2009.<br>2. F. A. Carey and R. A. Sundberg, **Advanced Organic Chemistry, Part B: Reactions and Synthesis** ($5^{th}$ edition), Springer, New York, 2009.<br>3. W. Kemp, **Organic Spectroscopy** ($2^{nd}$ edition), ELBS-Macmillan, 1987<br>4. I. Fleming, **Frontier Orbitals and Organic Chemical Reactions**, Wiley, London, 1976.<br>5. N. J. Turro, V. Ramamurthy and J. C. Scaiano, **Modern Molecular Photochemistry of Organic Molecules,** University Science Books, CA, 2010.<br>6. J. March and M. B. Smith, **March's Advanced Organic Chemistry: Reactions, MechanisM.S., and Structure** (6th Edition), Wiley, 2007. |

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|---|---|---|
| 1. | Course Code | **CH 623** |
| 2. | Title of the Course | **Synthetic and Mechanistic Aspects of Organic Chemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To develop understanding of the intermediates involved in reactions and applications of variety of oxidizing, reducing and organometallic reagents in organic synthesis |
| 7. | Course Syllabus | **Reactive intermediates** – Formation and stability of classical and non-classical carbonium ions, carbanions, carbenes, nitrenes, radicals and arynes; Nucleophilic, electrophilic and radical substitutions, addition and elimination reactions; Methods of determining reaction mechanisms, Kinetic isotope effect, Hard and soft acids and bases; Hammet equation. Mechanisms of some familiar name reactions: Robinson annulation, Peterson elimination, Stork enamine reaction, Mannich reaction, Sharpless asymmetric epoxidation, Barton reaction, Hofmann-Loffler-Freytag reaction, Shapiro reaction, Baeyer-Villiger reaction, Chichibabin reaction.<br>**Oxidations in Organic Chemistry:** oxidative processes based on one-electron and two-electron oxidants, oxidations with Cr(VI) oxidants; Collin oxidation, PCC, PDC and PFC, DM.S.O-oxidations: Swern, Moffat, DM.S.O-$SO_3$ complex, DM.S.O-$Ac_2O$, Hypervalent iodine oxidations: Dess-Martin periodinane, IBX, iodobenzene diacetate, Oxidations with $MnO_2$, $SeO_2$, $Tl(NO_3)_3$, $Ag_2O$, $RuO_4$ and $OsO_4$, Shi-epoxidation.<br>**Reductions in Organic Chemistry:** Different reductive processes, reduction with metal hydrides of B, Al, Sn and Si, catalytic and transfer hydrogenations, dissolving metal reductions, synthetically useful hydrogenolysis reactions, samarium and indium-based reducing agents, enzymatic and microbial reductions**.**<br>**Organometallic Chemistry:** Applications of organotransition metals in organic synthesis-preparative, structural and mechanistic aspects, Davies rule, catalytic nucleophilic addition and substitution reaction, coupling reaction-Heak, stille, Suzuki coupling, Sonogashira, Zieglar natta reaction, olefin metathesis, Tebbe's Reagent, Pauson-Khand reaction, functional organometalllic compounds, use of indium and zinc. Organosilicon chemistry, synthetic uses of silyl ethers, silylenol ethers, TM.SC.l, TM.S.I, TM.SC.N, alkene synthesis, alkenyl, vinyl, aryl, allyl and acyl silanes, Brook rearrangement, silicon Baeyer Villiger rearrangement. |
| 8. | Suggested Books | **Text Books**<br>1. W. Carruthers, **Modern Methods of Organic Synthesis**, Cambridge University Press, 1996.<br>2. I. Ojima, **Catalytic Asymmetric Synthesis** (2nd edition), Wiley−VCH, New York, 2000<br>3. N. S. Isaacs, **Physical Organic Chemistry**, ELBS, Longman, UK, 1987.<br>4. S. Warren, **Organic Synthesis, The disconnection Approach,** John Wiley & Sons, 2004.<br>**References**<br>1. L. Kuerti and B. Czako, **Strategic Applications of Named Reactions in Organic Synthesis,** Elsevier Academic Press, 2005.<br>2. J. Tsuji, **Palladium Reagents and Catalysts, New Perspectives for the 21st Century**, John Wiley & Sons, 2003.<br>3. R. Noyori, **Asymmetric Catalysis in Organic Synthesis**, John Wiley & Sons, 1994.<br>4. T. H. Lowry and K. S. Richardson, **Mechanism and Theory in Organic Chemistry** (2nd edition), Harper & Row, New York, 1981.<br>5. M. B. Smith, **Organic Synthesis** (2nd Edition), McGraw Hill, 2010.<br>6. J. Clayden, N. Greeves, S. Warren and P. Wothers, **Organic Chemistry**, Oxford University Press, 2001. |

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|---|---|---|
| 1. | Course Code | **CH 624** |
| 2. | Title of the Course | **Total Synthesis and Natural Products Chemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To familiarize students with modern methods of natural product synthesis |
| 7. | Course Syllabus | Modern approaches of synthesis of furan, thiophene, pyrrole, pyridine, quinoline, isoquinoline and indole; their reactivities, Synthesis and reactions of azidirines and azetidines.<br>**Natural Products**<br>Isoprene rule; Structure elucidation (by chemical and spectroscopical methods); synthesis, Biogenesis and Biosynthesis of representative examples of acyclic,12 monocyclic and bicyclic monoterpenes. Structural types – general introduction to sesqui, di-and tri-terpenoids. Familiarity with methods of structural elucidation (chemical and spectroscopical methods, biosynthesis, synthesis of alkaloids (ephedrine and atropine), **Steroids –** General methods of study and structural types, chemistry of cholesterol, hormones, bile acids, Vitamins of D-group, diosgenin.<br>**Alkaloids**: Structure, transformation and biosynthesis of alkaloids from terrestrial and marine sources; chemistry of indole and peptide alkaloids<br>**Carbohydrate:**<br>Deoxysugars, amino sugars, glycal sugars and their synthetic aspects. Carbohydrates as chiral pools in organic synthesis<br>**Total Synthesis:**<br>Total synthesis of Longifolene, Reserpine, Juvabione, Aphidicolin and Fredericamycin A and prostaglandins (PGE2, PGF2α), Taxol.<br>**Bio-Organic Chemistry:** Enzymes and antibodies ( syntheses and applications) |
| 8. | Suggested Books | **Text Books**<br>1. J. A. Joules and K. Mills, **Heterocyclic Chemistry** (5th edition), published by Chichester, Wiley-Blackwell, 2010.<br>2. E. J. Corey and X. M. Cheng, **The Logic of Chemical Synthesis**, John Wiley & Sons, 1995.<br>3. S. V. Bhat, B. A. Nagasampagi, and S. Meenakshi, **Natural Products Chemistry and Applications,** Narosa Publishing House, 2009.<br>4. E. M. Carreira and L. Kvaerno, **Classics in Stereoselective Synthesis**, Wiley VCH, 2009.<br>**References**<br>1. T. Eicher and S. Hauptmann, **The Chemistry of Heterocycles**, Wiley-VCH, Weinheim, 2003.<br>2. K. C. Nicolaou and S. A. Snyder, **Classics in Total Synthesis-II**, VCH, 2003.<br>3. K. C. Nicolaou and E. J. Sorensen, **Classics in Total Synthesis**, VCH, 1996.<br>4. R. M. Acheson, **An Introduction to the Chemistry of Heterocyclic Compounds** (3rd edition), Wiley India Pvt Ltd, 2008.<br>5. T.L. Gilchrist, **Heterocyclic Chemistry**, Prentice Hall, 1997. |

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| 1. | Course Code | **CH 641** |
| 2. | Title of the Course | **Advanced Topics in Inorganic Chemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To familiarize with synthesis, bonding and reactions of transition metal complexes |
| 7. | Course Syllabus | Transition Metal π-acid ligands, synthesis and reactivity of transition metal complexes with small molecules, LNCC and HNCC, Wade's rule and capping rule.<br><br>Synthesis, structure, bonding and reactivity of transition metal complexes with different unsaturated systems, Oxidative addition, reductive elimination, insertion reactions, activation of small molecules, different types of catalytic reactions of unsaturated hydrocarbons.<br><br>Formation constant from spectrophotometry, chelate and macrocyclic effect, associative and dissociative mechanism, trans effect, isomerisation, racemization, electron transfer reaction, fluxional molecules |
| 8. | Suggested Books | 1. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, **Advanced Inorganic Chemistry** ($6^{th}$ edition), John Wiley & Sons (Asia) Pvt. Ltd., 2003.<br>2. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, **Inorganic Chemistry** ($4^{th}$ edition), Pearson Education, 2006.<br>3. S. Asperger, **Chemical kinetics and Inorganic Reaction Mechanism** ($2^{nd}$ edition), Kluwer Academic, 2002.<br>4. R. C. Mehrotra and A. Singh, **Organometallic Chemistry** ($2^{nd}$ edition), New Age International (P) Ltd Publishers, 2007.<br>5. R. H. Crabtree, **The Organometallic Chemistry of transition Metals** ($5^{th}$ Edition), Wiley, 2009.<br>6. P. J. Dyson and J. S. McIndoe, **Transition Metal Carbonyl Cluster Chemistry**, Gordon and Breach Science Publishers, 2000.<br>7. P. Atkins, T. Overton, J. Rourke, M. Weller, and F. Armstrong, **Shriver & Atkins Inorganic Chemistry** ($4^{th}$ edition), Oxford University Press, 2009. |

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| 1. | Course Code | **CH 642** |
| 2. | Title of the Course | **Applied Inorganic and Nuclear Chemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To familiarize students with lanthanide-actinide chemistry, bio-organic, metal-organic frameworks and nuclear chemistry. |
| 7. | Course Syllabus | Boranes, carboranes, silicones, phosphazanes, isopoly-, heteropolyacids, zeolites and clay**,** Lanthanide and Actinide Chemistry<br><br>Role of metal ions in biology, metalloproteins in hydrolysis, structural role, nitrogen fixation and cycle, photosystem, oxygen carrying agent, uptake and storage of protein, redox reaction, model complex and metals in medicine.<br>Metal organic framework, synthesis, topology and applications.<br><br>Nuclear forces, Nuclear structure and properties, Radioactive decay, radiotracers and nuclear reactions. |
| 8. | Suggested Books | **Text books**<br>1. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, **Advanced Inorganic Chemistry** (6$^{th}$ edition), John Wiley & Sons (Asia) Pvt. Ltd. 2003.<br>2. J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, **Inorganic Chemistry** (4$^{th}$ Edition), Pearson Education, 2006.<br>3. S. Cotton, **Lanthanide and Actinide Chemistry**, Wiley, 2006,<br>4. S. J. Lippard and J. M. Berg, **Principles of Bioinorganic Chemistry**, Panima Publishing Corporation, 2005.<br>5. W. Kaim, B. Schwederski, **Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life,** Wiley, 2005.<br>6. L. R. MacGillivray, **Metal-Organic Frameworks**, Wiley, 2010<br>7. **Metal-organic Frameworks, Application from Catalysis to Gas storage,** Wiley.<br>8. W. D. Loveland, D. J. Morrissey and G. T. Seaborg, **Modern Nuclear Chemistry,** John Wiley, 2006.<br>9. G. Choppin, J.O. Liljenzin and J. Rydberg, **Radiochemistry & Nuclear Chemistry,** Butterworth Heinemann, 2002 |

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| 1. | Course Code | **CH 643** |
| 2. | Title of the Course | **Modern Techniques in Inorganic Chemistry** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To understand the correlation between modern techniques and inorganic chemistry |
| 7. | Course Syllabus | Electronic absorption spectra, Orgel diagram, Tanabe-Sugano diagram, adjusted crystal field theory, Nephelauxetic effect, MOT and octahedral and tetrahedral complex.<br><br>Magnetic behavious, spin-orbit coupling, quenching of orbital angular momenta, temperature independent paramagnetism, spin crossover.<br><br>Structural studies of Inorganic compound using IR, Raman and UV-vis spectra, Electron spin resonance spectroscopy in cubic and tetragonal ligand field, metal hyperfine coupling constant, Nuclear magnetic resonance spectroscopy, application with various inorganic nuclei, Mossbauer Spectra.<br><br>Precision and error, sampling, TGA-DSC, coulometry, polrography, amperometry, Cyclic voltametry, chromatography. |
| 8. | Suggested Books | **Text Books:**<br>1. J. A. Iggo, **NMR spectroscopy in Inorganic Chemistry**, Oxofrd University Press, 1999.<br>2. E. I. Solomon and A. B. P. Lever, **Inorganic Electronic Structure and Spectroscopy: Methodology**, John Wiley & sons, 2006<br>3. S. M. Khopkar, **Basic concept of Analytical chemistry** (2nd edition), New Age International Publishers, 2004.<br><br>**Reference Books:**<br>1. R. Boča, **A Handbook of Magnetochemical Formulae** (1st edition), Elsevier, 2012.<br>2. K. Nakamoto, **Infrared and Raman Spectra of Inorganic and Coordination Compounds** (6th edition), Wiley, 2009. |

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| 1. | Course Code | **CH 698** |
| 2. | Title of the Course | **PG Seminar Course** |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6 | Course Objective | To develop confidence and presentation skills of the student |
| 7. | Course Syllabus | In this course a PG student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her PG Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various relevant journals/conference proceeding, etc. |

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| 1. | Course Code | **CH 700** |
| 2. | Title of the Course | **Advanced Chemistry Lab** |
| 3. | Credit Structure | (L-T-P-Credit)<br>0-0-6-3 |
| 4. | Name of the Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Course | To expose students to the basic experimental techniques of all the branches of chemistry |
| 7. | Course Syllabus | **Inorganic Chemistry:**<br>1. Synthesis and characterization of metal complexes<br>2. Separation of metal ions using column chromatography<br>3. Electrochemical Investigation of potassium ferricyanide [$K_3Fe(CN)_6$]<br>**Organic Chemistry:**<br>A. **Techniques:**<br>1. Crystallization<br>2. Distillation<br>3. Steam Distillation<br>4. Vacuum Distillation<br>5. Extraction<br>6. Thin Layer Chromatography<br>7. Column Chromatography<br>8. Checking MP<br><br>B. **Synthesis and characterization of important organic molecules.**<br>Usual Spectroscopic Characterization (UV, IR, NMR, M.S. etc.)<br><br>**Physical Chemistry:**<br>**Exp. 1:** Colorimetric estimation of urease activity using UV-Vis spectroscopy.<br>**Exp. 2:** Solavtochromic shift of dye molecules using absorption and fluorescence spectroscopy.<br>**Exp. 3:** Preparation and characterization of silica particles under mild condition.<br>**Exp. 4:** Synthesis and characterization of liquid crystal<br>**Exp. 5:** Using Gaussian program predicting the transition state of organic reactions. |
| 8. | Suggested Books | Laboratory Manual |

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| 1. | Course Code | **CH 701** |
| 2. | Title of the Course | **Spectroscopic Techniques** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite | Nil |
| 6 | Scope of the course | |
| 7. | Course Syllabus | **Infrared Spectroscopy:** General principles, factors influencing vibrational frequencies, selection rules, Analysis of Infra-red technique, Fourier- transform IR–Spectroscopies. Introduction to terahertz spectroscopy, Application of IR and terahertz spectroscopy Spectroscopy to inorganic and organic compounds.<br>**Raman Spectroscopy:** Principles, normal, resonance and laser Raman Spectroscopies. Structure determination by symmetry selection rules (normal coordinate analysis). Application of Raman Spectroscopy to structural chemistry. Nuclear magnetic resonance Spectroscopy.<br>**Elctronic spectroscopy:** General principles, Electronic absorption spectra of organic and inorganic molecules, Selection rules and their implications. Instrumentation: analytical applications: qualitative and quantitative analyses.<br>**Luminescence Spectroscopy:** Introduction, characteristics of fluorescence and phosphorescence emission, effects of solvents on fluorescence spectra. Lippert equation, Time scale of excited state molecular processes in solution, Life times and quantum yields. Basic instrumentation, The Biochemical applications of solvent effects: localization of membrane-bound and protein- bound fluorophores, Polarization of emission, Measurements of fluorescence Polarization, Extrinsic causes of fluorescence depolarization. Effect of rotational diffusion on fluorescence anisotropies: the perrin equation. Chemical and biochemical applications of anisotropy measurements.<br>**NMR Spectroscopy:** Nuclear magnetic resonance Spectroscopy: General principles, sensitivity of the method, CW and FT-NMR, instrumentation. Application in chemical analysis (with special reference to 1H – NMR): Chemical shift, spin-spin splitting, area of peak, shift reagents, off-resonance decoupling, Nuclear Overhauser Effect, solid state and gas phase NMR spectra.<br>**Mass Spectrometry:** Mass spectrometry: Principles, advantages and limitations of Mass Spectrometry. Instrumentation, Methods of ionization, Metastable ions. Theory of Mass Spectrometry. Structure elucidation of inorganic and organic compounds.<br>**X-ray-diffraction and X-ray photoelectron spectroscopy:** Basics Principles and applications.<br>**Electron Paramagetic Resonance:** Basic Principles, Isotropic hyperfine effects, Zeeman energy, anisotropy, hyperfine anisotropy, applications<br>**Mössbauer Spectroscopy:** Fundamentals of Mössbauer spectroscopy and applications. |
| 8. | Suggested Books | 1. C.N. Banwell, **Fundamentals of Molecular Spectroscopy** ($4^{th}$ edition), Tata McGraw Hill, New Delhi, 1994.<br>2. R.M. Silverstein, G.C. Bassler, C. Morril, **Spectrometric Identification of Organic Compounds** ($5^{th}$ edition), John Wiley & Sons, 1991.<br>3. J. R. Lakowicz**, Principles of Fluorescence Spectroscopy** ($3^{rd}$ edition), 2006.<br>4. M. Rose, and R.A.W. Johnston, **Mass Spectrometry for Chemists and Biochemists** ($2^{nd}$ edition), Cambridge University Press, 1996.<br>5. D.L. Pavia, G.M. Lampman, G.S. Kriz, **Introduction to Spectroscopy** ($3^{rd}$ edition), Thomson Brooks/Cole, 2000.<br>6. Fritz Helmet, **Mössbauer Spectroscopy**<br>7. J.A. Weil, and J.R. Bolton, **Electron Paramagnetic Resonance: Elementary Theory and Practical Applications.** |

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| 1. | Course Code | **CH 704** |
| 2. | Title of the Course | **Chemistry at Surfaces and Interfaces** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | Undergraduate courses on surface chemistry or physics |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Introduction** to nanoscale and colloidal systems, Fundamentals of surface and interfacial chemistry. Surface tension and wettability. Insoluble monolayers.<br>**Self-assembled monolayers (SAM.S.):** Growth processes, Phase transitions, Mixed monolayers, applications of SAM.S.. Electrostatic interactions in self-assembling systems. Self-assembly of amphiphiles. Monolayers, micelles, and microemulaions.<br>**Adsorption phenomena:** Adsorption of surfactants at solid surfaces. Langmuir adsorption and models describing multilayer adsorption.<br>**Immobilization of biomolecules:** strategies and applications in nanobiotechnology. Enzyme responsive surface.<br>**Nanofabrication methods:** Bottom-up methods, photolithography, scanning probe methods, soft lithography, e-beam lithography.<br>**Chemical functionalization:** Recent advances in thiol-Au and silane chemistry. Layer-by- layer synthesis of multilayer assemblies. Applications.<br>**Spectroscopic and Imaging techniques:** AFM, STM, SEM, Confocal microscopy, Surface enhanced Raman spectroscopy (SERS), Imaging ellipsometry, X-ray based techniques.<br>**Heterogeneous Catalysis:** Historical Background, Catalysis, difference between homogeneous and heterogenous catalysis, reactive interfaces, effect of structures on reactivity, catalytic materials and their preparation, activity and selectivity, measurement of catalytic properties, applications in raw materials and their conversions, environmental protection and daily life, future of catalysis. |
| 8. | Suggested Books | 1. The Colloidal Domain: Where Physics, Chemistry, Biology and Technology Meet by D. Fennell Evans and Håkan Wennerström; 1999 John-Wiley and Sons, Inc.<br>2. Handbook of Surface and Colloid Chemistry by K. S. Birdi, 2008 CRC press.<br>3. Introduction To Surface Chemistry And Catalysis by Gabor A. Somorjai, Yimin Li, 2010 John Wiley and Sons.<br>4. Nano: The Essentials by T. Pradeep, 2007 Tata McGraw-Hill.<br>5. Nanobiotechnology II: More Concepts And Applications by Chad A. Mirkin, Christof M. Niemeyer, 2007 Wiley-vch Verlag Gmbh.<br>6. The Basis and Applications of Heterogeneous Catalysis by Bowker Michael, 1998 Oxford University Primer.<br>Research articles in the journals. |

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| 1. | Course Code | **CH 705** |
| 2. | Title of the Course | **Materials Chemistry** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Chemistry at the Nano-dimension:** Introduction: definition of a nano system, top-down and bottom up approach, dimensionality and size dependent phenomena, properties of Individual nanoparticles: Metal nanoparticles, semi-conducting nanoparticles, metal oxide nanoparticles, composite nanostructures, optical properties. Synthesis of Nanomaterials: Solution chemical methods, Gas or vapor based methods of synthesis: CVD, MOCVD and MBE, Sol-gel processing, Bioconjugation, Toxicity and green chemistry approaches of synthesis. Carbon nanotubes: synthesis, properties and surface functionalization, zeolites and graphenes. Magnetic nanoparticles: Synthetic methods and properties, Diamagnetism, paramagnetism and superparamagnetism, proton relaxation, surface modification. Applications in magnetic seperation, development of MRI contrast agents. Characterization of Nanomaterials: Electron microscopes-Scanning Electron Microscope, Transmission Electron Microscopes, Scanning Tunneling Microscopy, Atomic Force Microscopy, nano-tweezers, Dynamic Light scattering, Surface enhanced Resonance Raman spectroscopy, ICP-mass. Applications of Nanomaterials: Chemical and biomedical detection, imaging and therapy, Energy conversion: PV solar cells and Photo electro-chemical cells, Lasers, LEDs, photonic crystals.<br>**Metal Organic Frameworks:** Development of metal organic materials, guest removal and uptake, flexibility, topology and interpenetration, highly connected metal-organic framework, organometallic network, acentric and chiral network, application of metal-organic framework in nonlinear optics, selective absorption of gas and vapour, hydrogen, methane, carbon dioxide storage, magnetic materials.<br>**Organic Electronics:** OLED, WOLED, Liquid crystalline materials. NLO materials ($2^{nd}$ and $3^{rd}$ order NLO materials), 2Photon and multiphoton process. Organic solar cell, OFET (n-channel and P-channel) materials. |
| 8. | Suggested Books | 1. C.P. Poole, and F.J. Owens, **Introduction to Nanotechnology**, Wiley-India, 2006.<br>2. G.A. Ozin, C. Andre, and L. Arsenault, Cademartiri, **Nanochemistry: A chemical Approach to Nanomaterials**, Royal Society of Chemistry, 2005.<br>3. T. Pradeep, **NANO: The Essentials**, Tata-McGraw Hill, New Delhi, 2007.<br>4. K.J. Klabunde, **Nanoscale Materials in Chemistry**, Wiley-interscience, 2001.<br>5. Bharat Bhushan (Ed.) **Springer Handbook of Nanotechnology**, Springer, 2007.<br>Some recent publications in the reputed journals. |

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| 1. | Course Code | **CH 706** |
| 2. | Title of the Course | **Photochemistry** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Theories of electronic spectroscopy:** Introduction: Absorption, Scattering, reflection and emission, Light/Photon: Sources of light/photon, light detectors, Chromophores: From synthetic to naturally occurring chromophores<br>**Reactivity of electronic excited states of molecules:** Excited state deactivation pathways, Excited state reactions: excimers, exciplexes, electron transfer, energy transfer, proton transfer. Some photochemical organic reactions.<br>**Natural photochemical processes and application:** Mechanism of vision, Photosynthesis, Photo dynamic therapy (PDT) |
| 8. | Suggested Books | 1) "Fundamentals of photochemistry" by K.K. Rahatgi and K. K. Mukherjee.<br>2) "Modern Molecular photochemistry" by Nicholas J. Turro. |

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| 1. | Course Code | **CH 708** |
| 2. | Title of the Course | **Catalysis: Approaches and Applications** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | Masters in inorganic and organic chemistry |
| 6. | Scope of the Objective | To familiarize students with catalysts and there mode of interaction in homo- and heterogeneous conditions. |
| 7. | Course Syllabus | Catalysts and catalytic processes, important terminologies in catalysis (such as Turnover, TOF, TON, Catalyst poisoning, Deactivation, regeneration, recycling), Factors affecting catalyst and catalytic processes, Characterization of a catalyst and catalytic processes (Surface structure, chemical composition and topography by electron microscopy (SEM, TEM), X-ray and neutron methods (XRD, EDS, XPS), vibrational spectroscopy, NMR and others.)<br>Application of transition metal complexes and organometallic complexes based homogeneous catalysts in Metathesis reactions, Hydrogenation, Oxidation, Hydroformylation, C-C coupling reactions. Heterogeneous catalytic processes on free and supported nanocatalysts, Size dependent catalysis, Catalysts for CO oxidation, $H_2$ generation and C-C and C-heteroatom coupling reactions (such as, Sonogashira coupling, Heck reaction, Suzuki reaction, hydroamination etc.). |
| 8. | Suggested Books | **Text Books**<br>1. Introduction to surface chemistry and catalysis, G.A. Somorjai, Y. Li, 2010, Wiley-VCH. ISBN 978-0-470-50823-7.<br>2. Principle and practice of heterogeneous catalysis, J.M. Thomas, W.J. Thomas, 2008, VCH. ISBN 978-3-527-29239-4.<br>3. The chemistry of nanomaterials, C.N.R. Rao, A. Muller, A.K. Cheetham, Vol 2, 2006, Wiley-VCH. ISBN 978-3-527-30686-2.<br>4. Mechanisms in Homogeneous Catalysis, B. Heaton, 2005, Wiley-VCH. ISBN 978-3-527-31025-8,<br>5. Applied Homogeneous Catalysis, A. Behr, P. Neubert, 2012, Wiley-VCH. ISBN 978-3-527-32633-4,<br>**Reference Books**<br>1. Advanced nanomaterials, K.E. Geckeler, H. Nishide, Vol 1, 2010, Wiley-VCH. ISBN 978-3-527-31794-3.<br>2. Concept of modern catalysis and kinetics, I. Chorkendorff, J. W. Niemantsverdriet, 2$^{nd}$ revised Ed., 2007, Wiley-VCH. ISBN: 978-3-527-31672-4.<br>3. Nanoparticle and catalysis, D.A. Struc, 2008, Wiley-VCH. ISBN: 978-3-527-31572-7.<br>4. Catalysis-From Principles to Applications, M. Beller, A. Renken, R.A. van Santen, 2012, Wiley-VCH. ISBN 978-3-527-32349-4 |

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| 1 | Course Code | **CH 709** |
| 2 | Title of the Course | **Advanced Bioinorganic Chemistry** |
| 3 | Credit Structure | L-T-P-credits<br>2-1-0-3 |
| 4 | Name of the Concerned Department | Chemistry |
| 5 | Prerequisite if any | Undergraduate courses in inorganic chemistry |
| 6 | Learning Objectives | Main objective of this course is to give an overall unified understanding of bioinorganic chemistry by identifying the principles that have emerged in last few decades by arranging them in a logical and consistent order. This course will introduce the students the ever expanding frontier of bioinorganic chemistry by discussing some exemplary individual cases along with the principles that tie the realms of bioinorganic chemistry together. |
| 7 | Course Syllabus | Overview of bioinorganic chemistry, thermodynamic and kinetic aspects of coordination compound in bioinorganic chemistry, reaction of coordinated ligands, model complexes and concept of spontaneous self-assembly.<br>Coordinative properties of biological molecules : proteins, nucleic acids and other metal binding biomolecules<br>Different roles of metal ions in biology :<br>Roles of $Zn^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ in terms metalloproteins in hydrolysis exemplified by carboxypeptidase, carbonic anhydrase, α-amylase, ATPase, thermolysin, alkaline phosphatase *etc*.<br>Roles of $Fe^{2+}$ and $Cu^{+}$ as biological oxygen carrier, hemoglobins (human A, erythrocruorin, chlorocruorin), hemocyanins and hemerythrins, synthetic oxygen carrier and model systems.<br>Structural role of $Zn^{2+}$ in DNA binding metalloprotein as zinc finger and role of $Ca^{2+}$ in metalloregulatory proteins.<br>Metalloenzymes in biological nitrogen cycle : molybedenum-dependent nitrogen fixation<br>Uptake, transport and storage of essential metal ions exemplified by iron – transferrin and ferritin.<br>Manganese catalyzed oxidation of water to oxygen : photosystem I and II.<br>Cobalamins including Vitamin, reactions of the alkylcobalamin.<br>Biological functions of tungsten, vanadium and chromium.<br>$Cu^{+}$ and $Fe^{2+}$ in ATP synthesis – Cytochrome *c* oxidase.<br>Metalloproteins in electron transfer – blue copper proteins and iron sulphur proteins.<br>Role of metals ion in medicinal chemistry and as diagnostic tools, chelation therapy. |
| 8 | Suggested Books | 1. S. J. Lippard, J. M. Berg, **Principles of Bioinorganic Chemistry** (1995), University Science Books, Mill Valley, California, ISBN 978-0-935702-72-9<br>2. W. Kaim, B. Schwederski, **Bioinorganic Chemistry : Inorganic Elements in the Chemistry of Life** (1996), John Wiley & Sons, Sussesx, England, ISBN : 978-0-471943-69-3<br>3. H. B. Grey, E. I. Stiefel, J. S. Valentine, I. Bertini : **Biological Inorganic Chemistry : Structure and Reactivity** (2006), University Science Books, ISBN : 978-1-891389-43-6<br>4. Relevant papers and reviews in reputed international journals. |

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| 1. | Course Code | **CH 710** |
| 2. | Title of the Course | **Molecular Modeling and Computational Chemistry** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Chemistry |
| 5. | Pre–requisite, if any | Undergraduate courses in Physical Chemistry |
| 6. | Course Objective | To introduce students to various molecular modeling techniques such as molecular mechanics, molecular dynamics, *ab initio* electronic structure theory and their applications in chemical research. |
| 7. | Course Syllabus | ***Ab Initio* Methods:**<br>BO approximation, potential energy surfaces, LCAO, HF Molecular Orbital Theory, Slater Determinants, Anti-Symmetry Principle, SCF method, introduction to Electron Correlation: Overview of Perturbation, CI and CCSD Methods, introduction to Density Functional Theory.<br>**Molecular Mechanics/Force Field Methods:**<br>Comparisons and Performance of Various Force Fields, Inter and Intermolecular Interactions, Energy Minimizations, Normal Mode Analysis, Micro Canonical and Canonical Ensembles, Monte Carlo Simulations and Metropolis Sampling, Molecular Dynamic Simulations: Force Calculations, Integration Schemes, Liquid Models and Properties.<br>**Applied Computational Chemistry:**<br>Structures, Computable Quantities, Chemical Properties, Molecular Orbital's Plotting, Charge Distributions and Spectroscopic Properties. |
| 8. | Suggested Books | **Text Books**<br>1. Molecular Modeling: Principles and Applications. Andrew R. Leach, 2nd Ed., Prentice Hall, 2001.<br>2. Essentials of Computational Chemistry: Theories and Models. Christopher J. Cramer, 2nd Ed., Wiley & Sons, New York.<br>3. Organic Chemists book of Orbitals, by William L. Jorgensen and Lionel Salem; Wiley-VCH, 1973.<br>**Reference Books**<br>1. P. W. Atkins, Molecular Quantum Mechanics, Clarendon Press, Oxford, 1980.<br>2. I. N. Levine, Quantum Chemistry, 4th Edn., Prentice Hall of India Pvt. Ltd., New Delhi, 1995.<br>3. D. A. McQuarrie, Quantum Chemistry, University Science Books, 1983. |

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| 1. | Course Code | **CH 711** |
| 2. | Title of the Course | **Bio-Organic and Medicinal Chemistry** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | Undergraduate courses in Organic chemistry and Biology |
| 6. | Scope of the Objective | The first part of the course focuses on the protein, nucleic acids functions, structure, and physio-chemical aspects of enzymes involved in biological processes. In the second part, fundamental and current methodologies involved in the drug discovery process, application of drugs to various diseases like cancer, inflammation and infection by pathogens will be discussed in detail. |
| 7. | Course Syllabus | **Bio-organic Chemistry:** Weak interactions, Buffering against pH changes in biological systems. Amino acids, Peptides and proteins, The structure of proteins, Protein mis-folding and related to diseases. Protein data bank (pdb), Peptide self-assembly at the nanoscale. IR spectroscopy - Intra and intermolecular hydrogen bonding, effect of concentration, temperature and solvent, Applications of Circular dichroism (CD) and FT-IR in the structural elucidation of protein structures. Enzymes and enzymatic reactions, Enzyme inhibitors. Nucleotides and nucleic acids, Nucleic acid structures, Function of nucleotides, DNA based self-assembling nanostructures. Systems chemistry: Dynamic combinatorial chemistry and molecular self-replication, Molecular recognition for dynamic combinatorial libraries, Targeting peptides and proteins.<br>**Medicinal Chemistry:** Molecular basis of drug action and drug design-Molecular properties, geometries, stereochemistry, conformation, energetic; Drug discovery without leads, lead discovery strategies, combinatorial chemistry: high throughput screening, principles of rational drug design; Lead Modification-Pharmacophores, functional group modification, bioisosterism, structure modification: homologation, chain branching, SAR, QSAR: Electronics, hydrophobicity, sterics; Receptor Targets-Forces in drug receptor complex, drug receptor theories: occupancy, rate, induced-fit, macromolecular perturbation, activation-aggregation, stereochemical consideration: chirality, geometric isomers, conformational isomers, ring topology. |
| 8. | Suggested Books | **Reference Books**<br>1. J. M. Berg, J.L. Tymoczko, L. Stryer, **Biochemistry** (6th edition) W.H. Freeman and Company, 2006, ISBN 9780716767664.<br>2. M.M. Cox, D. L. Nelson, Lehninger **Principles of Biochemistry** (5th edition), W.H. Freeman and Company, 2008, ISBN 9780230226999.<br>3. P. T. Corbett, J. Leclaire, L. Vial, K. R. West, J.-L. Wietor, J. K. M. Sanders, S. Otto, **Chem. Rev. 2006**, **106**, 3652-3711.<br>4. R. B. Silverman, **The Organic Chemistry of Drug Design and Action**, 2$^{nd}$ Edition, Elsevier, New York, 2004, ISBN: 0-12-643732-7<br>5. G. L. Patric, **An Introduction to Medicinal Chemistry,** 4$^{th}$ Edition, Oxford University Press, 2009, ISBN-13: 978-0-19-923447-9<br>*6.* **Online Journals**: *Journal of the American Chemical Society; Journal of Medicinal Chemistry* *[http://pubs.acs.org/action/showPublications?display=journals](http://pubs.acs.org/action/showPublications?display=journals));*<br>*Angewandte Chemie-International Edition (http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291521-3773);*<br>*Nature Reviews Drug Discovery (http://www.nature.com/nrd/index.html)etc.,* |

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|---|---|---|
| 1. | Course Code | **CH 720** |
| 2. | Title of the Course | **Asymmetric Synthesis** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite | Nil |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Part-I: Principles of asymmetric synthesis**<br>**Introduction and terminology:** Topocity in molecules Homotopic, stereoheterotopic (enantiotopic and diastereotopic) groups and faces- symmetry, substitution and addition criteria. Prochirality nomenclature: Pro-R, Pro-S, Re and Si.<br>**Selectivity in synthesis:** Stereo specific reactions (substrate stereoselectivity). Stereo selective reactions (product stereoselectivity): Enantioselectivity and diastereoselectivity. Conditions for stereoselectivity: Symmetry and transition state criteria, kinetic and thermodynamic control. Methods for inducing enantio and diastereoselectivity.<br>**Analytical methods:** % Enantiomer excess, % enantioselectivity , optical purity, % diastereomeric excess and % diastereoselectivity. Techniques for determination of enantioselectivity: Specific rotation, Chiral 1H NMR, Chiral lanthanide shift reagents and Chiral HPLC, Chiral GC.<br>**Part-II: Methodology of asymmetric synthesis:** Classification of asymmetric reactions into 1.substrate controlled, 2. chiral auxiliary controlled, 3. chiral reagent controlled and 4. chiral catalyst controlled.<br>**1. Substrate controlled asymmetric synthesis:** Nucleophilic additions to chiral carbonyl compounds. 1, 2- asymmetric induction, Cram's rule and Felkin-Anh model.<br>**2. Chiral auxiliary controlled asymmetric synthesis:** α-Alkylation of chiral enolates, azaenolates, imines and hydrazones. Chiral sulfoxides. 1, 4-Asymmetric induction and Prelog's rule. Use of chiral auxiliaries in Diels-Alder and Cope reactions.<br>**3. Chiral reagent controlled asymmetric synthesis**: Asymmetric reductions using BINAL-H. Asymmetric hydroboration using IPC2 BH and IPCBH2. Reductions with CBS reagent.<br>**4. Chiral catalyst controlled asymmetric synthesis**: Sharpless, Jacobsen and Shi asymmetric epoxidations. Sharpless asymmetric dihydroxylation and amino hydroxylation. Asymmetric hydrogenations using chiral Wilkinson biphosphine and Noyori catalysts. Chiral catalyst controlled Diels- Alder and Michael reactions, Organocatalytic mediated asymmetric synthesis.<br>**Part-III: Total Synthesis of Biological Active Compounds** |
| 8. | Suggested Books | 1. Nasipuri, D., **Stereochemistry of Organic Compounds,** New Age Publications, $2^{nd}$ Ed, 1994<br>2. Eliel, E. *et. al.* **Stereochemistry of Organic Compounds**, Wiley-Interscience, 1994.<br>3. Carruthers, *et. al.* **Modern Methods of Organic Synthesis**, Cambridge University Press, $4^{th}$ Ed. 2005<br>4. Robert E. Gawley, R. E. Gawley, J. Aube, **Principles of Asymmetric Synthesis** Pergamon Title, Annotated Ed. 2004,<br>5. Nogradi, M.; **Stereoselective Synthesis: A Practical Approach,** Wiley-VCH, $2^{nd}$ Ed. 1994.<br>6. List. B. et.al. **Asymmetric Organocatalysis**, Springer $1^{st}$ Ed. 2010<br>7. Song, C. E.; **Cinchona Alkaloids in Synthesis and Catalysis: Ligands, Immobilization and Organocatalysis,** Wiley-vch Verlag Gmbh, 2009 |

| | | |
|---|---|---|
| 1. | Course Code | **CH 797 (Autumn Semester)**<br>**CH 798 (Spring Semester)** |
| 2. | Title of the Course | Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Chemistry |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various journals |

# Course Structure of

# PG and Ph.D. Program in Physics and Syllabi of Courses

# Course Structure of M.Sc. (2 year) and M.Sc. + Ph.D. Dual Degree Program in Physics

**Minimum Educational Qualification (MEQ):** 1. Bachelor's degree with Physics as a subject for at least two years/four semesters and Mathematics for at least one year/two semesters.

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE.
**(b) Indian Students:** Valid JAM qualification in Physics.

**Eligibility Requirement (ER):** As per the brochure of Joint Admission test for M.Sc. (JAM).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Not Applicable

**Duration of the Program:** 2 years on full-time basis**.**

**Course Structure for two-year Full-time M.Sc. (Physics) Program**

**1st Year: Semester-I**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| PH 601 | Electrodynamics | 2-1-0 | 3 |
| PH 603 | Classical Mechanics | 2-1-0 | 3 |
| PH 611 | Fundamental of Quantum Mechanics | 3-1-0 | 4 |
| PH 651 | Mathematical Methods | 2-1-0 | 3 |
| PH 691 | Physics Laboratory-I | 0-0-8 | 4 |
| | | **Total minimum credits during the semester** | **17** |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| PH 620 | Statistical Mechanics | 2-1-0 | 3 |
| PH 622 | Fundamentals of Solid State Physics | 2-1-0 | 3 |
| PH 624 | Electronics | 2-1-0 | 3 |
| PH 660 | Nuclear and Particle Physics | 2-1-0 | 3 |
| PH 692 | Physics Laboratory-II | 0-0-8 | 4 |
| PH 698 | PG Seminar Course | 0-2-0 | 2 |
| | | **Total minimum credits during the semester** | **18** |

**2nd Year: Semester-III**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ZZ XXX | Elective-I | x-x-x | 3 |
| PH 799 | M.Sc. Research Project (Stage-I: may cover concepts of experimental methods, numerical techniques, optics, atomic and Molecular Physics) | 0-0-36 | 18 |
| | | **Total minimum credits during the semester** | **21** |

**2nd Year: Semester-IV**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| PH 800 | M.Sc. Research Project (Stage-II) | 0-0-36 | **18** |
| | | **Total minimum credits during the program** | **74** |

**List of Physics Courses for Elective-I @**

| Course code | Course Title | Contact Hours (L-T-P) | Credit |
|---|---|---|---|
| PH 671 / IPH 471/AA471/AA671 | Relativity, Cosmology, and the Early Universe | 2-1-0 | 3 |
| AA 672N/ AA 472N | Galactic and Extragalactic Astronomy | 2-1-0 | 3 |
| PH 674 / IPH 474/AA474/AA674 | Basics of Radio Astronomy | 2-1-0 | 3 |
| PH 710 | Theory of Quantum Materials | 2-1-0 | 3 |
| PH 721 | Advanced Materials | 2-1-0 | 3 |
| PH 722 | X-ray Spectroscopy | 1-2-0 | 3 |
| PH 745 | Laser Physics | 2-1-0 | 3 |
| PH 761 | Theoretical Particle Physics | 2-1-0 | 3 |
| PH 765 | Experimental Techniques in High Energy Physics | 2-1-0 | 3 |
| PH 781 | Theory of Complex Systems | 2-0-2 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

**NOTE:**

1. Request for conversion from M.Sc. to M.Sc. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.** The confirmation of conversion of M.Sc. program and to M.Sc. + Ph.D. dual degree program is done during 4th semester with subject to successfully qualifying CSIR/UGC-JRF or equivalent fellowship to enable receiving Ph.D. scholarship.
2. The enhancement in the scholarship from M.Sc. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Sc. degree are fulfilled AND candidate successfully qualifies CSIR/UGC-JRF or equivalent fellowship, whichever is later.
3. **If the** student opts for Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Sc. degree can be earned **before the specified date during the 4th semester** of the normal M.Sc. Program by getting the M.Sc. Research Project examined in the standard manner as per the requirements for the award of an M.Sc. degree.

## Course Structure for Ph.D. Program in Physics
## (from AY 2010-11 to 2012-13)

### (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | PH 601 | Electrodynamics | 3-0-0-3 |
| 2 | PH 651 | Mathematical Methods | 3-0-0-3 |
| 3. | PH xxx | Elective-I | x-x-x-3 |
| 4 | PH 797* / PH 798* | Ph.D. Seminar Course | 0-2-0-2 |

### (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | PH 610 | Quantum Mechanics | 3-0-0-3 |
| 2 | PH 620 | Statistical Mechanics | 3-0-0-3 |
| 3 | PH 650 | Numerical Methods | 2-0-2-3 |
| 4 | PH 798* / PH 797* | Ph.D. Seminar Course | 0-2-0-2 |

Physics course for the Elective-I

| S.No. | Course Code | Course Title | Contact Hours (L-T-P-C) |
|---|---|---|---|
| 1 | PH 621 | Solid State Physics | 3-0-0-3 |
| 2 | PH 671N / IPH 471N/AA 471N/AA 671N | Relativity and Cosmology | 2-1-0-3 |
| 3 | PH 672N/ AA 672N/ AA 472N | Galactic and Extragalactic Astronomy | 2-1-0-3 |
| 4 | PH 674 /IPH 474/ AA 474/ AA 674 | Basics of Radio Astronomy | 2-1-0-3 |
| 5 | PH 761 | Theoretical Particle Physics | 2-1-0-3 |
| 6 | PH 765 | Experimental Techniques in High Energy Physics | 2-1-0-3 |
| 7 | PH 781 | Theory of complex systems | 2-0-2-3 |

Note:

1. M.Tech./MPhil qualified candidates have to do one semester coursework (with two-three PG level courses) while M.Sc./B.Tech. qualified candidates have to do two semester course work (with minimum five PG level courses).
2. All core courses are compulsory in semester-I (Autumn).
3. Only two courses out of the three core courses PH 610, PH 620 and PH 650 are compulsory in semester-II (Spring).

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

# Course Structure for Ph.D. Program in Physics
# (for AY 2013-14)

## (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | PH 613 | Developments in early 20th century in Physics | 2-1-0-3 |
| 2 | ZZ xxx | Elective-I* | x-x-x-3 |
| 3 | ZZ xxx | Elective-II* | x-x-x-3 |
| 4 | PH 797* / PH 798* | Ph.D. Seminar Course | 0-2-0-2 |

## (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | PH 652 | Mathematical Methods, Electrodynamics and Applications | 2-1-0-3 |
| 2 | ZZ xxx | Elective-III* | x-x-x-3 |
| 3 | ZZ xxx | Elective-IV* | x-x-x-3 |
| 4 | PH 797* / PH 798* | Ph.D. Seminar Course | 0-2-0-2 |

**Physics Courses for Elective I - IV @**

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines.

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | PH 671 / IPH 471 | Relativity, Cosmology, and the Early Universe | 2-1-0-3 |
| 2. | PH 674 / IPH 474 | Basics of Radio Astronomy | 2-1-0-3 |
| 3. | PH 710 | Theory of Quantum Materials | 2-1-0-3 |
| 4. | PH 721 | Advanced Materials | 2-1-0-3 |
| 5. | PH 722 | X-ray Spectroscopy | 1-2-0-3 |
| 6. | PH 745 | Laser Physics | 2-1-0-3 |
| 7. | PH 761 | Theoretical Particle Physics | 2-1-0-3 |
| 8. | PH 765 | Experimental Techniques in High Energy Physics | 2-1-0-3 |
| 9. | PH 781 | Theory of Complex Systems | 2-0-2-3 |
| 10. | PH 790 | Statistical Methods in Physical Sciences | 2-1-0-3 |

Notes:

1. M.Tech./MPhil qualified candidates have to do one semester coursework (with two-three PG level courses) while M.Sc./B.Tech. qualified candidates have to do two semester course work (with minimum five PG level courses).
2. It is expected that a total of 5 courses will be taken by Ph.D. students in Physics apart from the Seminar course, which is 2 credits and can be taken in either semester.
3. The student may take 2 courses in the first semester and 3 in the second, or vice versa.
4. * Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

# Course Structure for Ph.D. Program in Physics
# (from AY 2014-15)

## (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III | x-x-x-3 |
| 4 | PH 797* / PH 798* | Ph.D. Seminar Course | 0-2-0-2 |

## (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI | x-x-x-3 |
| 4 | PH 797* / PH 798* | Ph.D. Seminar Course | 0-2-0-2 |

**Physics Courses for Elective I -VI** (In addition to these courses, a student can also choose from the Ph.D. courses being offered by the other disciplines.)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | PH 613 | Developments in early 20$^{th}$ century in Physics | 2-1-0-3 |
| 2. | PH 652 | Mathematical Methods, Electrodynamics and Applications | 2-1-0-3 |
| 3. | PH 671N/ IPH 471N/ AA 471N/ AA 671N | Relativity and Cosmology | 2-1-0-3 |
| 4. | PH 672 / AA 472/ AA 672 | Extragalactic Astronomy | 2-1-0-3 |
| 5. | PH 674N/ IPH 474N/ AA 474N/ AA 674N | Radio Astronomy | 2-1-0-3 |
| 6. | PH 681 | Network Science | 2-1-0-3 |
| 7. | PH 710 | Theory of Quantum Materials | 2-1-0-3 |
| 8. | PH 721 | Advanced Materials | 2-1-0-3 |
| 9. | PH 722 | X-ray Spectroscopy | 1-2-0-3 |
| 10. | PH 725 | Characterization of Surfaces and Interfaces of Materials | 2-0-2-3 |
| 11. | PH 745 | Laser Physics | 2-1-0-3 |
| 12. | PH 761 | Theoretical Particle Physics | 2-1-0-3 |
| 13. | PH 765 | Experimental Techniques in High Energy Physics | 2-1-0-3 |
| 14. | PH 781 | Theory of Complex Systems | 2-0-2-3 |
| 15. | PH 790 | Statistical Methods in Physical Sciences | 2-1-0-3 |

**NOTE:** 1. A Ph.D. student having **M.Sc./ B.Tech./ BE or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*

2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses) Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

| | | |
|---|---|---|
| 1. | Course Code | **PH 601** |
| 2. | Title of the Course | **Electrodynamics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Vector calculus and Special Theory of Relativity |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Brief review of Electromagnetism: Vector Calculus, Greens Function, Coulomb's law, Gauss Law, Laplace's equation, Poisson's equation, electrostatics with conductors, capacitors, dielectrics, Biot-Savart's law, Ampere's law, Lorentz force. Faradays' law, Lenz's law, self and mutual inductance, energy in a magnetic field.<br>Electrodynamics: Maxwell's equations, displacement current, electromagnetic waves, plane wave solutions of Maxwell's equations.<br>Maxwell's equations in conducting media, Poynting's vector, wave propagation through a boundary, reflection, refraction, absorption and skin-depth. General boundary value problems using special functions.<br>Wave-guides, resonant cavities, cylindrical waveguides and optical fibers, potentials and fields, radiating systems, multipole fields and radiation, scattering and diffraction, relativistic electrodynamics, Lorentz transformations, 4-vectors, 4-momentum, mass-energy equivalence, relativistic covariance of Maxwell's equations, radiation from accelerated charges, communication and radar. |
| 8. | Suggested Books | **Text:**<br>1. J. D. Jackson, **Classical Electrodynamics** (3rd edition), John-Wiley & Sons, 1998.<br>2. W. Greiner, **Classical Electrodynamics**, Springer International Edition.<br>**References:**<br>1. D. J. Griffiths, **Introduction to Electrodynamics** (3rd edition), Prentice Hall, 1989.<br>2. R. P. Feynman et al, **The Feynman Lectures on Physics**, Narosa Publishing, 2008.<br>3. J. R. Ritz et al. **Foundations of Electromagnetic Theory** (4th edition), Pearson. |

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|---|---|---|
| 1. | Course Code | **PH 603** |
| 2. | Title of the Course | **Classical Mechanics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Discipline | Physics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **An overview of the Lagrangian formalism:** Some specific application of Lagrange's equation, small oscillations, normal modes and frequencies,<br>**Rigid bodies:** Independent coordinates, orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler's angles; Inertia tensor and principal axis system; Euler's equation;<br>**Hamilton's Principle:** Calculus of variations; Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action. Noether's theorem and conservation of charges.<br>**Canonical transformations:** Generating functions; example of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations<br>**Hamilton-Jacobi theory:** The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristics; Action angle variables.<br>**Special Theory of Relativity:** Lorentz transformations; 4-vectors, Tensors, Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and antisymmetric tensors; 4-dimensional velocity and acceleration; 4-momentum and 4-force; Covariant equations of motion; Relativistic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle. |
| 8. | Suggested Books | 1. H. Goldstein, C. P. Poole and J. L.. Safko, **Classical Mechanics** (3rd edition), Addison Wesley, 2001.<br>2. J. R. Taylor, **Classical Mechanics**, Uni. Science Books, 2005.<br>3. L. D. Landau, E. M. Lifshitz, **Course of Theoretical Physics - Vol. 1** (3rd edition), Butterworth-Heinermann, 1976.<br>4. V. I. Arnold, **Mathematical Methods of Classical Mechanics** (2nd edition), Springer, 1988.<br>5. J. B. Marion and S. T. Thornton, **Classical Dynamics of Particles and Systems** (4th edition), Holt Rinehart & Winston, 1995<br>6. A. K. Raychaudhuri, **Classical Mechanics: A Course of Lectures** (1st edition), Oxford University Press, 1984.<br>7. E. C. G. Sudarshan, **Classical Dynamics: A Modern Perspective** (1st edition), John Wiley & Sons, 1974. |

| | | |
|---|---|---|
| 1. | Course Code | **PH 610** |
| 2. | Title of the Course | **Quantum Mechanics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | An undergraduate course in Quantum Mechanics is preferred, though not necessary. |
| 6. | Scope of the Course | To impart a systematic exposition of basic concepts, techniques and methods in quantum mechanics to the graduate students so that they can confidently apply them in various fields of study and research. |
| 7. | Course Syllabus | **Fundamental Concepts**: The Stern-Gerlach experiment, Kets bras and operators, Base kets and matrix representations, Measurements, observables and the uncertainty relations, change of basis, position, momentum and translation, wave functions in position and momentum space<br>**Quantum dynamics** : Time evolution and the Schrodinger equation, The Schrodinger versus the Heisenberg picture, Simple harmonic oscillator, Schrodinger's wave equation<br>**Theory of angular momentum**: Rotation and angular momentum commutation relations, spin ½ systems and finite rotations, SO(3), SU(2) and Euler rotations, Density operators and pure vs mixed ensembles, Eigenvalues and eigenstates of angular momentum, Orbital angular momentum, addition of angular momenta, Tensor operators<br>**Approximation methods**: Time independent perturbation theory (Non degenerate case), Time-independent perturbation theory (The dependent case), hydrogen like atoms (Fine structure and Zeeman effect), Variational methods, Time dependent potentials (The interaction picture), Time dependent perturbation theory, Energy shift and decay width<br>**Scattering theory**: The Lippman-Schwinger equation, Optical theorem. Born approximation, Free particle states (Plane waves vs spherical waves), method of partial waves. |
| 8. | Textbook | 1. J.J. Sakurai , Modern quantum mechanics .<br>2. "Quantum mechanics" by E. Merzbacher, 3rd edition.<br>3. "Quantum mechanics" by A. Messiah.<br>4. "Quantum mechanics", Course of theoretical physics, Vol. 3, 3rd edition by L. Landau and L. Liftshitz.<br>5. "A Modern Approach to Quantum Mechanics" by J. Townsend.<br>6. "Quantum Mechanics" (Feynman lectures of physics vol. 3) by R. Feynman.<br>7. "Quantum mechanics" by Schiff.<br>8. "Lectures on Quantum Mechanics" by G Baym.<br>9. "Quantum Mechanics" by C. Cohen-Tannoudji, B. Diu, F. Laloë.<br>10. "Quantum mechanics" by A. S. Davydov.<br>11. "Principles of Quantum Mechanics" by R. Shankar |

| | | |
|---|---|---|
| 1. | Course Code | **PH 611** |
| 2. | Title of the Course | **Fundamental of Quantum Mechanics** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | An undergraduate course in Quantum Mechanics/ Modern physics is helpful, but not necessary. |
| 6. | Scope of the Course | To build up fundamental concepts in quantum mechanics as a precursor to study its applications in various branches of physics. |
| 7. | Course Syllabus | **Fundamental Concepts**: Wave particle duality, The Stern-Gerlach experiment, Kets, bras and operators, Base kets and matrix representations, Measurements, observables and the uncertainty relations, change of basis, position , momentum and translation, wave functions in position and momentum space<br>**Quantum dynamics**: Time evolution and the Schrodinger equation, The Schrodinger versus the Heisenberg picture, Simple harmonic oscillator, Schrodinger's wave equation ,WKB approximation, Tunneling through a barrier<br>**Theory of angular momentum**: Rotation and angular momentum commutation relations, spin ½ systems and finite rotations, SO(3), SU(2) and Euler rotations, Eigenvalues and eigenstates of angular momentum, Orbital angular momentum, addition of angular momenta, Wigner-Eckart theorem, Tensor operators.<br>**Approximation methods:** Time independent perturbation theory (Non degenerate case), Time-independent perturbation theory (The dependent case), hydrogen like atoms (Fine structure and Zeeman effect), Variational methods, Time dependent potentials (The interaction picture), Fermi's Golden Rule; Selection rules; Time dependent perturbation theory, Energy shift and decay width<br>**Identical particles**: Pauli's exclusion principle, spin-statistics connection;<br>**Scattering theory:** The Lippman-Schwinger equation, Optical theorem. Born approximation, Free particle states (Plane vs spherical waves)<br>**Relativistic Quantum Mechanics:** Klein-Gordon equation, Feynman-Struckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Helicity and chirality; Properties of matrices; Charge conjugation; Normalisation and completeness of spinors. |
| 8. | Suggested books | **Text Book:**<br>1. J. J. Sakurai, **Modern Quantum Mechanics** (2nd edition), Addison Wesley, ISBN:978-0805382914.<br>**Reference books:**<br>1. E. Merzbacher, **Quantum mechanics** (3rd edition), Wiley ISBN:978-0471887027.<br>2. A. Messiah, **Quantum mechanics**, Dover, ISBN:978-0486409245.<br>3. L. Landau and L. Liftshitz, **Quantum mechanics - Vol. 3** (3rd edition), Butterworth-Heinemann, ISBN: 978-0750635394.<br>4. J. Townsend, **A Modern Approach to Quantum Mechanics**, University Science Books, ISBN:978-1891389788.<br>5. R. Feynman, **Quantum Mechanics** (Feynman lectures of physics vol. 3), Basic Books ISBN:978-0465023820.<br>6. Schiff, **Quantum mechanics**, McGraw-Hill ISBN:978-0070856431.<br>7. G Baym, **Lectures on Quantum Mechanics**, Benjamin / Cummings ISBN:978-0805306675.<br>8. C. C. Tannoudji, B. Diu, F. Laloë, **Quantum Mechanics**, Wiley-Interscience; ISBN:978-0471569527.<br>9. A. S. Davydov, **Quantum mechanics**, Pergamon Press, ISBN:978-0080204376.<br>10. R. Shankar, **Principles of Quantum Mechanics**, Springer, ISBN:978-0306447907. |

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| 1. | Course Code | **PH 620** |
| 2. | Title of the Course | **Statistical Mechanics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Review of thermodynamics, Introduction to statistical methods, elementary probability theory, random variable, binomial, Poisson, normal distribution, random walk, micro canonical ensemble, canonical ensemble, grand canonical ensemble, formulation of quantum statistics<br>Semi-classical systems, unified treatment of ideal Fermi and Bose systems, Bose condensation, degenerate Fermi gas Phase transition, Ising model, thermal fluctuations, Langevin and generalized Langevin equations |
| 8. | Suggested Books | 1. R. K. Pathria, **Statistical Mechanics**, Oxford, New York.<br>2. K. Huang, **Statistical Mechanics** (2nd edition), John Wiley & Sons.<br>3. W. Greiner, L. Neise and H. Stoker, **Thermodynamics and Statistical Mechanics**, Springer.<br>4. D. Chandler, **Introduction to Modern Statistical Physics**, Oxford University Press. |

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|---|---|---|
| 1. | Course Code | **PH 621** |
| 2. | Title of the Course | **Solid state physics** |
| 3. | Credit Structure | 2-1-0-3 |
| 4. | Name of the Concerned Discipline/Discipline | Physics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | To expose graduate students to a broad range of theoretical concepts, ideas and approaches applied in solid state physics and condensed matter, emphasizing those based on quantum mechanics and collective phenomena. In addition, this course gives exposure to students to major current fields of research in this subject. |
| 6. | Course Syllabus | Sommerfield theory, Crystal structure and symmetry, Reciprocal lattice, Bloch Theorem, electrons in weak periodic potential, Band structure, tight binding method, semiclassical method of electron dynamics, de Haas-van Alphen effect and other Fermi surface probes, Hartree-Fock equations, Screening, Thomas-Fermi theory, Fermi Liquid theory, classical and quantum theory of harmonic crystals, phonons, electron-phonon interactions, diamagnetism and paramagnetism, magnetic structure, ordering and properties, superconductivity and superfluids. |
| 7 | Textbook | “Solid State physics” by Ashcroft and Mermin |
| 8. | Suggested References | 1. “Introduction to solid state physics” by Charles Kittel<br>2. “Condensed matter physics” by Micheal P. Marder<br>3. “Solid State Physics” by Grosso and Parravicini<br>4. “Advanced solid state physics” by Philips and Philips<br>5. “Theory of solids” by Ziman<br>6. “Introduction to superconductivity” by Tinkham<br>7. “Quantum phase transitions” by Subir Sachdev<br>8. “Condensed matter field theory” by Atlands and Simons<br>9. “Quantum field theory of many particle systems” by Fetter and Walecka |

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| 1. | Course Code | **PH 622** |
| 2. | Title of the Course | **Fundamentals of Solid State Physics** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Crystal lattices, Reciprocal lattice, Bonding & Packing in crystals; Diffraction, Structure factor; Point and Space groups; Phonons, elastic and thermal properties, lattice specific heat, anharmonic effects, Umklapp processes, Defects and dislocations; Free electron theory, Drude model, Sommerfield theory; Band theory of solids, Kronig-Penney Model; Metals and Insulators, Semiconductors, Concept of hole, Hall effect, Thermoelectric power; Optical and Dielectric properties of solids, Ferroelectric Materials; Magnetic ordering, dia-, para-, ferro- and anti-ferromagnetism, spin-waves; Superconductivity, type–I, type -II superconductors, D.C and A.C Josephson effect; Mean Field Theory; Fluctuation Dissipation Theorem; Mott transition (metal –insulator transition) |
| 8. | Suggested Books | **Textbook:**<br>1. C. Kittel, **Introduction to Solid State Physics** (7$^{th}$ Edition), John Wiley & Sons.<br>2. Ashcroft and Mermin, **Solid State Physics**, Thomson Press (India) Ltd.<br>**Reference Books:**<br>1. A. J. Dekker, **Solid State Physics**, MacMillan India Ltd.<br>2. M. Ali Omar, **Elementary Solid State Physics: Principles and Applications**, Addison Wesley.<br>3. J. M. Ziman, **Principles of the Theory of Solids**, Cambridge University Press.<br>4. M. Tinkham, **Introduction to superconductivity** (2$^{nd}$ edition), Dover Publications.<br>5. A. R. Verma and O. N. Srivastava, **Crystallography for Solid state Physicists**, Narosa Publishing. |

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| 1. | Course Code | **PH 624** |
| 2. | Title of the Course | **Electronics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Solid state Physics, Electrodynamics |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Review of Semiconductor Device Physics:** Effect of Doping on Fermi level and Concept of Junctions; Junction Characteristics and its application as a diode, transistor and field effect transistors.<br>Application of diodes and transistors in Rectifier circuits, Filters circuits and Regulated power supplies. AC and DC transformers. Oscillators.<br>**Optoelectronic Devices:** Introduction to interaction of radiation with matter, Solar Cells, Photo-detectors (scintillation detector), High purity Germanium Detector, GM Counter, Single Channel and Multichannel analyzer.<br>**Digital Electronic:** Review of digital electronics including number system and Logic gates. Digital techniques and applications (registers, counters, comparators and similar circuits); A/D and D/A converters; operational amplifiers and their applications; microprocessor and microcontroller basics.<br>**Introductory Signal Analysis:** Introduction to Signal Analysis and its applications.<br>**Introduction to Electronic Instrumentation and Measurement techniques**: Transducers and their applications, sensors and physical principles of various types of sensors.<br>AC, DC, and Stepper motors |
| 8. | Suggested Books | 1. J. M. Christos, C. Halkias and S. Jit, **Electronic Devices and Cricuits**, McGraw Hill, International student edition. ISBN: 0070634556.<br>2. S.M. Sze, **Physics of semiconductor devices**, Wiley-Interscience,1969.<br>3. A. P. Malvino and J. A Brown, **Digital Computer Electronics**, Tata McGraw-Hill Education ISBN: 0028005945.<br>4. A. Kitai, **Principles of Solar Cells, LEDs and Diodes: The role of the PN junction**, Wiley-Interscience, 2011, ISBN: 1444318330.<br>5. D. P. Leach and A. P. Malvino, **Digital Principles and Applications**, ISBN: 978-0028018218.<br>6. R. L. Boylestad and L. Nashelsky, **Electronic Devices and Circuit Theory**, ISBN: 978-0131189058.<br>7. W. D. Cooper, **Electronic Instrumentation and Measurements Techniques**, PHI India. |

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| 1. | Course Code | **PH 650** |
| 2. | Title of the Course | **Numerical Methods** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Basic Knowledge of Computer and any computer language |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Computational Algorithms**: Structure of a Computer, some examples of algorithms<br>**Computer Arithmetic**: Floating point representation of numbers, errors in numbers, Binary representation of numbers<br>**Iterative Methods**: The method of successive bisection, the method of false position, Newton Raphson Iterative method, The Secant method, The method of successive approximations<br>**Solution of simultaneous Algebraic Equations:** Gauss elimination method, gauss Siedel iterative method<br>**Interpolation:** Lagrange interpolation<br>**Least Squares approximation of Functions:** Linear regression, polynomial regression<br>A**pproximation of functions:** Taylor Series representation, Chebyshev series<br>**Differentiation and Integration:** Simpson's rule, Gaussian quadrature formulae<br>**Numerical Solution of Differential equations:** Euler's method, Taylor Series method, Runge-Kutta method, Predictor-corrector method |
| 8 | Textbook | 1. V. Rajaraman, Computer oriented numerical methods , Prentice-Hall of India<br>2. James M. Ortega, Andrew S. Grimshaw, An Introduction to C++ and Numerical Methods, Oxford University Press, USA<br>3. B.H. Flowers An Introduction to Numerical Methods in C++, Oxford university Press<br>4. Bradley L. Jones, Sams Teach Yourself C++ in 21 Days Sams; 5 edition (December 2004) |

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| 1. | Course Code | **PH 651** |
| 2. | Title of the Course | **Mathematical Methods** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | **Vector Analysis**: Curvilinear coordinates, Concept of geometry: lines and planes, Linear Algebra and Introduction to Tensors<br>**Group Theory and Representation Theory**: Lie algebras, Lie groups, and some of their applications. Representation theory. Explicit construction of finite-dimensional irreducible representations; Invariant operators and their eigenvalues; Tensor operators. Boson and fermion realizations; Differential realizations; Quantum dynamical applications<br>**Complex analysis** (residue calculus, method of steepest descent): Single and multiple valued complex variables, singularities, poles and branch points, Cauchy's conditions and theorem, mapping, dispersion relations, complex integrations.<br>**Differential equations and Green's functions**: Ordinary differential equations, partial differential equations, first and second order equations, homogeneous and nonhomogeneous equations, singular points, series solutions, Sturm-Liouville Theory<br>**Integral Transforms:** General properties of Fourier series, advantages and applications of Fourier series, Fourier transforms, Laplace Transforms.<br>**Special Functions**: Bessel, Legendre, Laguerre, Hermite, Chebyshev, Hypergeometric Functions, Spherical Harmonics.<br>**Probability and Statistics**: Probability distributions, Statistical Inference. |
| 8. | Suggested Books | 1. G. B. Arfken and H. J. Weber, **Mathematical Methods for Physicists** (6th edition), Academic Press, 2005.<br>2. S. Hassani, **Mathematical Physics: A modern introduction to its foundations**, Springer-Verlag, 1999.<br>3. K. F. Riley, M.P. Hobson and S.J. Bence, **Mathematical Methods for Physics and Engineering: A Comprehensive Guide** (3rd edition), Cambridge University Press.<br>4. E. Kreyszig, **Advanced Engineering Mathematics** (8th edition), John Wiley & Sons,.<br>5. M.L. Boas, **Mathematical Methods in the Physical Sciences** (3rd edition), John Wiley & Sons. |

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| 1. | Course Code | **PH 660** |
| 2. | Title of the Course | **Nuclear and Particle Physics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | An undergraduate course in Quantum mechanics/Modern Physics. |
| 6. | Scope of the Course | To introduce students with the concepts and important developments in last century in our understanding of nucleus and elementary particles and their interactions. |
| 7. | Course Syllabus | Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Electric and magnetic moments; Fermi gas model of nucleus; nuclear shell model; Liquid drop model; Rutherford scattering; Fission and fusion; Atomic Reactors, Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Isospin; Deuteron problem; Evidence of shell structure, single- particle shell model, its validity and limitations;<br>Rotational spectra; Elementary ideas of alpha, beta and gamma decays and their selection rules; Electromagnetic transitions in nuclei multipole radiation; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions;<br>Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); quark model; Bag model; Symmetries and Conservation laws; Spin and parity assignments, isospin, strangeness; Gell-Mann-Nishijima formula; C, P, and T invariance and applications of symmetry arguments to particle reactions, parity non-conservation in weak interaction; Relativistic kinematics. Particle Accelerators and Detectors; Experimental prospective of detection of elementary particles. Introduction to QCD and Quark-Gluon Plasma (Qualitative). |
| 8. | Suggested books | 1. W. E. Burcham and M. Jobes, **Nuclear and Particle Physics**, Addison Wesley Longman Ltd., Harlow, 1995.<br>2. B. R. Martin and G. Shaw, **Particle Physics**, John Wiley and sons, Chicester, 1996.<br>3. G. D. Coughlan and J. E. Dodd, **The ideas of particle physics**, Cambridge University Press, 1991.<br>4. N. G. Cooper and G. B.West (eds.), **Particle Physics: A Los Alamos Primer**, Cambridge University Press,1988.<br>5. R. C. Fernow, **Introduction to experimental Particle Physics**, Cambridge University Press, 1986.<br>6. F. Halzen and A. D. Martin, **Quarks and Leptons: An introductory Course in particle physics**, John Wiley and Sons, New York, 1984.<br>7. F. E. Close, **An introduction to Quarks and Partons**, Academic Press, London, 1979.<br>8. D. H. Perkins, **Introduction to High Energy Physics**, Cambridge University Press, 2000.<br>9. D. Griffiths**, Introduction to Elementary Particles**, Wiley-vch Verlag Gmbh, 2008.<br>10. W. S. C. Williams, **Nuclear and Particle Physics**, Oxford University Press, USA.<br>11. A. Das and T. Ferbel, **Introduction to Nuclear and Particle Physics***,* World Scientific Publishing Company, 2003. |

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| 1 | Course Code | **AA 671N/ PH 671N/ AA 471N/ IPH 471N** |
| 2 | Title of the Course | **Relativity and Cosmology** |
| 3 | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4 | Name of the Discipline of Center | Astronomy, Astrophysics and Space Engineering |
| 5 | Pre–requisite, if any | |
| 6 | Scope of the Course | This course aims to introduce students to cosmology through an understanding of the General Theory of Relativity. Special emphasis will be placed on linear perturbation theory in the early universe, leading to the formation of the cosmic microwave background, as this illustrates basic undergraduate physics in the context of the frontiers of research in cosmology. |
| 7 | Course Syllabus | **1. Special Relativity:** Michaelson-Morley Experiment, Galilean vs. Lorentz transformations, Lorentz invariance, scalars in special relativity, relativistic dynamics, acceleration in special relativity<br>**2. Cosmology:** Olber's paradox; difficulty with Newtonian cosmology; brief introduction to general theory of relativity, especially the line element; Schwarzschild metric, horizon, orbits, Hawking radiation; FRW metric as a consequence of cosmological principle; redshift, angular and luminosity distances; evolution of scale factor from Newtonian cosmology; density parameter; LCDM cosmology; flatness and horizon problems, basics of inflation theory; thermal history of the Universe, big bang nucleosynthesis; microwave background.<br>**3. Structure formation:** Jeans instability in an expanding background; initial perturbation and anisotropies in CMBR, formation of dark matter halos, galaxy formation and star formation; millennium simulation; Sunyaev-Zeldovich effect; neutral hydrogen and other elements in the IGM, Lyman α forest and damped clouds; reionization, AGN/star-formation history of the universe; Gunn-Peterson effect. |
| 8 | Suggested Books | 1. S. Dodelson, ***Modern Cosmology***, Academic Press, 2003, ISBN: 0-1221-9141-2.<br>2. S. Carroll, ***Spacetime and Geometry: An Introduction to General Relativity***, 2003, ISBN: 0-8053-8732-2.<br>3. J. A. Peacock, ***Cosmological Physics***, Cambridge University Press, 1998, ISBN: 9780521422703.<br>4. P. J. E. Peebles, ***Principles of Physical Cosmology***, Princeton University Press, 1993, ISBN: 0-6910-1933-9.<br>5. P. J. E. Peebles, ***Large-Scale Structure of the Universe***, Princeton University Press, 1980, ISBN: 0-6910-8240-5. 6. D. H. Lyth, & A. R. Liddle, ***The Primordial Density Perturbation***, Cambridge University Press, 2008, ISBN: 0-5218-2849-X.<br>6. S. Weinberg, ***Cosmology***, Oxford University Press, 2008, ISBN: 0-1985-2682-7.<br>7. R. Durrer, ***The Cosmic Microwave Background***, CUP 2008.<br>8. S. Weinberg, ***The First Three Minutes***, Basic Books, 1993, ISBN: 0-4650-2437-8. |

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| 1. | Course Code | **PH 674/ IPH 474/ AA474/ AA674** |
| 2. | Title of the Course | **Basics of Radio Astronomy** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Discipline | Physics |
| 5. | Pre–requisite, if any | Basics of Electronics procedure of conducting experiments |
| 6. | Scope of the Course | This course is intended to impart the hands-on Astronomy to students. It aims to introduce Radio Astronomy as well as basic instrumentation and Engineering in Astronomy. It also aims to introduce students to the basics of Extragalactic Astronomy and Cosmology. |
| 7. | Course Syllabus | **Review of Electromagnetic theory:** Maxwell's equations and basics of electric and magnetic fields, Basic Electromagnetic Theory and radiation of electromagnetic waves, E & B Field Measurable quantities and Polarization.<br>**Radio Universe and Antenna:** The Radio Universe and the Atmospheric Radio Window Brightness, Flux density and antenna fundamentals-I, Effects of the earth's atmosphere, Basics of Radiative Transfer, Antenna fundamentals–II, Antenna Fundamentals–III.<br>**Radio Interferometry:** Introduction, Uses and Advantages, Essential Ingredients of an interferometer.<br>**Radiometers:** from Voltages to Spectra, Galactic Astrophysics and observations.<br>**Extragalactic Astrophysics:** Fundamentals, Galaxies, Clusters of Galaxies, A brief introduction to cosmology, Astrophysics with 21 cm emission.<br><br>**Experiments:**<br>1. Measuring Beam Patterns – 4 sessions<br>2. Measuring telescope aperture efficiency – 2 sessions<br>3. Measuring the brightness of the sun and the moon – 2 sessions<br>4. Galactic Observations – 21 cm – 4 sessions<br>5. Extragalactic Observations – 21 cm – 6 sessions<br>6. Cosmological Comtinuum and spectral line observations – 4 sessions<br>7. Final Projects – 8-10 sessions |
| 8. | Suggested Books | 1. B. Ryden, **Introduction to Cosmology**, Addison Wesley, 2003, ISBN: 0-8053-8912-1 |

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| **Course code** | **PH 681** |
| **Title of the course** | **Network Science** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Physics |
| Pre-requisite, if any | Basic knowledge of linear algebra and probability theory |
| Scope of the course | The course will teach basic and advanced concepts of network/graph theory and its various applications in biological, social, technological systems and deep learning. The course will enable students to model real-world complex systems existing in above fields concerning networks or graphs, and analyze their properties. |
| Course Syllabus | **Basic definitions:** graph, network, adjacency matrix, path, degree, the importance of nodes betweenness, closeness and degree centrality, clustering coefficient and modularity, degree-degree correlations, weak ties<br>**Graph algorithms:** ER Random, Scalefree: rich get richer, Small-world: 6 degree of separation, the configuration model, Graph visualization Softwares<br>**Biological Networks:** Protein-protein interaction networks, gene regulatory networks, signal transduction networks, metabolic networks, brain networks, network construction from biological data such as gene expression data and genomic data<br>**Social Networks:** Facebook, Twitter, movie actor and collaboration network<br>**Technological Networks:** Power grid networks, transport networks, electrical networks, world-wide-web (www), Machine learning algorithms for network evolution and relation with deep learning<br>Graph spectra and applications, Importance of graph spectra<br>Community detection methods, Graph partitioning<br>**Dynamics on networks:** Introduction to synchronization on Networks and its applications to various fields spanning from power-grids to biology, Epidemics and other spreading phenomena (SI, SIS, SIR models)<br>**Advanced Topics:** Multilayer networks, Graphs spectra, and relation with random matrix theory |
| Suggested Books | 1. M. E. J. Newman, **Networks : An introduction,** Oxford University Press, Oxford, 2012, 978-0199206650<br>2. S. N. Dorogovtsev and J. F. Mendes, ***Evolution of Netwokrs,*** Oxford University Press, Oxford, 2013, 978-0199686711<br>3. Bjorn H. Junker and Falk Schreiber, ***Analysis of Biological Networks,*** John Wiley & Sons, New Jersey, 2011, 978-0470041444<br>4. Piet Van Mieghem, ***Graph Spectra for Complex Networks,*** Cambridge University Press, Cambridge, 2010, 978-0521194587 |

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|---|---|---|
| 1. | Course Code | **PH 691** |
| 2. | Title of the Course | **Physics Laboratory-I** |
| 3. | Credit Structure | L-T- P-Credits<br>0-0-8-4 |
| 4. | Name of the Discipline | Physics |
| 5. | Pre–requisite, if any | Basics of Safety Procedures and Conduct in Laboratories |
| 6. | Scope of the Course | This course aims to introduce basic laboratory techniques in Physics through experiments that will be conducted as Experimental Projects.<br>Students will be expected to attend laboratory sessions having familiarized themselves with basic theory of the experiments. Every experiment would be carried out in the form of a project, and students will be expected to submit a report for every experiment. |
| 7. | Course Syllabus | 1. **Thermal diffusivity** : teaches student how to do Fourier analysis of a periodic function of time. Theory involves the diffusion equation which gives thermal waves decaying in amplitude and changing in phase as they propagate.<br>2. **Dielectric constant of benzene and dipole moment of acetone**: explains the difference between polar and non- polar molecules, the concept of the local electric field different from the applied field, and the application of the Clausius-Mosotti relation.<br>3. **Verification of Curie-Weiss law for a ferroelectric using a ceramic capacitor**: The ceramic capacitor contains a ferroelectric material as a dielectric with a Curie temperature around 20 $^{o}$C. This provides a cheap and convenient method of verifying Curie-Weiss law.<br>4. **Thermal relaxation of a serial light bulb**: This experiment verifies the Debye's relaxation formula which is of importance in many areas.<br>5. **B-H curve using an integrator**: Uses a hard material so that measurement of the remanent induction, coercive field and energy loss in a cycle is easy. It also uses an integrator and indicates how by integrating Farady's law one may get the flux change.<br>6. **Calibration of a Lock in Amplifier and measurement of mutual inductance of a coil and low resistance (below 1 Ohm)**: The Lock in amplifier illustrates phase sensitive detection. One can verify all laws of mutual inductance and measure MI of about 100 μhenry to an accuracy of 2 to 3% using a current less than 1 milliampere.<br>7. **Geiger-Muller Counter:** i) Statistical nuclear counting ii) Verification of Gaussian and Poissionian Distribution.<br>8. **Feigenbaum and Chua circuits for non-linear dynamics**: This indicates how one goes from order to chaos in a deterministic non-linear system through a process of bifurcations. The Chua circuit illustrates how a non-linear negative resistive device can be built using op-amps and illustrates bifurcation in frequencies and shows different types of attractors.<br>9. **Tracing FM to PM transition in Ni and crystal structure transition in Shape memory alloy through resistivity measurement**: The experiments on phase transitions illustrate how resistivity can be used to trace phase transitions.<br>10. **Percolation**: To measure the percolation threshold for conductivity and show how conductivity varies near the threshold.<br>11. **Michelson's interferometry:** Laser diffraction (single, double and multiple slits, diffraction grating)<br>12. **Fiber optics experiment:** numerical aperture of optical fiber, study of single and multi mode optical fibers. Calibration of an unknown source using Gama-ray spectrometer. |
| 8. | Suggested Books | 1. B. L. Worsnop and H. T. Flint, **Advanced Practical Physics for Students**, Metheun & Co. Ltd.<br>2. J. B. Rajam, **Atomic Physics**. |

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|---|---|---|
| 1. | Course Code | **PH 692** |
| 2. | Title of the Course | **Physics Laboratory-II** |
| 3. | Credit Structure | L-T- P-Credits<br>0-0-8-4 |
| 4. | Name of the Discipline | Physics |
| 5. | Pre–requisite, if any | Basics of Safety Procedures and Conduct in Laboratories |
| 6. | Scope of the Course | This course aims to introduce basic laboratory techniques in Physics through experiments that will be conducted as Experimental Projects. |
| 7. | Course Syllabus | 1. Study of half-wave and full wave rectifiers.<br>2. Designing regulated power supply (Zener diodes, regulators)<br>3. Study of transistor characteristics, Using transistor as an amplifier.<br>4. Designing a coupled amplifier.<br>5. Study of various oscillators.<br>6. Operational Amplifiers (Adder, subtractor, Integrator and Differentiator circuits)<br>7. 555 Timer circuits.<br>8. Logic gates (AND, OR, NOT, NAND, NOR) using ICs<br>9. Seven segment Decoder.<br>10. Flip Flops<br>11. Measurement of cosmic muon lifetime<br>12. Thin Films: Deposition, resistivity, reflectivity and thickness measurement<br>13. Powder XRD |
| 8. | Suggested Books | 1. P. B. Zbar, A. P. Malvino, M. A. Miller, **Basic Electronics: A Text Lab Manual**, McGraw Hill.<br>2. B. L. Worsnop and H. T. Flint, **Advanced Practical Physics for Students**, Metheun & Co. Ltd.<br>3. J. B. Rajam, **Atomic Physics**. |

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| 1. | Course Code | **PH 698** |
| 2. | Title of the Course | **PG Seminar Course** |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Nil |
| 6 | Course Objective | To develop confidence and presentation skills of the student |
| 7. | Course Syllabus | In this course a PG student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her PG Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 8. | Other references | Books and research publications in various relevant journals/conference proceeding, etc. |

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| 1. | Course Code | PH 710 |
| 2. | Title of the Course | Theory of Quantum Materials |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Discipline of Physics |
| 5. | Pre–requisite, if any | Basic Knowledge of Quantum Mechanics and Solid State Physics |
| 6. | Scope of the Course | This course aims at introducing the many body theory revolving around the second quantization. After having a profound understanding of many body theory, the course will transit to electron phonon interaction and superfluidity. The novel properties of new generation materials would be an exciting way to wrap this course finally. |
| 7. | Course Syllabus | **Second Quantization for Particles and Many Body Physics**<br>Homogenous Electron gas, Dirac notations; Physics of Hamiltonian Harmonic Oscillator and Phonons, Hubbard Model, Interaction Matrix elements, Polaron constant, Spin Hamiltonian, Homogenous Spin Systems, Ising Model, Phonon Dispersions, Dynamical Stability, Eliashberg theory, Allen Dynes formalism, High Pressure Physics, Phase Transformations, Dependence of electron-phonon interaction under hydrostatic pressure, uniaxial and biaxial strain.<br><br>**Many Body Theory of Superfluidity**<br>Introduction of superfluidity, Hartee and Exchange for Liquid $^4$He, Bogoliubov Theory of $^4$He, Off-diagonal long range order, Interaction between quasiparticle excitations, quasiparticle transport, Quantum Hall Effects, Landau Levels, Fixed Density, Fixed Chemical Potential, Impurity Dominated quantum hall effect, Laughlin Wave Function, Collective excitations, Magetorotons, Quasiholes.<br><br>**Fundamental Properties of new generation Materials**<br>Rashba Splitting, Rashba Dresselhaus Phenomena, Charge Carrier Recombination, Charge Carrier Dynamics, Excitonic effect, Van der Waals forces, London Dispersion forces, Stronger dipole-dipole forces, Non-linear Poisson Boltzmann Treatment for Solid liquid interface, Effect of Non-centrosymmetric and Spin Coupling effect on electronic band structures. |
| 8. | Suggested Books | 1. G. D. Mahan, **Many-Particle Physics,** Springer, 2000 **ISBN:** 9781475757149 (**Text Book**)<br>2. P. Coleman, **Introduction of Many Body Physics**, Cambridge University Press, 2015, **ISBN**: 9781139020916<br>3. H. Bruus, Karsten Flensberg, **Many-Body Quantum Theory in Condensed Matter Physics: An Introduction**, Oxford University Press, 2001, **ISBN: 9780191057472.**<br>4. R. Martin, **Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press,** 2004 **ISBN:** 978-0521534406<br>5. R. Eisberg, Robert Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, John Wiley & Sons, ISBN: 978-0471873730<br>6. N. W. Ashcroft and N. Mermin, **Solid State Physics, ISBN** 978-0030839931<br>7. C. J. Joachain, B. H. Bransden, **Physics of Atoms and Molecules, ISBN:** 9788177582796 |

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|---|---|---|
| 1. | Course Code | **PH 721** |
| 2. | Title of the Course | **Advanced Materials** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Basics of solid state physics, electricity and magnetism |
| 6. | Scope of the Course | To introduce the students with the modern materials; their properties, applications and associated phenomena. |
| 7. | Course Syllabus | Magnetism, correlations of structural, magnetic and electronic properties, Direct and indirect exchange interactions.<br>Review of superconductivity, high temperature superconductors, Josephson junctions, flux dynamics, recent advances in superconductivity ($MgB_2$, Fe-based superconductors, Borocarbide superconductor etc.)<br>Dilute magnetic semiconductors, spin electronics and technology based on it.<br>Ferroelectric, Multiferroic and Magnetoelectric materials.<br>Introduction to nanotechnology and nanoscience.<br>Colossal magnetoresistive manganites, Giant magnetoresistance, Ferrites, magnetic multilayers, Chare-orbital ordering, Phase-separation, Photofunctionality of some materials.<br>Shape memory alloys: NiTi and magnetic alloys<br>Recent/important discoveries in materials. |
| 8. | Suggested Books | 1. M. Getzlaff, **Fundamentals of magnetism**, Springer, 2010.<br>2. N. A. Spaldin, **Magnetic Materials: Fundamentals and Device applications** (2nd edition), Cambridge University Press, 2011.<br>3. Chaikin and Lubensky, **Principles of condensed matter physics**, Cambridge University Press, 2000.<br>4. B. D. Cullity, C. D. Graham, **Introduction to magnetic materials**, IEEE press and Wiley publications, 2009.<br>5. H. Ibach and H. Lutz, **Solid State Physics: An introduction to materials science**, Springer, 2002.<br>6. Ashcroft and Mermin, **Solid State Physics**, Wiley Publications.<br>7. J. Singleton, **Band Theory and Electronic Properties of solids**, Oxford University Press, 2001.<br>8. R. C. O'Handley, **Modern Magnetic Materials: Principles and Applications**, Wiley-Interscience Publications, 2000.<br>9. R. E. Newnham, **Properties of Materials: Anisotropy, Symmetry, Structure**, Oxford University Press, 2005.<br>10. D. C. Lagoudas, **Shape Memory Alloys: Modeling and Engineering Applications**, Springer, 2008.<br>11. V. A. Chernenko, **Advances in Shape Memory Materials: Magnetic Shape Memory Alloys**, Trans Tech Publications, 2008. |

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|---|---|---|
| 1. | Course Code | **PH 722** |
| 2. | Title of the Course | **X-ray Spectroscopy** |
| 3. | Credit Structure | L-T-P-Credits<br>1-2-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any (for the students) | Basic knowledge of Quantum Mechanics, Solid State Physics and Atomic Physics |
| 6. | Scope of the course | To introduce the students to different X-ray based sophisticated experimental probes that are widely used for modern day materials research. Importantly, the techniques taught in this course will be established at IIT Indore in near future and this course will be of immense benefit to the students who would like to use these techniques. |
| 7. | Course Syllabus | **Scattering of X-Rays, X-ray Diffraction (XRD)** – Theory, Instrumentation, Data Analysis – Introduction to Rietveld method, diffraction from amorphous solids, small angle scattering, Reflectivity.<br>**Photoelectron Spectroscopy** – Instrumentation, Core-levels and Final States, Low-Energy Satellites, Valance Band in Metallic solids and Insulators, Quantitative and Qualitative Data analysis,<br>Other related processes – Auger Effect and ESCA, Inverse Photoelectron spectroscopy, X-ray Fluorescence<br>**Emission Spectroscopy** – Resonant inelastic and Non-resonant X-ray Emission Spectroscopy (RIXS and NXES), Theory, Instrumentation, Data interpretation<br>**X-ray Absorption:** Near Edge and Extended X-Ray Absorption Fine Structure (XANES and EXAFS), Transmission and Fluorescence method of detection, X-ray Magnetic Circular Dichroism (XMCD), Data interpretation.<br>**X-ray Spectrometers:** Cauchois-type bent crystal X-ray spectrograph, Johnson and Johansson spectrometers and two crystal x-ray spectrometers |
| 8. | Suggested Books | 1. Elements of X-ray Diffraction (3rd Edition) – B. D. Cullity and S. R. Stock, Prentice Hall, ISBN: 978-0201610918<br>2. Photoelectron Spectroscopy: Principles and Applications – Stefan Hüfner, Springer 2003, ISBN : 9783-54041-8023<br>3. Modern Spectroscopy (4th Edition), – J. Michael Hollas, John Wiley & Sons, Ltd. ISBN: 978-0-470-84416-8<br>4. X-Ray absorption : principles , applications, techniques of EXAFS, SEXAFS and XANES – Ed. By D. C. Koningsberger and R. Prins, John Wiley & Sons, ISBN: 978-0-47187-5475 |

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|---|---|---|
| 1. | Course Code | **PH 725** |
| 2. | Title of the Course | **Characterization of Surfaces and Interfaces of Materials** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Concerned Discipline | Physics |
| 5. | Pre–requisite | Basic Knowledge of Quantum Mechanics, and Mathematics. |
| 6. | Scope of the course | To make the students to understand the mechanisms and applications of the characterization techniques/methods commonly used in the experimental research. |
| 7. | Course Syllabus | **Scattering:** Introduction, Review of crystallography, unit cell notation; Nature of x-rays, EM spectrum, generation of x-rays, spectra; Bohr model and transitions, Relation to multiple techniques Interaction of EM radiation with matter, absorption, Filters.<br>**X-ray scattering:** X-Ray Diffraction, Bragg's law; Intensities of diffracted beams, Scattering, form factor, Structure factor; Single Crystal X-ray Diffraction; Powder X-ray Diffraction; Grazing Incidence X-ray Diffraction (GIXRD); X-ray reflectivity to characterize the surface and interfaces of thin films (<~100nm in Å order resolution); Small angle x-ray scattering (SAX), Wide angle x-ray scattering (WAX), Grazing-Incidence Small-Angle x-ray Scattering (GISAXS). Application of these techniques in characterization of soft-matters, thin films and nano-materials; Neutron Scattering; Counters; Advantage of use of Synchrotron; Radiation for material characterization.<br>**Spectroscopy:** Near Edge X-ray Absorption Fine Structure (NEXAFS) Spectroscopy for organic materials and extension to EXAFS; Electronic Spectroscopy: Vacuum ultraviolet (VUV), UV-visible spectroscopy of organic materials/thin films; Surface spectroscopies based on electrons or photons or ions: X-ray Photo Electron Spectroscopy (XPS), Electron Energy Loss Spectroscopy (EELS), Secondary Ion Mass Spectroscopy (SIM.S.)<br>**Microscopy:** SEM; TEM (HRTEM, SAD), High Angle Annular Dark field STEM (HAADF STEM); SPM (STM, AFM).<br>**NMR:** Basics and application to biological structure determination; Vibrational spectroscopies: IR and Raman. |
| 9. | Suggested books | 1. P.E.J. Flewitt and R.K. Wild, **Physical Methods for Materials Characterization**, Taylor & Francis (2003).<br>2. H.H. Willard, L.L. Merritt, Jr., J.A. Dean, F.A. Settle, Jr. **Instrumental Methods of Analysis**, Wadsworth Publishing Company (1988).<br>3. B.D. Cullity and S.R. Stock, **Elements of X-Ray Diffraction**, Prentice Hall (2001).<br>4. Jens Als-Nielsen, **Elements of Modern X-ray Physics**, (2nd Edition). John Wiley & Sons, Ltd. (2011)<br>5. G.F. Knoll, **Radiation Detection and Measurement**, Wiley (2010).<br>6. C.N. Banwell and E.M. McCash, **Fundamentals of Molecular Spectroscopy**, McGraw-Hill College (1994).<br>7. D.C. Harris, M.D. Bertolucci, **Symmetry and Spectroscopy – An Introduction to Vibrational and Electronic Spectroscopy**, Oxford University Press, USA, Dover publications (1989).<br>8. J.M Hollas, **Modern Spectroscopy**, Wiley (2004).<br>9. J. Stöhr, **NEXAFS Spectroscopy**, Springer (2003).<br>10. D.B. Williams, C. B. Carter, **Transmission Electron Microscopy: A Textbook for Materials Science,** Plenum Press: New York, 1996.<br>12. E.E. Hunter, **Practical Electron Microscopy: A Beginner's Illustrated Guide**, Cambridge University Press (1993).<br>13. J.W. Edington, **Practical Electron Microscopy in Materials Science** Macmillan- Philips Technical Library (1974).<br>14. J.K.M. Sanders and B.K. Hunters; **Modern NMR Spectroscopy**. Oxford Univ. Press (1987).<br>15. A.Rahman and M.I.Choudhary; **Solving ProbleM.S. with NMR Spectroscopy**. Academic Press (1996) |

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| 1. | Course Code | **PH 745** |
| 2. | Title of the Course | **Laser Physics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Fundamentals of Quantum Mechanics and Basic Modern Physics |
| 6. | Scope of the Course | To understand various aspects of Lasers |
| 7. | Course Syllabus | Spontaneous and stimulated emission, Einstein A & B coefficients; Lasers, optical pumping, population inversion, rate equation; Modes of resonators and coherence length,<br>Techniques for the control of laser output employing Q-switching, mode locking and mode-dumping. Optical cavity design and laser stability criteria. Description of common types of conventional lasers. Physic of semiconducting optical materials, degenerate semiconductors and their Homojunctions and Hetrojunctions. Light emitting diodes (LED's) junction lasers, Laser systems and applications. |
| 8. | Suggested books | **Textbook:**<br>1. O. Svelto, **Principles of Lasers**, ISBN: 978-1441913012.<br><br>**Reference Books:**<br>1. K. Thyagarajan and A. K. Ghatak, **Lasers: Theory and Applications**, ISBN: 9780333904466.<br>2. W. T. Silfvast, **Laser Fundamentals**, ISBN: 9780521138475.<br>3. G. Streetmen and Sanjay Banerjee, **Solid state electronic devices**, ISBN: 81-7758-365-4.<br>4. A. Beiser, **Concepts of Modern Physics**, ISBN: 9780070495531. |

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|---|---|---|
| 1. | Course Code | **PH 761** |
| 2. | Title of the Course | **Theoretical Particle Physics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Classical Mechanics, Fundamentals of Quantum Mechanics |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | Review of Dirac Equation, Dirac Algebra, Review of Euler Lagrange Equation, Canonical quantization of free and interacting fields, S-Matrix, Wick's theorem. Feynman Diagrams.<br>Quantum Electrodynamics: Tree level and higher order processes, Regularization and Renormalization, group flow, LSZ formula,<br>Introduction to Lie groups.<br>Gauge theory: Gauge invariance in abelian and non-abelian gauge theories, weak interactions, standard model and Higgs mechanism. Beyond standard model physics. |
| 8. | Suggested Books | 1. Halzen & Martin, **Quarks and Leptons: Introductory Course in Modern Particle Physics**.<br>2. D. Griffiths, **Introduction to Elementary Particles**.<br>3. A. Lahiri & P. B. Pal, **A First Book of Quantum Field Theory**.<br>4. Peskin & Schroeder, **Quantum Field Theory**.<br>5. Cheng & Li, **Gauge Theory of Elementary Particle Physics**. |

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| 1. | Course Code | **PH 765** |
| 2. | Title of the Course | **Experimental Techniques in High Energy Physics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Special Theory of Relativity and Particle Physics |
| 6. | Scope of the Course | To familiarize students in the frontiers of detectors used in high energy experiments, the physics of quark-gluon plasma, hadron physics and techniques to handle large-scale data. |
| 7. | Course Syllabus | **Interaction of Radiation with Matter:** The Bethe-Bloch formula for energy loss, Minimum Ionizing particle (MIP), Cherenkov Radiation, Radiation length, Bremsstrahlung, Interaction of Photon, Electron-Photon Showers<br>**Detectors for Particle Identification (principles and applications):** Energy Resolution, The Fano Factor, Detector Efficiency, Read-out and Dead Time, Gaseous Ionization Detectors, Proportional Counters, Multi Wire Proportional Counter, Photon Multiplicity Detector, Drift Chamber, Time Projection Chamber, Time of Flight Detector, Muon Chamber, Transition Radiation Detector, Calorimeters (Electromagnetic and Hadronic Calorimeters), Silicon Detectors for tracking, Scintillation Detectors and Photomultipliers. Development of a prototype detector.<br>**Accelerator Physics:** Concepts of van de Graff, Cyclotron and Linac, Colliders and Fixed target Experiments, Luminosity, Cross-sections, Concept of Event Triggering.<br>**Relativistic Kinematics:** Lorentz Transformations; concept of four vectors, proper time, transformation from laboratory to center of momentum frame, Relativistic Kinematics, Hadron Physics, Quark Gluon Plasma (QGP).<br>**Data Analysis Techniques:** Data Reduction and Error Analysis in High Energy Experiments, Analysis framework and ROOT. |
| 8. | Suggested Books | 1. W. R. Leo, **Techniques for Nuclear and Particle Physics Experiments** (2nd edition), Narosa Publishing.<br>2. G. F. Knoll, **Radiation Detection and Measurement** (3rd edition), John-Wiely and Sons.<br>3. C. Y. Wong, **Introduction to High Energy Heavy-Ion Collisions**, World Scientific publishing, 1994.<br>4. R. Vogt, **Ultra-Relativistic Heavy Ion Collisions** (1st edition), Elsevier Publishing, 2007.<br>5. S. Sarkar, **The Physics of the Quark-Gluon Plasma**, Springer, 2010, ISBN 978-3-642-02285-2.<br>6. J. R. Taylor, **An Introduction to Error Analysis** (2nd edition), University Science Books.<br>7. P. R. Bevington, D. K. Rabinson, **Data Reduction and Error Analysis** (3rd edition), Mc Graw Hill.<br>8. R. Kaiser, Taylor & Francis, **Hadron Physics**, 2006.<br>9. Alex H. Blin, **Hadron Physics**, American Institute of Physics, 2000.<br>10. D. Griffiths, **Introduction to Elementary Particles**, Wiley-VCH |

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| | | Verlag Gmbh, 2008. |

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| 1. | Course Code | **PH 781** |
| 2. | Title of the Course | **Theory of Complex Systems** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Knowledge of elementary probability and statistics.<br>Computer and Technical Requirement: Students should have a working knowledge of a programming language such as Fortran, C or JAVA. |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | • Methods in complex systems, Nonlinearity, chaos and order<br>• Self-organization. Self-organization and emergence. Self-organized criticality<br>• Edge of chaos and cellular automata cellular automaton rules; Cellular automata as models of complex systems, sand pile model, percolation<br>• Network theory: Characteristics of network topology. Complex networks: Random networks, Small-world networks, Scale-free networks, Spectral graph theory<br>• Multi-agent models, Game theory |
| 8. | Suggested Books | 1. D. Sornette**, Critical Phenomena in Natural Sciences: Chaos, Fractals, Self-organization and Disorder: Concepts and Tools** ($2^{nd}$ edition), Springer-Verlag, 2003.<br>2. R. Hilborn, **Chaos and non-linear dynamics: An introduction for scientists and Engineers**, Oxford University Press, Oxford 2000.<br>3. R. Devaney, **Differenetial equations, dynamical systems, and introduction to chaos (pure and applied mathematics)**, Academic Press, USA, 2004.<br>4. M. Tabor, **Chaos and Integrability in non-linear dynamics: An introduction**, John Wiley and Sons, 1989.<br>5. B. Bollobas, **Modern graph theory**, Springer-Verlag, New York 1998.<br>6. N. Dorogovtsev and J. F. F. Mendes, **Evolution of Networks**, Oxford University Press, Oxford, 2003.<br>7. S. Wasserman and K. Faust, **Social Network Analysis**, Cambridge University Press, Cambridge, 1994.<br>8. C. D. Meyer, **Matrix analysis and applied linear algebra**, SIAM, Philadelphia, USA, 2000. |

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| 1. | Course Code | **PH 790** |
| 2. | Title of the Course | **Statistical Methods in Physical Sciences** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | Some knowledge of numerical methods and any programming language, preferably C++. Basics of Statistics. |
| 6. | Scope of the course | To familiarize students in various areas of experimental data analysis. |
| 7. | Course Syllabus | **Review of Statistical Distributions:** General properties of continuous and discrete distributions: Binomial, Negative Binomial, Poisson, Gaussian, Exponential, Breit-Wigner or Cauchy and other statistical distributions with applications to physical systems.<br>**Data Reduction and Error Analysis:** Central limit theorem, rejection of data, weighted averages, combination of errors, propagation of errors, statistical and systematic errors, how to report and use uncertainties, statistical distribution of random uncertainties.<br>**Estimation and Least Squares:** Properties of estimators, basic estimators, maximum likelihood, method of moments, least squares, the straight line fit, fitting binned data, chi square distribution and errors, linear least squares and matrices, non-linear least squares, kinematic fitting. Covariance and Correlations<br>**Probability and Confidence:** Probability and confidence levels, student's t-distribution<br>**Taking Decisions:** Hypothesis Testing, interpreting experiments, goodness of fit, the two sample problem, analysis methods for several samples<br>**Monte Carlo Methods:** Random number generation, Markov chain, applications of Monte Carlo calculations in various physical systems.<br>**Experiments:** Handling of experimental data in ROOT GUI object oriented programming. |
| 8. | Suggested Books | 1. R.J. Barlow, Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences, Wiley Publishing<br>2. J. R. Taylor, An Introduction to Error Analysis, 2nd edition, University Science Books<br>3. P.R. Bevington, D.K. Rabinson, Data Reduction and Error Analysis, 3rd edition, Mc Graw Hill.<br>4. L. Lyons, Statistics for Nuclear and Particle Physicists, Cambridge University Press, 1986<br>5. F. James, Statistical Methods in Experimental Physics, 2nd edition, World Scientific Publishing |

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|---|---|---|
| 1. | Course Code | **PH 797 (Autumn Semester)**<br>**PH 798 (Spring Semester)** |
| 2. | Title of the Course | Ph.D. Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Physics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various journals |

# Course Structure

# of

# PG and Ph.D. Program in Mathematics

# and

# Syllabi of Courses

## (AY 2015-16)

**Curriculum for M.Sc. and M.Sc. + Ph.D. dual degree Program in Mathematics from AY 2015-16**

**Minimum Education Qualification (MEQ):** Bachelor's degree with Mathematics as a subject for at least two years/four semesters.

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE.
**(b) Indian Students:** Valid JAM qualification in Mathematics.

**Eligibility Requirement (ER):** As per the brochure of Joint Admission test for M.Sc. (JAM).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Not Applicable

**Duration of the Program:** 2 years on full-time basis**.**

**Course Structure for 2-Year Full-time M.Sc. (Mathematics) Program**

**1st Year: Semester-I**

| Course Code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| MA 611 | Analysis-I | 3-1-0 | 4 |
| MA 621 | Ordinary Differential Equations | 2-1-0 | 3 |
| MA 641 | Linear Algebra | 3-1-0 | 4 |
| MA 673 | Fundamentals of Discrete Mathematics | 2-1-0 | 3 |
| MA 675 / ME 675 | Probability and Statistical Methods | 2-0-2 | 3 |
| | | **Total minimum credits during the semester** | **17** |
| **Additional Course (as per requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course Code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| MA 610 | Complex Analysis | 3-1-0 | 4 |
| MA 612 | Analysis-II | 3-1-0 | 4 |
| MA 620 | Partial Differential Equations | 2-1-0 | 3 |
| MA 640 | Algebra-I | 3-1-0 | 4 |
| MA 680 | Computational Techniques | 3-0-2 | 4 |
| | | **Total minimum credits during the semester** | **19** |

**2nd Year: Semester-III**

| Course Code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| MA 603 | Topology-I | 3-1-0 | 4 |
| MA 631 | Functional Analysis | 3-1-0 | 4 |
| MA 643 | Algebra-II | 2-1-0 | 3 |
| MA 651 | Numerical Analysis | 2-1-0 | 3 |
| MA 671 / ME 671 / ME 471 | Operations Research | 2-0-2 | 3 |
| MA 799 **OR**<br>ZZ xxx | M.Sc. Research Project (Stage-1) **OR one Elective course in lieu** [Elective-I] | 0-0-6<br>**OR** x-x-x | 3 |
| | | **Total minimum credits during the semester** | **20** |

**2nd Year: Semester-IV**

| Course Code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| ZZ xxx | Elective I **OR** [Elective II] | x-x-x | 3 |
| ZZ xxx | Elective II **OR** [Elective III] | x-x-x | 3 |
| MA 800<br>**OR**<br>ZZ xxx<br>ZZ xxx<br>ZZ xxx | M.Sc. Research Project (Stage-2)<br>**OR**<br>Three elective courses [i.e. Electives IV-VI] | 0-0-18<br>**OR**<br>x-x-x<br>x-x-x<br>x-x-x | 9 |
| | | **Total minimum credits during the semester** | **15** |
| | | **Total minimum credits during the program** | **71** |

**Courses from Discipline of Mathematics for the PG students in Mathematics @:**

MA 652/ MA 452: Theory of Transforms
MA 654/ MA 454: Mathematical Modeling and Simulations
MA 714: Advanced Complex Analysis
MA 734: Fourier Analysis on Euclidean Spaces
MA 736: Wavelet Analysis
MA 742: Commutative Algebra
MA 780: Mathematical Logic
MA 782: Theory of Computations

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines. An M.Sc. student can also choose elective courses from Ph.D. course curriculum of Mathematics except the courses MA 741: Algebra, MA 711: Analysis, MA 720: Differential Equations, MA 703: Topics in Analysis.

**NOTE:**

**1.** During the second semester, students will choose their research project guide(s) and continue their research project work in the third and fourth semesters.

**2.** Students will submit a dissertation after the completion of their research project work as per the time schedule mentioned in the PG course curriculum.

3. Request for conversion from M.Sc. to M.Sc. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their**

**program.** The confirmation of conversion of M.Sc. program and to M.Sc. + Ph.D. dual degree program is done during 4th semester with subject to successfully qualifying CSIR/UGC-JRF or equivalent fellowship to enable receiving Ph.D. scholarship.

4. The enhancement in the scholarship from M.Sc. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Sc. degree are fulfilled AND candidate successfully qualifies CSIR/UGC-JRF or equivalent fellowship, whichever is later**.**

**5. If the** student opts for Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Sc. degree can be earned **before the specified date during the 4th semester** of the normal M.Sc. Program by getting the M.Sc. Research Project examined in the standard manner as per the requirements for the award of an M.Sc. degree.

## Course Structure for Ph.D. program in Mathematics
## (during AY 2010-11 to 2012-13)

**(A) Semester-I (Autumn / Spring)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | MA 601 | Topology | 2-1-0-3 |
| 2 | MA 703 | Topics in Analysis | 2-1-0-3 |
| 3 | ZZ xxx | Elective-I | 2-1-0-3 |
| 4 | MA 797 */ MA 798* | Seminar Course | 0-2-0-2 |

**(B) Semester-II (Spring / Autumn)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | MA 702 | Conformal Mappings | 2-1-0-3 |
| 2 | MA 704 | Probability Theory | 2-1-0-3 |
| 3 | MA 706 | Numerical Linear Algebra | 2-1-0-3 |
| 4 | ZZ xxx | Elective-II | x-x-x-3 |
| 5 | MA 798 * / MA 797* | Seminar Course () | 0-2-0-2 |

**Mathematics course for the Elective-I and Elective-II** *(in addition these courses students can take courses from the other disciplines / School)*

| S.No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | MA 701 | Experimental Designs and Data Analysis | 2-1-0-3 |
| 2 | MA 705 | Applied Operator Theory | 2-1-0-3 |
| 3 | MA 707 | Special Functions | 2-1-0-3 |
| 4 | MA 708 | Ergodic Theory | 2-1-0-3 |
| 5 | MA 709 | Advance Numerical Methods for Linear Control Systems | 2-1-0-3 |
| 6 | MA 710 | Fractional Differential Equations | 2-1-0-3 |
| 7 | MA 712 | Advanced Analysis | 2-1-0-3 |

Note: M.Tech./MPhil qualified candidates have to do one semester coursework (with 2-3 PG level courses) while M.Sc./B.Tech./BE qualified candidates have to do two semester course work (with minimum 5 PG level courses).

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

# Course Structure for Ph.D. program in Mathematics

# (for AY 2013-14)

## (A) Semester-I (Autumn / Spring)

| Sr. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | MA 711 | Analysis | 2-1-0-3 |
| 2 | MA 741 | Algebra | 2-1-0-3 |
| 3 | ZZ XXX | Elective – I | x-x-x-3 |
| 4 | MA 798***** / MA 797***** | Ph.D. Seminar Course | 0-2-0-2 |

## (B) Semester-II (Spring / Autumn)

| Sr. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | MA 720 | Differential Equations | 2-1-0-3 |
| 2 | ZZ XXX | Elective – II | x-x-x-3 |
| 3 | MA 798***** / MA 797***** | Ph.D. Seminar Course | 0-2-0-2 |

### Mathematics course for the Elective I-II

(In addition to these elective courses, students can take elective courses from other Disciplines also).

| S. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | MA 601 | Topology | 2-1-0-3 |
| 2. | MA 701 | Experimental Designs and Data Analysis | 2-1-0-3 |
| 3. | MA 702 | Conformal Mappings | 2-1-0-3 |
| 4. | MA 703 | Topics in Analysis | 2-1-0-3 |
| 5. | MA 704 | Probability Theory | 2-1-0-3 |
| 6. | MA 705 | Applied Operator Theory | 2-1-0-3 |
| 7. | MA 706 | Numerical Linear Algebra | 2-1-0-3 |
| 8. | MA 707 | Special Functions | 2-1-0-3 |
| 9. | MA 708 | Ergodic Theory | 2-1-0-3 |
| 10. | MA 709 | Advance Numerical Methods for Linear Control Systems | 2-1-0-3 |
| 11. | MA 710 | Fractional Differential Equations | 2-1-0-3 |
| 12. | MA 712 | Advanced Analysis | 2-1-0-3 |

**NOTE:** 1. A Ph.D. student having **M.Sc./ B.Tech./ BE or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*

2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses) Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

# Course Structure for Ph.D. program in Mathematics

# (from AY 2014-15)

## (A) Semester-I (Autumn / Spring)

| Sr. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective – I | x-x-x-3 |
| 2 | ZZ xxx | Elective – II | x-x-x-3 |
| 3 | ZZ xxx | Elective – III | x-x-x-3 |
| 4 | MA 798***** / MA 797***** | Ph.D. Seminar Course | 0-2-0-2 |

## (B) Semester-II (Spring / Autumn)

| Sr. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective – IV | x-x-x-3 |
| 2 | ZZ xxx | Elective – V | x-x-x-3 |
| 3 | ZZ xxx | Elective – VI | x-x-x-3 |
| 4 | MA 798***** / MA 797***** | Ph.D. Seminar Course | 0-2-0-2 |

**NOTE:**

1. A Ph.D. student having **M.Sc./ B.Tech./ BE or equivalent qualification** has to do 5 to 7 Ph.D. level courses of at least 3 credits each and 1-2 Ph.D. seminar courses of at least 2 credits each. Minimum number of courses will be 5 Ph.D. level courses and one Ph.D. seminar course *(minimum coursework of 17 credits).*

2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses) Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

## Mathematics courses for Electives I-VI

(In addition to these elective courses, students can take elective courses from other Disciplines also).

| S. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | MA 601 | Topology | 2-1-0-3 |
| 2. | MA 652/ MA 452 | Theory of Transforms | 2-1-0-3 |
| 3. | MA 654/ MA 454 | Mathematical Modeling and Simulations | 2-1-0-3 |
| 4. | MA 701 | Experimental Designs and Data Analysis | 2-1-0-3 |
| 5. | MA 702 | Conformal Mappings | 2-1-0-3 |
| 6. | MA 703 | Topics in Analysis | 2-1-0-3 |
| 7. | MA 704 | Probability Theory | 2-1-0-3 |
| 8. | MA 705 | Applied Operator Theory | 2-1-0-3 |
| 9. | MA 706 | Numerical Linear Algebra | 2-1-0-3 |
| 10. | MA 707 | Special Functions | 2-1-0-3 |
| 11. | MA 708 | Ergodic Theory | 2-1-0-3 |
| 12. | MA 709 | Advance Numerical Methods for Linear Control Systems | 2-1-0-3 |
| 13. | MA 710 | Fractional Differential Equations | 2-1-0-3 |
| 14. | MA 711 | Analysis | 2-1-0-3 |
| 15. | MA 712 | Advanced Analysis | 2-1-0-3 |
| 16. | MA 720 | Differential Equations | 2-1-0-3 |
| 17. | MA 741 | Algebra | 2-1-0-3 |

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|---|---|---|
| 1. | Course Code | **MA 601** |
| 2. | Title of the Course | **Topology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | An M. Sc. Level course in real and complex analysis |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Overview of General Topology:** Topological spaces, separation axioms, products, metrisation, function spaces, uniform spaces, topological groups<br>**Overview of Algebraic Topology:** Paths, homotopy, fundamental group, category theory, chain complexes, homology and cohomology, simplicial and singular homology and cohomology, applications, cup product<br>**Overview of Differential Topology:** Differentiable manifolds, tangent spaces, embeddings, differential forms, deRham cohomology |
| 8. | Suggested Books | 1. James R. Munkres, Topology, Second Edition,Prentice Hall, 2000<br>2. James R. Munkres, Elements of Algebraic Topology,Addison-Wesley,<br>3. Edwin H. Spanier, Algebraic Topology, Springer, 1994<br>4. Marvin J. Greenberg and John R. Harper, Algebraic Topology – A First Course, Benjamin/Cummings, 1981<br>5. Victor Guillemin and Alan Pollack, Differential Topology, Prentice-Hall, 1974<br>6. John Milnor, Topology from the Differential Viewpoint, Princeto University Press, 1997<br>7. D. B. Fuks and V. A. Rokhlin, Beginner's course in Topology, Springer-Verlag 1984 |

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|---|---|---|
| 1. | Course Code | **MA 603** |
| 2. | Title of the Course | **Topology-I** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Analysis-I |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in point set topology, countability, connected space, metrization theorem. |
| 7. | Course Syllabus | Topological spaces, Basis for a topology, The order topology, Subspace topology, Closed sets.<br><br>Countability axioms, Limit points, Convergence of nets in topological spaces, Continuous functions, The product topology, Metric topology, Quotient topology.<br><br>Connected spaces, Connected sets in R, Components and path components, Compact spaces, Compactness in metric spaces, Local compactness, One point compactification.<br><br>Separation axioms, Uryshon's lemma, Uryshon's metrization theorem, Tietz extension theorem, The Tychonoff theorem, Completely regular spaces, Stone -Czech compactification. |
| 8. | Suggested Books | 1. J. Munkres, *Topology* (2nd Edition), Prentice Hall, 2000.<br>2. J. Dugundji, *Topology*, Allyn and Bacon, Inc., 1966.<br>3. K. Janich., *Topology*, Springer, 1984.<br>4. M. A. Armstrong, *Basic Topology,* Springer, 1983.<br>5. K. D. Joshi**,** *Introduction to General Topology***,** New Age International, 1983.<br>6. J. L. Kelley, *General Topology***,** Springer, 1975.<br>7. C. D. Aliprantis and O. Burkinshaw, *Principles of Real Analysis* (3rd Edition), Academic Press, 1998. |

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|---|---|---|
| 1. | Course Code | **MA 610** |
| 2. | Title of the Course | **Complex Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Analysis-I |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Differentiability and analyticity of complex functions, conformal mappings, Complex integration, Classification of singularities and Residue theory. |
| 7. | Course Syllabus | Geometry and topology of the complex plane, Riemann sphere, Limits, Continuity, Differentiability, Analytic functions, Cauchy-Riemann equation, Harmonic functions, Multi-valued functions, Mappings by elementary functions, Sequences and series, Uniform convergence, Radius of convergence of power series, power series as an analytic function.<br><br>Elementary conformal mappings, Linear fractional transformations, Cross ratio, Inverse Points, Mappings of disks and half-planes, Symmetric Principle.<br><br>Complex integration, Arcs and closed curves, Line integral, Analytic functions in regions, Length and area, Cauchy's theorem, Index of a point with respect to a closed curve, Cauchy's integral formula, Morera's theorem, Weierstrass's theorem.<br><br>Classification of singularities, Taylor's and Laurent's series and theorems, Casorati-Weierstrass theorm, Cauchy's residue theorem, Evaluation of definite integrals.<br><br>Zeros of analytic functions, Lioville's theorem, Fundamental theorem of algebra, Uniqueness theorem, Maximum modulus principle / theorem, Schwarz lemma. Argument principle, Rouche's theorem, Hurwitz's theorem, Open mapping theorem, Inverse function theorem. |
| 8. | Suggested Books | 1. L. V. Ahlfors, *Complex Analysis*, McGraw-Hill International Editions, Third Edition, New Delhi, 1979.<br>2. J. B. Conway, *Functions of One Complex Variable*, Springer International Student Edition, Narosa Publishing House, New Delhi, 1973.<br>3. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, Second Edition, New Delhi, 2005.<br>4. T. W. Gamelin, *Complex Analysis*, Undergraduate Texts in Mathematics, Springer, NY, 2001.<br>5. S. Ponnusamy and H. Silverman, *Complex Variables with Applications*, Birkhaeuser, Boston, 2006.<br>6. B. P. Palka, *An Introduction to Complex Function Theory*, Springer-Verlag, 1991. |

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|---|---|---|
| 1. | Course Code | **MA 611** |
| 2. | Title of the Course | **Analysis-I** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Analysis in metric space, Differentiability, Riemann-Stieltjes integral, and convergence criteria in sequences and series of functions. |
| 7. | Course Syllabus | Review of real number system, Dedekind's cut (without proof), Infimum and supremum, countability.<br><br>Review on convergence of sequences and series of real numbers, Continuity and differentiability.<br><br>Metric spaces: Open and closed sets, continuity, connectedness, compactness, Heine-Borel theorem, Bolzano Weierstrass theorem, Cantor Intersection theorem, finite intersection property, uniform continuity, totally boundedness, completeness, completion, Contraction mapping theorem, Baire category theorem.<br><br>Functions of bounded variations and Riemann-Stieltjes integral.<br><br>Sequences and series of functions, pointwise and uniform convergence, Interchanging limits, Dini's theorem, equicontinuity, Arzela-Ascoli's theorem, Stone-Weierstrass theorem. |
| 8. | Suggested Books | 1. T. M. Apostol, *Mathematical Analysis*, 2nd ed., Narosa Publishers, 2002.<br>2. K. Ross, *Elementary Analysis: The Theory of Calculus*, Springer Int. Edition, 2004.<br>3. W. Rudin, *Principles of Mathematical Analysis*, 3rd ed., McGrawHill, 1983.<br>4. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, John Wiley & Sons, International Ed., 1982.<br>5. R. R. Goldberg, *Methods of Real Analysis,* 2nd ed., John Wiley & Sons, 1976.<br>6. S. Ponnusamy, *Foundations of Mathematical Analysis*, Birkhäuser, 2012.<br>7. N. L. Carothers, *Real Analysis,* 1st ed., Cambridge University Press, Indian Edition, 2009. |

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|---|---|---|
| 1. | Course Code | **MA 612** |
| 2. | Title of the Course | **Analysis-II** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Analysis-I |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Multivariable calculus, Inverse function and Implicit function theorem. Lebesgue measure and integration. |
| 7. | Course Syllabus | Differential Calculus: Functions of several variables, Limits and continuity, Directional derivatives, Partial derivatives, Total derivative, Derivatives of vector fields, Jacobian matrix, Chain rules, Mean value Theorem, Higher order derivatives, Taylor's theorem.<br><br>Applications of Differential Calculus: Maxima, Minima, Lagrange's multipliers, **Inverse function theorem***, **Implicit function theorem***.<br><br>Lebesgue Integration: Lebesgue Measure; Lebesgue Outer Measure; Lebesgue Measurable Sets. Sigm algebra, Measure space, Measurable Functions, simple functions, Integration.<br><br>Fatou's lemma, Lebesgue's Monotone Convergence Theorem, Dominated Convergence Theorem, **Lp - Spaces. Differentiation and Fundamental theorem for Lebesgue integration***.<br><br>Product measure, Fubini's theorem. |
| 8. | Suggested Books | 1. T. Apostol, *Mathematical Analysis*, 2nd ed., Narosa Publishers, 2002.<br>2. W. Rudin, *Principles of Mathematical Analysis*, 3rd ed., McGrawHill, 1983.<br>3. N. L. Carothers, *Real Analysis,* 1st ed., Cambridge University Press, 2009 Indian Edition.<br>4. R. R. Goldberg, *Methods of Real Analysis,* 2nd ed., John Wiley & Sons, 1976.<br>5. G. de Barra, *Measure Theory and Integration,* 2nd ed. New Age International Publishers, 2013.<br>6. H. L. Royden and P. M. Fitzpatrick, *Real Analysis,* 4th ed., Pearson Prentice Hall (Indian reprint), 2012. |

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|---|---|---|
| 1. | Course Code | **MA 620** |
| 2. | Title of the Course | **Partial Differential Equations** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Ordinary Differential Equation |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Second order partial differential equations, One dimensional diffusion equation, and The Laplace equation. |
| 7. | Course Syllabus | Mathematical models leading equations. First order partial differential equations: Linear, quasi-linear and fully nonlinear equations-Lagrange and Charpit methods. Cauchy-Kowalewski's Theorem.<br>Second order partial differential equations: Classification and Canonical forms of equations in two independent variables, One dimensional wave equation- D'Alembert's solution. Solution of three-dimensional wave equation. Method of decent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions.<br><br>One dimensional diffusion equation: Maximum Minimum principle for the diffusion equation, Diffusion equation on the whole line, Diffusion on the half-line, inhomogeneous equation on the whole line, Heat equation, Uniqueness of solutions via energy method.<br><br>The Laplace equation: Maximum-Minimum principle, Existence theorem by Perron's method, Harnack's theorems. Fourier method for heat equation, wave equation and Laplace equation. |
| 8. | Suggested Books | 1. I. N. Sneddon, *Elements of Partial Differential equations*, McGraw-Hill, New York, 1986.<br>2. E. T. Copson, *Partial Differential Equations*, Cambridge university press, London, 1975.<br>3. W. E. Williams, *Partial Differential Equations*, Clarendon Press, Oxford, 1980.<br>4. Y. Pinchover and J. Rubinstein, *An Introduction to Partial Differential Equations,* Cambridge University press.<br>5. E. DiBenedetto, *Partail Differential Equations*, Birkhauser, Boston, 1995. |

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|---|---|---|
| 1. | Course Code | **MA 621** |
| 2. | Title of the Course | **Ordinary Differential Equations** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Mathematics |
| 5. | Pre–requisite, if any (for the students) | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Power series methods of solution of ODE, Existence and Uniqueness theory of Initial Value Problems, Solution of system of differential equations, and boundary value problems. |
| 7. | Course Syllabus | Review of solution methods for first order as well as second order equations, Power Series methods with properties of Bessel functions and Legendre polynomials.<br>Existence and Uniqueness of Initial Value Problems: Picard's and Peano's Theorems, Gronwall's inequality, Continuation of solutions and maximal interval of existence, Continuous dependence.<br>Systems of Differential Equations: Algebraic properties of solutions of linear systems, the eigenvalue-eigenvector method of finding solutions, Complex eigenvalues, Equal eigenvalues, Fundamental matrix solutions, Matrix exponential, Nonhomogeneous equations, Variation of parameters.<br>Boundary Value Problems for Second Order Equations: Green's function, Sturm comparison theorems and oscillations, Eigenvalue problems. |
| 8. | Suggested Books | 1. G. F. Simmons, *Differential Equations with Applications and Historical Notes,* Second edition, Tata Book House, 1991.<br>2. G. Birkhoff and G. C. Rota, *Ordinary Differential Equations*, Wiley & Sons, 4th Ed., 1989.<br>3. E. A. Coddington, *Ordinary Differential Equations,* Prentice Hall of India, 1974.<br>4. M. Hirsch, S. Smale and R. Deveney, *Differential Equations*, *Dynamical Systems and Introduction to Chaos*, Academic Press, 2004.<br>5. D. A. Sanchez, *Ordinary Differential Equations and Stability Theory: An Introduction*, Dover Publ. Inc., New York, 1968.<br>6. L. Perko, *Differential Equations and Dynamical Systems, Texts in Applied Mathematics*, Vol. 7, 2nd ed., Springer Verlag, New York, 1998. |

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|---|---|---|
| 1. | Course Code | **MA 631** |
| 2. | Title of the Course | **Functional Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Department | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Analysis-I, Analysis-II, Linear Algebra |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Normed linear spaces, Banach spaces, spaced of bounded operators, Hahn-Banach theorem and inner product spaces. |
| 7. | Course Syllabus | Normed linear space; Banach spaces and basic properties: Heine-Borel theorem, Riesz lemma and best approximation property: Inner product space and projection theorem; Orthonormal bases; Bessel inequality and Parseval's formula; Riesz-Fischer theorem.<br><br>Bounded operators and basic properties; Space of bounded operators and dual space; Riesz representation theorem; Adjoint of operators on a Hilbert space; Examples of unbounded operators; Convergence of sequence of operators.<br><br>Hahn-Banach Extension theorem; Uniform boundedness principle; Closed graph theorem and open mapping theorem and their applications.<br><br>Invertibility of operators; Spectrum of an operator. |
| 8. | Suggested Books | 1. J.B. Conway, *A Course in Functional Analysis*, 2nd ed., Springer, Berlin, 1990.<br>2. E. Kreyzig, *Introduction to Functional Analysis with Applications*, John Wiley & Sons, New York, 1978.<br>3. B.V. Limaye, *Functional Analysis*, 2nd ed., New Age International, New Delhi, 1996.<br>4. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Mc-Graw Hill, 2004.<br>5. M.T. Nair, *Functional Analysis, A First Course*, Prentice Hall of India, 2002. |

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|---|---|---|
| 1. | Course Code | **MA 640** |
| 2. | Title of the Course | **Algebra-I** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Group and Ring theories. |
| 7. | Course Syllabus | Binary operation, and its properties, Definition of a group, Examples and basic properties. Subgroups, Coset of a subgroup, Lagrange's theorem. Cyclic groups, Order of a group. Normal subgroups, Quotient group. Homomorphisms, Kernel and Image of a homomorphism, Isomorphism theorems. Permutation groups, Cayley's theorems. Direct product of groups. Group action on a set. Sylow' theorems. Structure of finite Abelian groups.<br><br>Rings: definition, examples and basic properties. Zero divisors, Integral domains, Fields, Characteristic of a ring, Quotient field of an integral domain. Subrings, Ideals, Quotient rings, Isomorphism theorems. Ring of polynomlals. Prime, Irreducible elements and their properties, UFD, PID and Euclidean domains. Prime ideal, Maximal ideals, Prime avoidance theorem, Chinese remainder theorem. |
| 8. | Suggested Books | 1. I. N. Herstein, *Topics in Algebra* (2nd Edition), John Wiley & Sons, 2005.<br>2. T. W. Hungerford, *Algebra*, Springer, 2008.<br>3. M. Artin, *Algebra*, Prentice Hall of India, 1999.<br>4. D. S. Dummit and R. M. Foote, *Abstract Algebra* (2nd Edition), John Wiley and Sons, 2003.<br>5. S. Lang, *Algebra* (3rd Edition), Springer, 2004.<br>6. N. Jacobson, *Basic Algebra vol 1*, Hindustan Publishing Corporation, 1993.<br>7. P. M. Cohn, *Basic Algebra*, Springer, 2005. |

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|---|---|---|
| 1. | Course Code | **MA 641** |
| 2. | Title of the Course | **Linear Algebra** |
| 3. | Credit Structure | L-T- P-Credits<br>3-1-0-4 |
| 4. | Name of the Concerned Department | Mathematics |
| 5. | Pre–requisite, if any (for the students) | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Vector space, Linear transformations, rank, Eigenvalues and eigenvectors, Inner product spaces, and Bilinear forms. |
| 7. | Course Syllabus | Vector spaces, subspaces, bases and dimension.<br>Systems of linear equations, matrices, rank. Linear transformations, the matrix of linear map, rank-nullity theorem, duality and transpose.<br>Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonal-lization, Invariant subspace, Rational canonical form, Jordan canonical form.<br>Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, Operators on real vector spaces, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators.<br>Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic forms, Sylvester's law of inertia. |
| 8. | Suggested Books | 2. S. Axler, *Linear Algebra,* Done Right, Springer, 1997.<br>3. M. Artin, *Algebra*, Prentice Hall of India, 1994.<br>4. K. Hoffman and R. Kunze, *Linear Algebra*, Pearson Education (India), 2003. Prentice-Hall of India, 1991.<br>5. S. Lang, *Linear Algebra*, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989.<br>6. G. Strang, *Linear Algebra and Its Applications*, Brooks/Cole, 2006.<br>7. P. Lax, *Linear Algebra*, John Wiley & Sons, New York,. Indian Ed. 1997.<br>8. H. E. Rose, *Linear Algebra*, Birkhauser, 2002. |

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|---|---|---|
| 1. | Course Code | **MA 643** |
| 2. | Title of the Course | **Algebra-II** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Linear Algebra (MA 641), Algebra-I (MA 640) |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Field and Galois theories. |
| 7. | Course Syllabus | Fields: definition and examples. Ring of polynomials over a field. Field extensions. Algebraic and transcendental elements. Algebraic extensions. Splitting field of a polynomial. Algebraic closure of a field. Normal, separable, purely inseparable extensions. Primitive elements of a field extension – simple extensions.<br><br>Fundamental theorem of Galois. Geometric constructions. Cyclotomic extensions. Solvability by radicals, Solutions of cubic and quartic polynomials, Insolvability of quintic and higher degree polynomials. |
| 8. | Suggested Books | 1. J. Rotman, *Galois Theory* (2nd Edition), Springer, 1998.<br>2. E. Artin, *Galois Theory*, Dover Publications, 1998.<br>3. D. A. Cox, *Galois Theory* (2nd Edition), John Wiley & Sons, 2012.<br>4. F. Borceux and G. Janelidze, *Galois Theories*, Cambridge University Press, 2001.<br>5. S. Lang, *Algebra* (3rd Edition), Springer, 2004. |

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|---|---|---|
| 1. | Course Code | **MA 651** |
| 2. | Title of the Course | **Numerical Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Analysis-I, Linear Algebra, ODE |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in interpolation theory, Numerical integration, numerical solution of system of linear equations, Numerical solution of ordinary differential equations, and finite difference methods. |
| 7. | Course Syllabus | Introduction, finite floating point arithmetic, catastrophic cancellation, chopping and rounding errors.<br>Interpolation by polynomials, divided differences, error of the interpolating polynomial, piecewise linear and cubic spline interpolation.<br>Numerical integration, composite rules, error formulae.<br>Solution of a system of linear equations. Solution of a nonlinear equation, bisection and secant methods. Newton's method, rate of convergence, solution of a system of nonlinear equations.<br>Numerical solution of ordinary differential equations, Euler and Runge-Kutta methods, multi-step methods, predictor-corrector methods, order of convergence, global errors, algebraic and shooting methods for boundary value problems.<br>Finite difference methods, numerical solutions of elliptic, parabolic and hyperbolic partial differential equations. Eigen-value problem, power method, QR method, Gershgorin's theorem. Exposure to software packages like MATLAB. |
| 8. | Suggested Books | 1. G. W. Stewarts, *Afternotes on Numerical Analysis*, SIAM, 1996.<br>2. S. D. Conte and C. de Boor, *Elementary Numerical Analysis- An Algorithmic Approach* (3rd Edition), McGraw- Hill, 1980.<br>3. G. Dahlquist and Å. Björck, *Numerical methods in Scientific Computing*, Vol-1, SIAM-2008.<br>4. C. E. Forberg, *Introduction to Numerical Analysis* (2nd Edition), Addison-Wesley, 1981.<br>5. D. Watkinson, *Fundamentals of Matrix Computations*, Wiley-Interscience (2nd edition), 2002.<br>6. M. L. Overton, *Numerical Computing with IEEE floating point Arithmetic*, SIAM 2001. |

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| **Course code** | **MA 652/ MA 452** |
| **Title of the course** | **Theory of Transforms** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mathematics |
| Pre-requisite, if any | Calculus, Complex Variable, Differential Equations |
| Scope of the course | This course provides a working knowledge of analytical methods required in pure and applied mathematics, physics and engineering. It also gives a systematic exposition of the basic properties of various integral transforms and their applications to the solution of initial and boundary value problems in mathematical physics, engineering, and applied mathematics. |
| Course Syllabus | Fourier Series, Riemann-Lebesgue Lemma, Gibbs Phenomenon, Fourier Sine and Cosine Series, Fourier Transform, Fourier Integral Theorem, Convolution and Parseval_s Theorem, Applications to Partial Differential Equations.<br><br>Laplace Transform: definition and properties, Complex Inversion, Convolution Theorem, Heaviside's Expansion Theorem, Bromwich Contour Integral, Applications to Initial and Boundary Value Problems.<br><br>Fundamental Theorem of the Discrete Fourier Transform, Cyclical Convolution, and Parseval's Theorem. Z Transform: definition and examples, Basic Operational Properties of Z Transforms, Inverse<br><br>Z Transform and Examples, Applications of Z Transforms to Finite Difference Equations and Summation of Infinite Series. |
| Suggested Books | 1. L. Debnath, D. Bhatta, ***Integral transforms and their applications,*** Chapman & Hall/CRC, New York, 2006, 1584885750<br>2. R. J. Beerends, H. G. ter Morsche, J. C. van den Berg, E. M. van de Vrie, ***Fourier and Laplace Transforms,*** Cambridge University Press, New York, 2003, 0521534410<br>3. A. Pinkus, S. Zafrany, ***Fourier Series and Integral Transforms,*** Cambridge University Press, New York, 1997, 0521597714<br>4. U. Graf, ***Applied Laplace Transforms and Z-Transforms for Scientists and Engineers***, Birkhauser Verlag, Basel, Switzerland, 2004 : 3034895933 |

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| **Course code** | **MA 654/ MA 454** |
| **Title of the course** | **Mathematical Modeling and Simulations** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Mathematics |
| Pre-requisite, if any | Differential Equations, Linear Algebra |
| Scope of the course | The Mathematical model plays a significant role providing a quantitative framework for understanding and solving many real-life problems under certain conditions. Most of the mathematical models have been like individual works of art that reflected the personal characteristics and scientific views of the modeler. At the end of the course, students should be exposed to fundamental knowledge of implementing the models in real-world situations. They will get the bright idea about constructing or selecting the appropriate model, identify the problem, Analytically or numerically computing the solution and test the validity of models. This course provides an introduction to modeling through in-depth discussion of a series of real examples. |
| Course Syllabus | **Introduction to Mathematical Modeling:** Characteristics, Classifications, Tools, Techniques, Deterministic and stochastic models, Modeling approaches, Compartmental models, Introduction to Discrete Models and Continuous Models, Dynamical systems and its mathematical models.<br><br>**Models from systems of natural sciences:** Population models for a single species (discrete and continuous-time models), Modeling of population dynamics of two interacting species, Analytical Tool: Kolmogorov Theorem, Linear Stability Analysis, Lotka-Volterra Model, Variation of the Classical LV Model, Leslie-Gower Model, Prey-Predator Model, Arms Race Model, Holling-Tanner Model, Modified HT Model, Applications of Lyapunov functions.<br><br>**Modeling of Atmospheric, Mining and Engineering systems:** Spatial Models Using Partial Differential Equations, Modeling with Stochastic Differential Equations, Models of Heating and Cooling, Models for traffic flow, Model for detecting land mines, Models in Mechanical Systems, Models in Electronic systems, Models for vehicle dynamics, Kicked Harmonic oscillator, Modeling the ventilation system of a mine.<br><br>MATLAB/MATHEMATICA programs to study the dynamics of the developed model systems. |
| Suggested Books | 1. B. Barnes, G. R. Fulford, ***Mathematical Modeling with Case Studies,*** CRC PRESS, Taylor & Francis, London, New York, 2009, 13, 978-1-4200-8348-4<br>2. Edward A. Bender, ***An Introduction to Mathematical Modeling***: John Wiley & Sons, United States of America, 1978, 0-471-02951-3<br>3. R. K. Upadhyay, S. R. K. Iyengar, ***Introduction to Mathematical Modeling and Chaotic Dynamics,*** CRC Press Taylor & Francis, London, New York, 2014, 13: 978-1-4398-9887-1<br>4. S. Banerjee, ***Mathematical Modeling,*** Models, Analysis and Applications, CRC Press, Taylor & Francis, London, New York, 2014, 13: 978-1-4822-2916-5 |

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| 1. | Course Code | **MA 671/ ME 671 / ME 471** |
| 2. | Title of the Course | **Operations Research** |
| 3. | Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Disciplines | Mathematics and Mechanical Engineering |
| 5. | Pre–requisite, if any | Basic course in probability and statistics |
| 6. | Scope of the Course | To develop analytical problem solving and decision-making capability through methods of Operations Research. Relate the course material to some of the research problems. |
| 7. | Course Syllabus | **Introduction:** Origin and development of operations research, general methodology of OR, applications of OR to industrial problems.<br>**Linear Programming Problems:** Different types of models, formulation of linear programming problems (LPPs), product-mix problems, deterministic models, graphical solution.<br>**Simplex Method:** Simplex algorithm, computational procedure in simplex method, applications of simplex technique to industrial problems.<br>**Duality and Sensitivity:** Duality and its concept, dual linear programming, application of elementary sensitivity analysis.<br>**Linear Optimization Techniques:** Integer programming problems (IPPs), assignment models: mathematical formulation, methods of solutions, transportation problems: methods of obtaining optimal solution degeneracy in transportation problems, transshipment problems.<br>**Game Problems:** Introduction and scope of game problems in business and industry, min-max criterion and optimal strategy, solution of two-person zero-sum game, game problem as a special case of linear programming.<br>**Queuing Problems:** Queuing systems and concepts, classification of queuing situations; Kendall's notation, solution of queuing problems, single channel, single stage, finite and infinite queues with Poisson arrival and exponential service time, applications to industrial problems. |
| 8. | Suggested Books | 1. H.A. Taha, **An Introduction to Operations Research** (6th edition), Prentice Hall of India, 2001.<br>2. F.J. Hillier, G.J. Lieberman, **Introduction to Operations Research** (7th edition), Holden Day Inc., 2001.<br>3. H.M. Wagner, **Principles of Operations Research**, Prentice Hall of India, 1980, ISBN:9788120301627.<br>4. D. Gross, and C.M. Harris, **Fundamentals of Queuing Theory** (2nd edition), John Wiely & sons, New York, 1985, ISBN: 9780471890676. |
| 9. | Lab | Apply readily available software packages for solution of management problems.<br>Summarize and present analysis of results in a clear and a coherent manner. |

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| 1. | Course Code | **MA 673** |
| 2. | Title of the Course | **Fundamentals of Discrete Mathematics** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in basic graph theory, basic mathematical logics, boolean algebras, basic combinatorics, and advanced set theory. |
| 7. | Course Syllabus | **Graphs:** Graphs and Graph Models, Graph Terminology and Special Types of Graphs, Representing Graphs and Graph Isomorphism, Connectivity, Euler and Hamilton Paths, Shortest-Path Problems, Planar Graphs, Graph Coloring.<br><br>**Logic:** Propositional Logic, Propositional Equivalences, Predicates and Quantifiers, Nested Quantifiers, Rules of Inference.<br><br>**Boolean Algebras:** Lattices, Distributive and Complemented lattices, Boolean Algebras, Uniqueness of Finite Boolean Algebras, Boolean Functions, Switching Circuits.<br><br>**Combinatorics:** Numbers and Counting, Partitions and Permutations, Principle of Inclusion and Exclusion, Pigeon Hole Principle, Recurrence Relations, Generating Functions.<br><br>**Set Theory:** Axiom of Choice, Zorn's Lemma, Cardinality, Schroder-Bernstein Theorem, Countability and Uncountability, Cantor's Theorem, Cardinal Arithmatic. |
| 8. | Suggested Books | 1. K. H. Rosen, *Discrete Mathematics and Its Applications*, McGraw-Hill Education, 4th Edition, 1999.<br>2. C. L. Liu and D. P. Mohapatra, *Elements of Discrete Mathematics*, Tata McGraw-Hill, 3rd Edition.<br>3. D. J. Hunter, *Essentials of Mathematics*, Jones & Bartlett Publishers, 2010.<br>4. P. R. Halmos, *Naive Set Theory*, Springer-Verlag, New York, 1974.<br>5. P. J. Cameron, *Combinatorics: Topics, Techniques, Algorithms*, Cambridge University Press, 1994. |

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| 1. | Course Code | **MA 675 / ME 675** |
| 2. | Title of the Course | **Probability and Statistical Methods** |
| 3. | Credit Structure | L-T- P-Credits<br>2-0-2-3 |
| 4. | Name of the Concerned Disciplines | Mathematics and Mechanical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | The primary goal is to develop ability as well as awareness of reasoning and decision-making utilizing statistical data. The quality of decision making is decided by the way data and information is handled/interpreted by a researcher. |
| 7. | Course Syllabus | **Introduction to statistics**: definitions and terminology; data classification; data collection techniques, various scales for measurement and their relevance<br>**Descriptive statistics:** frequency distributions; measures of central tendency, Variation<br>**Probability:** basic concepts; multiplication and addition rules, Bayes rule, Discrete probability distributions: basic concepts; Binomial, Poisson, and other discrete distributions, Continuous probability distributions: Exponential, Normal, Weibull, and other continuous distribution.<br>**Normal probability distributions**: introductory concepts; the standard normal Distribution; central limit theorem, applications of normal distributions, approximations to discrete probability distributions<br>**Correlation and Regression analysis:** overview of correlation; linear regression,<br>**Hypothesis Testing:** Null and Alternative Hypothesis, Type I and Type II errors, Confidence intervals: confidence intervals for the mean (large samples and small samples) and for population proportions, p-value, z-test, t-test, F-test, etc. Analysis of Variance<br>**Taguchi Method and Design of Experiments, Non-parametric tests,**<br>**Case studies and applications to managerial decision making** |
| 8. | Suggested Books | 1. P.L. Meyer, **Introductory Probability and Statistical Applications**, Oxford and IBH Publishers, ISBN: 0-201-04710-1.<br>2. I.R. Miller, J.E. Freund, R. Johnson, **Probability and Statistics for Engineers**, Prentice-Hall (I) Ltd, ISBN: 9788177581843.<br>3. R.E. Walpole and R.H. Myers, **Probability & Statistics for Engineers and Scientists**, Macmillan, ISBN: 9788131715529.<br>4. S.M. Ross, **Introduction to Probability and Statistics for Engineers and Scientists**, Academic Press, ISBN: 9780123704832. |
| 9. | Lab | It will mainly involve use of computer software (Minitb, Statistica, etc.) to solve complex engineering problems/ case studies as well as manually solving some of the basic tutorials and interpreting the results for decision making. Following points will be mainly covered:<br>i) General, data representation, Mean, expectations, pdf, cdf<br>ii) Chebyshevs’ inequality, probability distributions: Poisson, Binomial, Normal, Weibull, etc.<br>iii) MGF,<br>iv) Sampling with and without replacement<br>v) Type I , II and Hypothesis testing, Hypothesis testing<br>vi) Chi-square test,<br>vii) Regression<br>viii) RBD, CRD, Factorial, Taguchi |

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| 1. | Course Code | **MA 680** |
| 2. | Title of the Course | **Computational Techniques** |
| 3. | Credit Structure | L-T- P-Credits<br>3-0-2-4 |
| 4. | Name of the Concerned Department | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Basic knowledge in matrix algebra, differential equations, calculus, and statistics. |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge in data structures, algorithms, programming languages, and computations using MATLAB, Mathematica, and R-Software. |
| 7. | Course Syllabus | **Programming in C:** Background, Variables, Constants, Data types, Operators and Expressions, Conditional statements: if, if-else, Loops: for, while, do-while, Array, Function, Pointers, Dynamic memory allocation, Files.<br><br>**Data Structure and Algorithm:** Stack, Applications of stack: arithmetic expression evaluation, recursion, Queue, Circular queue, Linked list: Single linked list, Circular linked list, Doubly linked list, Tree Data Structure: Binary tree, Tree traversal techniques, AVL Tree, B-tree, B+-tree, Graph: representation of graph using adjacency matrix and linked list, Applications of graph structures: Minimum spanning trees, Connectivity in graph, DFS, BFS, Hashing: Hash function, Collision resolution in hashing, Complexity Analysis of Algorithms: Asymptotic notations, Searching and Sorting: Linear search, binary search, Bubble sort, Selection sort, Insertion sort, Quick sort, Heap sort, merge sort.<br><br>**MATLAB:** IEEE Arithmetic, Mathematical Functions, Matrix and Array operations, Matrix manipulation, Script and functions, working with mfiles and the matlab path, two dimensional graphics (Basic plots), Three dimesional Graphics, LU, QR, Systems of Linear Equation, Basic numerical Methods for solving simple ODE, Data fitting, Optimization, non linear equation.<br><br>**Mathematica:** User interface, Mathematica language and syntax, Introduction to computation, polynomial operations, solving equations, functions and simplification, 2D and 3D plotting, plotting data, creating dynamic and interactive graphics, solving simple ordinary differential equations.<br><br>**The R Software:**<br><br>Introduction to R; Importing and exporting data from - Excel, SPSS, SAS, Stat, CSV, txt file; Data Types (like vector, matrix, dataframe, list, numeric, factors, characters,etc); Viewing Data, Date Values, Access to DBM.S.; Sorting Data , Merging Data, Appending Data, Reshaping Data, Subsetting Data; Data Type Conversion, Merging, RMySQL (joins); R-packages, Built-in-Functions, write functions, call functions; Local & global variables and functions; Control Structures- if, ifelse, for, while, switch, stop , break, which function; Descriptive Statistics; Frequency & Crosstab; Visualization, Graph and plots (Histogram, time series, box plot). |

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| 8. | Suggested Books | 1. A. V. Aho, J. D. Ullman, and J. E. Hopcroft, *Data Structures and Algorithms*, Addison-Wesley, 1983.<br>2. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, McGraw-Hill, 2001.<br>3. Y. Kanetkar, *Let Us C*, BPB Publications, ISBN-13: 9788183331630, 2012.<br>4. E. Balaguruswamy, *Programming in ANSI C*, Tata McGraw-Hill, ISBN-13: 9781259004612, 2012.<br>5. B. W. Kernighan and D. M. Ritchie, *The C Programming Language*, Prentice Hall of India, ISBN-13: 9788120305960, 2009.<br>6. B. Gottfried, *Schaum's Outline of Programming with C*, Tata McGraw-Hill, ISBN-13: 9780070240353.<br>7. D. Samanta, *Classic Data Structures*, PHI, Second Edition, 2009.<br>8. S. Lipschutz, *Data Structure with C*, Schaum's OuTlines, TMH, 2011.<br>9. Y. Langsam, M. J. Augenstein, and A. M. Tenenbaum, *Data Structure using C and C*++, Prentice Hall, Second Edition, 2009.<br>10. D. J. Higham and N. J. Higham, *MATLAB Guide*, 2$^{nd}$ Edition, SIAM, 2005.<br>11. A. Gilat, *MATLAB: An Introduction with Applications*, John Wiley & Sons Inc. 5$^{th}$ Edition, 2014.<br>12. S. Wolfram, *Mathematica: Standard Add-on Packages*, Cambridge University Press, 1996.<br>13. P. R. Wellin, R. J. Gaylord, and S. N. Kamin, *An Introduction to Programming with Mathematica*, 3$^{rd}$ Edition, Cambridge University Press, 2005.<br>14. H. Ruskeepaa, *Mathematica Navigator: Mathematics, Statistics, and Graphics*, 3$^{rd}$ Edition, Academic Press Inc., 2009.<br>15. W. N. Venables and D. M. Smith, *An Introduction to R*, Network Theory Limited, Second Edition, 2009.<br>16. P. Teetor, *R Cookbook*, O'Reilly Media, First Edition, 2011. |
| 9 | Lab | Laboratory components include Programming using C++ language, computations using MATLAB, Mathematica and the R Software. All these will be taught in computer lab using computers. |

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| 1. | Course Code | **MA 701** |
| 2. | Title of the Course | **Experimental Designs and Data Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the course | |
| 7. | Course Syllabus | Review of standard discrete and continuous statistical distributions.<br>Sampling distributions such as chi-square, Student's t and, F- distribution.<br>Estimation and Tests of Hypotheses.<br>Regression and Correlation Analysis.<br>Test for independence and goodness of fit.<br>Non-parametric tests.<br>Analysis of Variance (ANOVA): One way and Two way classification.<br>Analysis of Covariance (ANCOVA).<br>Experimental Designs: CRD, RBD, LSD, BIBD. Split plot and missing plot technique.<br>Orthogonal Arrays: Application to Taguchi Method.<br>Introduction to Response Surface Methodology (RSM). |
| 8. | Suggested Books | 1. R.E. Walpole, **Probability and Statistics for Engineers and Scientists**, Prentice-Hall-Gale, 1998. (ISBN:0138402086.)<br>2. D.C. Montgomery, **Design and Analysis of Experiments** ($5^{th}$ edition), John Wiley & Sons (Asia) Pte. Ltd. Singapore, 2004. (ISBN: 0471316490).<br>3. R. Y. Myers, et al., **Response Surface Methodology: Process and Product Optimization using Designed Experiments** ($3^{rd}$ edition), Wiley, 2009.<br>4. M.S. Phadke, **Quality Engineering Using Robust Design**, Prentice Hall, Englewood Cliff, New Jersey, 1989. |

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| 1. | Course Code | **MA 702** |
| 2. | Title of the Course | **Conformal Mappings** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Complex Analysis |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Preliminaries:** Analytic functions, Basic theorems, The Riemann sphere, Möbius transformations, Cross ratio, Inverse points, Characterization of maps between special domains.<br><br>**Conformal Mappings:** Definition of conformal maps, Disk automorphism, Schwarz's lemma, Schwarz-Pick's lemma, The hyperbolic metric in the unit disk, The upper half plane model.<br><br>**The Riemann Mapping Theorem:** Normal families, The Riemann mapping theorem, the hyperbolic metric in simply connected domains, The Schwarz reflection principle, The Schwarz-Christoffel mappings.<br><br>**Quasiconformal Mappings:** Conformal and quasiconformal maps, Introduction to Grötzsch problem, Complex dilatation, Definition of quasiconformal maps, Solution to Grötzsch problem, Composition maps, Extremal length, Geometric definition of quasiconformal maps, Mori's theorem. |
| 8. | Suggested Books | 1. Lars V. Ahlfors, Complex Analysis, McGraw Hill, 1996.<br>2. T.W. Gamelin, Complex Analysis, Springer (Corrected edition), 2001.<br>3. S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser, 2006.<br>4. Zeev Nehari, Conformal Mapping, Dover Publications, 1982.<br>5. L. Keen and N. Lakic, Hyperbolic Geometry from a Local Viewpoint (London Mathematical Society Student Texts), Cambridge University Press, 2007.<br>6. Lars V. Ahlfors, Lectures on Quasiconformal Mappings, American Mathematical Society (Second Edition with additional chapters by C.J. Earle and I. Kra, M. Shishikura, J.H. Hubbard), 2006. (Originally published by D. Van Nostrand Company, Inc. 1966)<br>7. O. Lehto and K.I. Virtanen, Quasiconformal mappings in the plane, Springer, 1973.<br>8. O. Lehto, Book Title: Univalent functions and Teichmüller spaces, Springer, 1986.<br>9. K. Asthala, T. Iwaniec, and G. Martin, Elliptic Partial Differential Equations and Quasi-conformal Mappings in the Plane, Princeton University Press, 2008. |

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| 1. | Course Code | **MA 703** |
| 2. | Title of the Course | **Topics in Analysis** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/Discipline | Mathematics |
| 5. | Pre–requisite, if any | Real Analysis, Complex Analysis, Functional Analysis, Fourier Series |
| 6. | Scope of the course | |
| 7. | Course Syllabus | Functions of bounded variations, Riemann-Stieltjes Integration, Riemann<br>Mapping Theorem, Univalent Functions, Bieberbach's Theorem, Hadamard's three circle theorem, Riemann's Zeta Function, Continuous<br>but nowhere differentiable functions (example), Weierstrass approximation theorem (Stone-Weierstrass Theorem), Hahn Banach Theorem, Fourier series, Dirichlet's Theorem, Fejer's Theorem. |
| 8. | Suggested Books | 1. H.M. Edwards, Riemann's Zeta Function, Dover Publications; Dover<br>2. Ed edition, 2001, ISBN: 9780486417400.<br>3. E.C. Titchmarsh, The theory of the Riemann Zeta-Function, Oxford<br>4. University Press, USA; 2 edition, 1987, ISBN: 9780198533696.<br>5. Walter Rudin, Principles of mathematical analysis (3rd. ed.), McGraw-Hill, 1976, ISBN: 978-0070542358.<br>6. Walter Rudin, Functional analysis, McGraw-Hill, 1973, ISBN:<br>7. 9780070542365.<br>8. Peter L. Duren, Univalent Functions, Springer-Verlag Berlin and<br>9. Heidelberg GmbH & Co. K, 1983, ISBN: 9783540907954.<br>10. Georgi P. Tolstov, Fourier Series, Dover Publications, 1976, ISBN: 978-0486633176.<br>11. G.H. Hardy and W.W. Rogosinski, Fourier Series, Dover Publications 1999, 978-0486406817. |

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| 1. | Course Code | **MA 704** |
| 2. | Title of the Course | **Probability Theory** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1- 0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Measure Theory |
| 6. | Scope of the course | |
| 7. | Course Syllabus | Probability Space, Random Variables, Kolmogorov Consistency Theorem, Independence and Dependence, Weak and Strong law of large numbers, Central Limit Theorem, Characteristic Function, Levy's Inversion Formula, Levy's Continuity Theorem, Conditional Expectation, Martingales, Markov Chains, Wiener Process, Stationary Process, Entropy and its Applications, Large Deviations. |
| 8. | Suggested Books | 1. Daniel W. Stroock, Probability Theory, an Analytic View, Cambridge University Press; Revised edition (January, 2000), ISBN-10: 0521663490, ISBN-13: 978-0521663496.<br>2. Krishna B. Athreya and Soumendra Lahiri, Probability Theory, Hindusthan Book Agency, 2006, ISBN: 978-81-85931-70-8.<br>3. A.N. Kolmogorov, Foundations of the Theory of Probability, Chelsea Pub Co, 2nd edition,1960 (ISBN: 9780828400237)<br>4. K.R. Parthasarathy, Introduction to Probability and Measure (Texts & Readings in Mathematic), Hindustan Book Agency, New Delhi, 2005. (ISBN: 9788185931555)<br>5. W. Feller, An Introduction to Probability Theory and Its Applications, Wiley, 3 edition,1968. (ISBN: 9780471257080) |

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| 1. | Course Code | **MA 705** |
| 2. | Title of the Course | **Applied Operator Theory** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Real Analysis, Complex Analysis and Linear Algebra. |
| 6. | Scope of the course | Familiarize the basic concepts of functional analysis and their application in solving various operator equations |
| 7. | Course Syllabus | Normed Linear Space, Linear Transformations, Zorn's Lemma, Hamel Basis and Hahn-Banach Theorem, The Baire Theorem and Uniform Boundedness Theorem, The interior mapping and closed mapping Theorems, Weak convergence, Reflexive Space.<br><br>Hilbert Spaces, Orthogonality and Bases, Linear functonals and operators, Spectral Theory, Strum-Liouville Theory.<br><br>Calculus in Banch spaces, The Frechet Derivative, The chain Rule and Mean value Theorems.<br><br>Basic Approximate methods of Analysis, The method of iteration, Regularization method, Projection methods, The Galerkin method, The Rayleigh-Ritz method, Conjucate Direction methods, Methods Based on Homotopy and continuation. |
| 8. | Suggested Books | 1. W. Cheney, *Analysis for Applied Mathematics,* Springer, 2001. ISBN: 978-0-387-95279-6<br>2. E. Zeidler, *Applied Functional Analysis: Applications to Mathematical Physics,* Springer 1995. ISBN: 978-0387944425<br>3. L.P. Lebedev, I.I. Vorovich and G.M.L. Gladwell, *Functional Analysis: Applications in Mechanics and Inverse Problems,* Kluwer Academic Publishers, 2002. ISBN: 978-1402006678<br>4. L. Collatz, *Functional Analysis and Numerical Mathematics*, Springer-Verlag New York ,1966.<br>5. J.T. Oden and L.F. Demkowicz, *Applied Functional Analysis* CRC-Press, 1996. ISBN: 978-0849325519 |

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| 1. | Course Code | **MA 706** |
| 2. | Title of the Course | **Numerical Linear Algebra** |
| 3. | Credit Structure | 2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Knowledge of basic linear algebra. |
| 6. | Scope of the course | Problems in Numerical Linear Algebra arise in a wide variety of scientific and engineering applications including the control theory, the analysis of electrical networks, and the modeling of chemical processes. This course will cover the analysis and implementation of algorithms used to solve linear algebra problems. We will study algorithms for linear systems solution, linear least-square problems, and eigenvalue and singular value problems. Further, we study the sensitivity and stability analysis of the above algorithms to improve efficiency of problems by using various structures of matrices. |
| 6. | Course Syllabus | Floating point error, Round off error, Gram-Schmidt orthonormal process, Modified Gram-Schmidt orthonormal process,<br>**Solution of linear system:** Triangular systems and Inverse of a triangle matrix, Gauss elimination and LU Factorization method, QR factorization, QR Algorithm.<br>Rank deficient least square problems, SVD, Moore Penrose inverse, Linear iterative methods – Convergence results for Jacobi & Gauss - Seidel and relaxation method.<br>Stationary & non stationary iterative methods Convergence analysis of the Richardson method, the gradient method, the Conjugate gradient method.<br>Method based on Krylov subspace Arnoldi method, the GMRES, The Lanczos method. Approximation of Eigen value: Power method, Inverse iteration, Sensitivity analysis of Eigen values and Eigen vectors, canonical forms of matrices, Reduction to Hessenberg and tridiagonal form, conditioning of numerical algorithms.<br>Applications to control, $H_\infty$ control, Distance problems.<br>Analysis of electric network.<br>Finite Difference analysis of ordinary differential equation- Beam bending problem.<br>Finite difference analysis of partial differential equation-Heat equation.<br>Applications to Internet search engine-Google Matrix. |
| 7. | Suggested Books | 1. G. H. Golub and V. Van Loan, Matrix Computations, third edition, John Hopkins U. Press, Baltimore, 1996.<br>2. C. Pozrikidis, Numerical Computation in Science and Engineering, Oxford University Press, 1998.<br>3. A. Quarteroni, R. Sacco, and S. Fausto, Numerical Mathematics, second edition Springer-Berlin Heidelberg, 2007.<br>4. K. Bryan and T. Leise, The $ 25,000,000,000 eigenvector: The Linear Algebra Behind Google, SIAM Review, 48, 569-581.<br>5. David S. Watkins, Fundamentals of Matrix Computations, Wiley 3rd edition.<br>6. James W. Demmel, Applied Numerical Linear Algebra, 1st edition, SIAM 1997.<br>7. B. N. Datta, Numerical Linear Algebra and Application 2nd edition SIAM<br>8. B. N. Datta, Numerical Methods for Control Systems Design and Analysis, Elsevier Academic Press, 2003. |

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| 1. | Course Code | **MA 707** |
| 2. | Title of the Course | **Special Functions** |
| 3. | Credit Structure | 2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Basic complex analysis and differential equations |
| 6. | Scope of the course | |
| 7. | Course Syllabus | **Preliminaries:** Infinite product; Gamma function; Beta function<br><br>**Hypergeometric Functions:** Integral form; The contiguous function relation; Hypergeometric differential equation; Logarithmic solution; Relation between functions of z and 1-z<br><br>**Bessel's Functions:** Definition; Bessel's differential equation; Recurrence relation; A generating function; Bessel's integral; Modified Bessel's function<br><br>**Generating Functions:** Functions of the form G(2xt-t^2); Functions of the form exp(t) ψ(xt); Functions of the form A(t) exp(-xt/(1-t))<br><br>**Orthogonal Polynomials:** Legendre polynomial; Hermite polynomial; Laguerre polynomial; Jacobi polynomial |
| 8. | Suggested Books | 1. Earl D. Rainville, *Special Functions*, Chelsea Pub. Co. NY, 1971. ISBN: 978-0828402583<br>2. G.E. Andrews, R. Askey, and R. Roy, *Special Functions*, Cambidge University Press, 1999. ISBN: 978-0521623216<br>3. R. Beals and R. Wong, *Special Functions: A Graduate Text*, Cambidge University Press, 2010. ISBN: 978-0521197977<br>4. N.M. Temme, *Special Functions, An Introduction to the Classical Functions of Mathematical Physics*, Wiley-Interscience, 1996. ISBN:978-0471113133<br>5. A.M. Mathai and H.J. Haubold, *Special Functions for Applied Scientists*, Springer, 2008. ISBN: 978-0387758930<br>6. W.W. Bell, *Special Functions for Scientists and Engineers*, Dover Publication, 2004. ISBN: 978-0486435213 |

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|---|---|---|
| 1. | Course Code | **MA 708** |
| 2. | Title of the Course | **Ergodic Theory** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Measure Theory |
| 6. | Scope of the course | |
| 7. | Course Syllabus | Measure Preserving and Continuous Transformation, Poincare's recurrence Lemma, Ergodic Theorems, Ergodicity, Mixing and weak mixing and their Spectral Characterizations, isomorphism invariants, Discrete Spectrum Theorem, Entropy and Kolmogorov, Sinai Theorem, Stacking method of constructing transformations, Ambrose theorem on representation of flows. Van der Waerden's theorem on arithmetical Progressions. |
| 8. | Suggested Books | 1. I.P. Cornfeld, S.V. Fomin, and Ya G. Sinai, Ergodic Theory, Springer-Verlag Berlin and Heidelberg GmbH Co. K (December 31,1982), ISBN-10: 3540905804, ISBN-13: 978-3540905806.<br>2. P. Walters, An Introduction to Ergodic Theory (Graduate Texts in Mathematics), Springer, 2000. (ISBN: 9780387951522)<br>3. M.G. Nadkarni, Basic Ergodic Theory, Hindusthan Book Agency, 1995. |

| | | |
|---|---|---|
| 1. | Course Code | **MA 709** |
| 2. | Title of the Course | **Advance Numerical Methods for Linear Control Systems** |
| 3. | Credit Structure | 2-1-0-3 |
| 4. | Name of the Concerned Discipline/Discipline | Mathematics |
| 5. | Pre–requisite, if any | Basic Linear Algebra and Numerical Linear Algebra Techniques |
| 6 | Scope of the course | Modern Numerical linear techniques for mathematical problems arising in the design and analysis of linear control systems both for the first-order and second-order models. In this course we impose systematic descriptions and implementations of numerical algorithms based on well-established, efficient, and stable manner so that it will be help full to solve the various problems on design and analysis of linear control systems. |
| 7. | Course Syllabus | Review of Basic Concepts and Results from Theoretical Linear Algebra; Fundamental Tools and Concepts from Numerical Linear Algebra; Canonical Forms Obtained via Orthogonal Transformations; Linear State Space Models and Solutions of the State Equations; Controllability, Observability and Distance to Uncontrollability; Stability, Inertia and Robust Stability; Numerical Solutions and Conditioning of Lyapunov and Sylvester Equations; Numerical Methods and Conditioning of the Eigenvalue Assignment Problems; State Estimation; Numerical Solutions and Conditioning of Algebraic Riccati Equations; |
| 8. | Suggested Books | 1. B. N. Dutta, *Numerical Methods for Linear Control System,* Elsevier Academic Press, 2003<br>2. G. H. Golub and V. Van Loan, *Matrix Computations,* 3rd edition, John Hopkins U. Press, Baltimore, 1996.<br>3. B. N. Dutta, *Numerical Linear Algebra and Application,* 2nd edition, SIAM. |

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|---|---|---|
| 1. | Course Code | **MA 710** |
| 2. | Title of the Course | **Fractional Differential Equations** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Real Analysis |
| 6. | Scope of the course | Answering the following questions:<br>1. Why do we need fractional calculus / fractional differential equation?<br>5. How to solve the fractional differential equations explicitly?<br>6. When does the fractional differential equations have unique solutions? |
| 7. | Course Syllabus | Introduction to Fractional calculus, Grunwald-Letnikov Fractional Derivatives, Riemann-Liouville Fractional Derivatives, Caputo's Fractional Derivative.<br><br>Introduction to Fractional Differential Equation, Explicit solution of fractional differential equation via Integral Transform Methods.<br><br>Existence and Uniqueness Theorem for initial value problem, boundary value problem. Fractional delay differential equation. |
| 8. | Suggested Books | 1. A.A. Kilbas, H.M. Srivastava and J.J. Trujillo, *Theory and Applications of fractional differential equations*, Elsevier, USA, 2006. ISBN: 978-0-444-51832-3.<br>2. I. Podlubny, *Fractional Differential Equations*, Academic Press, USA, 1999. ISBN: 978-0-12-558840-2.<br>3. K. Diethelm, *The analysis of fractional differential Equations*, Springer, New York, 2010. ISBN: 978-3-642-14573-5.<br>4. R. Hilfer, *Applications of fractional calculus in physics*, World Scientific, Singapore, 2000. ISBN: 978-9810234577 |

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|---|---|---|
| 1. | Course Code | **MA 711** |
| 2. | Title of the Course | **Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Elementary Analysis, Functional Analysis, Multivariable Calculus, Elementary Topology and Measure Theory |
| 6. | Objectives of the course | It is one of the basic fundamental courses for research scholars in Discipline of Mathematics. This course will enable them to understand topics from various branches in Mathematics. |
| 7. | Course Syllabus | Metric spaces, Open and closed sets, Compactness and connectedness, Completeness, Continuous functions (several variables and on metric spaces), uniform continuity, C(X) for a compact metric space X, Uniform convergence, Compactness criterion, Weierstrass approximation theorem (Stone-Weierstrass Theorem), Differentiation, Inverse and Implicit fuction theorems, Riemann Integration, Lebesgue Integration, L^p-spaces, Banach Spaces and Hilbert Spaces. |
| 8. | Suggested Books | 1. G.F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill International, New York, 1963.<br>2. H.L. Royden, *Real Analysis*, Macmillan Publishing Company, New York, 1968.<br>3. B.V. Limaye, *Functional Analysis with Applications*, New Age International, 2008.<br>4. W. Rudin, *Principles of Mathematical Analysis*, McGraw-Hill International, 1976.<br>5. Tom. M. Apostol, *Mathematical Analysis*, Addison-Wesley, 1974.<br>6. I.J. Maddox, *Elements of Functional Analysis*, Cambridge University Press, 1988. |

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|---|---|---|
| 1. | Course Code | **MA 712** |
| 2. | Title of the Course | **Advanced Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/Discipline | Mathematics |
| 5. | Pre–requisite, if any | Basic functional analysis |
| 6. | Scope of the course | It is the fundamental course for research scholars in the Discipline of Mathematics. This course will enable them to understand various branches in Mathematics. |
| 7. | Course Syllabus | Review of general measure and integral; Positive Borel measures; Riesz representation theorem; Luzin's theorem; Vitali Caratheodory theorem. Lp-spaces and their dense subspaces, Elementary Hilbert space theory, Examples of Banch space Techniques, Complex measures; Absolute continuity; Radon-Nykodym theorem, Product measures; Fubini's theorem; Convolutions. |
| 8. | Suggested Books | 1. W. Rudin, *Real and Complex Analysis*, Third edition, McGraw-Hill, International Editions, 1986. ISBN: 978-0070542341<br>2. H.L. Royden, *Real Analysis* (3rd ed.), Prentice Hall, 1988, ISBN: 978-0024041517<br>3. I.K. Rana, *An Introduction to Measure and Integration*, Alpha Science International Limited, 2004. ISBN: 978-1842651049<br>4. P.R. Halmos, *Measure Theory*, Springer-Verlag, 1974. ISBN: 978-0387900889 |

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|---|---|---|
| 1. | Course Code | **MA 714** |
| 2. | Title of the Course | **Advanced Complex Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Complex Analysis |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Harmonic functions, Meromorphic and entire functions, Analytic continuation, Riemann Mapping and Uniformization Theorems. |
| 7. | Course Syllabus | **Harmonic Functions:** Definition and basic properties, The Mean-value property, Poisson's formula, Harnack's principle, The Dirichlet problem.<br>**Meromorphic and Entire Functions:** Infinite sums and meromorphic functions, Infinite products, The gamma function, The zeta function, Jensen's formula, The order and the genus of entire functions, Hadamard's factorization theorem, Weierstrass's product theorem, Mittag-Leffler's theorem.<br>**Analytic Continuation:** Schwarz's Reflection principle, Direct Analytic Continuation, Analytic continuation along arcs, Monodromy Theorem.<br>**Range of Analytic Functions:** Univalent functions, The Schwarz-Pick lemma, Normal families, The Riemann mapping theorem, Bloch's theorem, The little Picard theorem, Schottky's theorem, The great Picard theorem.<br>**Riemann Surfaces:** Topological spaces, Neighborhood systems, Germs and sheaves, Analytic manifolds, Covering spaces, The uniformization theorem. |
| 8. | Suggested Books | 1. L. V. Ahlfors, *Complex Analysis*, McGraw-Hill International Editions, Third Edition, New Delhi, 1979.<br>2. J. B. Conway, *Functions of One Complex Variable*, Springer International Student Edition, Narosa Publishing House, New Delhi, 1973.<br>3. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, Second Edition, New Delhi, 2005.<br>4. T. W. Gamelin, *Complex Analysis*, Undergraduate Texts in Mathematics, Springer, NY, 2001.<br>5. S. Ponnusamy and H. Silverman, *Complex Variables with Applications*, Birkhaeuser, Boston, 2006. |

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|---|---|---|
| 1. | Course Code | **MA 720** |
| 2. | Title of the Course | **Differential Equations** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Elementary Ordinary and Partial Differential Equations |
| 6. | Objectives of the course | It is one of the basic fundamental courses for research scholars in Discipline of Mathematics. This course will enable them to understand topics from various branches in Mathematics. |
| 7. | Course Syllabus | Preliminaries, Picard's Method of Successive Approximations, Existence Theorems, Continuous Dependence on Initial Conditions, Linear equations, general theory, Solutions of linear equations with constant coefficients, Equations with periodic coefficients, Green's Functions, Sturm-Liouville Problems, Lyapunov theory of stability.<br><br>First order quasi-linear equations, Nonlinear equations, Cauchy-Kowalewski's theorem, Classification of second order equations, One dimensional wave equation and De'Alembert's method, Solution of wave equation, Solutions of equations in bounded domains and uniqueness of solutions, BVPs for Laplace's and Poisson's equations, Maximum principle and applications, Green's functions and properties, Existence theorem by Perron's method, Heat equation, Maximum principle, Uniqueness of solutions via energy method, Uniqueness of solutions of IVPs for heat conduction equation, Green's function for heat equation. |
| 8. | Suggested Books | 1. E.A. Coddington, *Introduction to Ordinary Differential Equations*, Prentice Hall, 1961.<br>2. E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, Tata McGraw-Hill, 1955.<br>3. P. Prasad and R. Ravindran, *Partial Differential Equations*, New Age International, 1985.<br>4. S.G. Deo and V. Raghavendra, *Ordinary differential equations and stability theory*, Tata McGraw-Hill, 1980.<br>5. F. John, *Partial Differential Equations*, Springer, 1981.<br>6. I.N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill, 1972.<br>7. I.N. Sneddon, *Elements of Partial Differential Equations*, Dover Publications, 2006.<br>8. G.B. Folland, *Introduction to Partial Differential Equations*, Princeton University Press, 1995. |

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|---|---|---|
| 1. | Course Code | **MA 734** |
| 2. | Title of the Course | Fourier Analysis on Euclidean Spaces |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Functional Analysis |
| 6. | Objectives of the course | At the end of course, students should have the basic understanding of Fourier series, Fourier transform, Maximal function and Hilbert Transform. |
| 7. | Course Syllabus | Fourier series, Summability methods, Convergence in norm.<br><br>Fourier transform, the Schwartz space, Fourier Inversion and Plancherel theorem, The Poission summation formula.<br><br>Interpolation of operators, The Hardy-Littlewood Maximal function, Lebesgue Differentiation theorem, Hilbert Transform, Boundedness of Singular integral operators. |
| 8. | Suggested Books | 1. E. M. Stein and R. Shakarchi, *Fourier Analysis: An Introduction*, Princeton University Press, 2003.<br>2. E. M. Stein and G. Weiss, *Introduction to Fourier analysis on Euclidean Spaces*, Princeton University Press, 1975.<br>3. J. Duoandikoetxea, *Fourier Analysis*, GSM-29 American Mathematical Society, 2001.<br>4. H. Dym and H. McKean, *Fourier Series and Integrals*, Academic Press, 1985.<br>5. Y. Katznelson, *An Introduction to Harmonic Analysis* (3rd Edition), Cambridge University Press, 2004.<br>6. L. Grafakos, *Classical Fourier Analysis* (2nd Edition), Springer , 2011.<br>7. A. Torchinsky, *Real-Variable Methods in Harmonic Analysis*, Dover Publications, 2004. |

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|---|---|---|
| 1. | Course Code | **MA 736** |
| 2. | Title of the Course | **Wavelet Analysis** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Functional Analysis |
| 6. | Objectives of the course | At the end of course, students should have the basic understanding in Fourier Analysis, Wavelet transforms, Time-frequency Analysis and Multi-resolution Analysis. |
| 7. | Course Syllabus | **ELEMENTS OF FOURIER ANALYSIS:** Fourier series, Fourier transforms Inversion formula, Parseval Identity and Plancherel Theorem, Continuous-time convolution and the delta function, Poisson's summable formula, Shanon sampling theorem.<br><br>**WAVELET TRANSFORM.S. AND TIME- FREQUENCY ANALYSIS:** The Balian-Low theorem, The Gabor transform, Windowed Fourier transform, uncertainty principle, Integral wavelet transform, Dyadic wavelets, Frames, Wavelet series.<br><br>**MULTI-RESOLUTION ANALYSIS:** Multiresolution Analysis, Scaling functions, Wavelets and their duals, linear phase filtering, compactly supported wavelets, orthogonal wavelets. |
| 8. | Suggested Books | 1. C. K. Chui, *An Introduction to Wavelets*, Academic Press, 1992.<br>2. M. W. Frazier, *An Introduction to Wavelets Through Linear Algebra*, Springer, 2001.<br>3. G. Bachmann, L. Narici and Edward Beckenstein, *Fourier and wavelet analysis*, Springer, 1999.<br>4. E. Hernandez and G. Weiss, *A first course on wavelets*, CRC Press, 1996.<br>5. L. Debnath, *Wavelet transforms and their applications*, Birkhäuser Boston, 2001.<br>6. I. Daubechies, *Ten lectures on wavelets*, SIAM, 1992.<br>7. P. Wojtaszczyk, *Introduction to Wavelets*, Cambridge University Press, 1997.<br>8. D. F. Walnut, *An Introduction to Wavelet Analysis*, Birkhäuser Boston, 2001.<br>9. M. Pinsky, *Introduction to Fourier analysis and wavelets*, China Machine Press, 2002. |

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| 1. | Course Code | **MA 741** |
| 2. | Title of the Course | **Algebra** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | Elementary Abstract Algebra and Linear Algebra |
| 6. | Objectives of the course | It is one of the basic fundamental courses for research scholars in Discipline of Mathematics. This course will enable them to understand topics from various branches in Mathematics. |
| 7. | Course Syllabus | Groups, Basic properties, Isomorphism theorems, Permutation groups, Cauchy's Theorem, Sylow's Theorems, Structure theorem for finite abelian groups.<br><br>Rings, Integral domains, Fields, division rings, Ideals, Maximal ideals, Euclidean rings, Polynomial ring over a ring, Maximal & Prime ideals over a commutative ring with unity, Prime avoidance theorem, Chinese Remainder theorem, Field Extension, Algebraic elements and extensions, Finite fields.<br><br>Vector spaces, Linear transformations, Characteristic and minimal polynomial, diagonalization, Inner product spaces. |
| 8. | Suggested Books | 1. I. N. Herstein, *Topics in Algebra* (2nd Edition), John Wiley & Sons, 1975. ISBN: 978-0471010906<br>2. Thomas W. Hungerford, *Algebra*, Springer, 1980. ISBN: 978-0387905181<br>3. Michael Artin, *Algebra*, Prentice Hall of India, 1991. ISBN: 978-0130047632<br>4. David S. Dummit and Richard M. Foote, *Abstract Algebra* (3rd Edition), John Wiley and Sons, 2003. ISBN: 978-0471433347<br>5. Serge Lang, *Algebra* (3rd Edition), Springer, 2002. ISBN: 978-0387953854<br>6. P.B. Bhattacharya, S.K. Jain, and S.R. Nagpaul, *Basic Abstract Algebra*, Cambridge University Press, 2nd Edition, 1994. ISBN: 978-0521466295 |

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|---|---|---|
| 1. | Course Code | **MA 742** |
| 2. | Title of the Course | **Commutative Algebra** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | Algebra-I, Algebra-II |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Commutative Algebra. |
| 7. | Course Syllabus | Commutative rings, ideals, prime and maximal ideals, Noetherian Artinian rings, Primary decomposition and Noetherian rings, Modules over commutative rings, Exact sequences, tensor product of modules, rings and modules of fractions, integral dependence, valuations and dedekind domains. Completions, filtrations, graded rings and modules, associated graded ring. Hilbert functions, dimension theory, regular local rings. |
| 8. | Suggested Books | 1. M. F. Atiyah and I. G. MacDonald, *Introduction to Commutative Algebra* (1st Edition), Levant Books, Kolkata, 2007.<br>2. H. Matsumura, *Commutative Ring Thoery*, Cambridge University Press, 2005.<br>3. D. Eisenbud, *Commutative Algebra With a View Toward Algebraic Geometry*, Springer, 2003.<br>4. R. Y. Sharp, *Steps in Commutative Algebra*, London Mathematical Society, 1990.<br>5. G. Kemper, *A Course in Commutative Algebra*, Springer, 2011. |

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|---|---|---|
| 1. | Course Code | **MA 780** |
| 2. | Title of the Course | **Mathematical Logic** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge in Mathematical Logic. |
| 7. | Course Syllabus | **First Order Logic:** Syntax of FOL, Semantics, Consequences, Calculations, Prenex Form, Skolemization, Herbrand Interpretation, Skolem-Lowenheim Theorem.<br><br>**Proof Theory:** Resolution in PL, Propositional Calculus (PC), Completeness and Compactness of PC, Analytic Tableaux for PL, Analytic Tableaux for FL, Completeness of Analytic Tableaux, Compactness of PL and FL, Issue of Decidability. |
| 8. | Suggested Books | 1. A. Singh, *Logics for Computer Science*, PHI Learning, New Delhi, 2003.<br>2. A. Margaris, *Mathematical Logic*, Dover Publications, Inc., New York, 1990.<br>3. R. E. Hodel, *An Introduction to Mathematical Logic*, PWS Publishing Company, Boston, 1995. |

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|---|---|---|
| 1. | Course Code | **MA 782** |
| 2. | Title of the Course | **Theory Of Computation** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline/School | Mathematics |
| 5. | Pre–requisite, if any (for the students) | None |
| 6. | Objectives of the course | At the end of the course, students should be exposed to fundamental knowledge in the theory of computations. |
| 7. | Course Syllabus | Some Fundamental Proof Techniques. Finite Automata: Finite Automata and Regular Languages, Languages that are and are not Regular, Algorithm Aspects of Finite Automata. Context-free Grammars: Push-down Automata, Languages that are and are not context-free, Algorithms for Context-free Grammars. Basic Turing Machine Model and Turing Computability: Variants of Turing Machines. Grammars and Turing Machines: Primitive Recursive Functions, μ-recursive Functions and Turing Computability. Church-Turing Thesis and Universal Turing Machines: Halting Problem, Some Undecidable Problems. Time-bounded Turing Machines: Classes *P* and *NP*, *NP*-completeness, Examples of *NP*-complete Problems. |
| 8. | Suggested Books | 1. H. R. Lewis and C. H. Papadimitriou, *Elements of Theory of Computation*, Prentice-Hall, 2nd Edition, Englewood, New Jersey, 1997.<br>2. J. Hopcroft, R. Motwani, and J. Ullman, *Introduction to Automata Theory, Language, and Computation*, Pearson Education, 2nd Edition, 2001.<br>3. M. Sipser, *Introduction to the Theory of Computation*, Wadsworth Publishing Co Inc., 3rd Edition, 2012. |

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|---|---|---|
| 1. | Course Code | **MA 797 (Autumn Semester)**<br>**MA 798 (Srping Semester)** |
| 2. | Title of the Course | Ph.D. Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Mathematics |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various journals |

# Course Structure
# of
# PG and Ph.D. Programs
# in
# Discipline of Biosciences and Biomedical Engineering (BSBE)
# and
# Syllabi of the Courses

# Course Structure for M.Sc. (2 year)/ M.Sc. + Ph.D. Dual Degree Program in Biotechnology (from AY 2017-18)

**Minimum Education Qualification (MEQ):** Bachelor's degree.

**Qualifying Examination (QE):**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE.
**(b) Indian Students:** Valid JAM qualification in Biotechnology.

**Eligibility Requirement (ER):** As per the brochure of Joint Admission test for M.Sc. (JAM).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Not Applicable

**Duration of the Program:** Two years on full-time basis.

**Course Structure for two-year Full-time M.Sc. (Biotechnology) Program**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| BSE 601 | Advanced Molecular Biology | 2-1-0 | 3 |
| BSE 603 | Analytical Biochemistry | 2-1-0 | 3 |
| BSE 605/ BSE 405 | Molecular Biophysics | 2-1-0 | 3 |
| BSE 609 | Microbiology | 2-1-0 | 3 |
| BSE 611 | Biochemistry | 2-1-0 | 3 |
| BSE 651 | Biochemistry Lab | 0-0-4 | 2 |
| BSE 659 | Microbiology Lab | 0-0-4 | 2 |
| **Total minimum credits earned during the semester** | | | **19** |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-I**

**1st Year: Semester-II**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| BSE 610 | Cell and Developmental Biology | 2-1-0 | 3 |
| BSE 612 | Immunology and Immunotechnology | 2-1-0 | 3 |
| BSE 614 | General Physiology | 2-1-0 | 3 |
| BSE 616 | Infectious Diseases and Medical Microbiology | 2-1-0 | 3 |
| BSE 618 | Biostatistics and Bioinformatics | 2-0-2 | 3 |
| BSE 652 | Genetic Engineering Lab | 0-0-6 | 3 |
| BSE 698 | PG Seminar Course | 0-2-0 | 2 |
| **Total minimum credits earned during the semester** | | | **20** |

**2 nd Year: Semester–III**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| BSE 799 | M.Sc. Project (Statge–I) | 0-0-36 | 18 |
| **Total minimum credits to be earned during the semester** | | | **18** |

**2 nd Year: Semester–IV**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| BSE 800 | M.Sc. Project (Stage–II) | 0-0-36 | 18 |
| **Total minimum credits to be earned during the semester** | | | 18 |
| **Total minimum credits to be earned during the program** | | | **75** |

**NOTE:** 1. Request for conversion from M.Sc. to M.Sc. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivating PG students at the end of the **third semester of their program.** The confirmation of conversion of M.Sc. program and to M.Sc. + Ph.D. dual degree program is done during 4$^{th}$ semester with subject to successfully qualifying CSIR/UGC-JRF or equivalent fellowship to enable receiving Ph.D. scholarship.
2. The enhancement in the scholarship from M.Sc. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Sc. degree are fulfilled AND candidate successfully qualifies CSIR/UGC-JRF or equivalent fellowship, whichever is later**.**
**3. If the** student opts for Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Sc. degree can be earned **before the specified date during the 4th semester** of the normal M.Sc. Program by getting the M.Sc. Research Project examined in the standard manner as per the requirements for the award of an M.Sc. degree.

# Course Structure for Ph.D. program in Biosciences and Biomedical engineering

# (w.e.f. AY 2013-14)

**(A) Semester-I (Autumn / Spring)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective- III | x-x-x-3 |
| 4 | BSE 797 / BSE 798* | Ph.D. Seminar Course | 0-2-0-2 |

**(B) Semester-II (spring / autumn)**

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 4 | BSE 798 / BSE 797* | Ph.D. Seminar Course | 0-2-0-2 |

**NOTE:**

1. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses). Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course i.e. *(minimum coursework of 8 credits)*.
2. A Ph.D. student having **B.Tech./ B.E./ M.Sc.** or **equivalent qualification** admitted to Ph.D. Program in an Engineering discipline shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course (minimum coursework of 20 credits).

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/Thesis Supervisor.

**Courses for the Electives-I to VI** (In addition to this course list, a student can also opt from the PG courses being offered by other disciplines.)

| S. No. | Course Code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1. | BSE 601 | Advanced molecular Biology | 2-1-0-3 |
| 2. | BSE 602 | Modern NMR Spectroscopy | 1-2-0-3 |
| 3. | BSE 603 | Analytical Biochemistry | 2-1-0-3 |
| 4. | BSE 604/ BSE 404 | Biomedical Imaging | 2-1-0-3 |
| 5. | BSE 605/ BSE 405 | Molecular Biophysics | 2-1-0-3 |
| 6. | BSE 606 | Molecular Virology and Viral Pathogenesis | 2-1-0-3 |
| 7. | BSE 607 | Bioremediation: Principles & Practices | 2-1-0-3 |
| 8. | BSE 608 | Advanced Drug Delivery Systems | 2-1-0-3 |
| 9. | BSE 613/ BSE 413 | Omics Technologies | 2-1-0-3 |
| 10. | BSE 615 | Chemical Biology | 2-1-0-3 |
| 11. | BSE 617/ BSE 417 | Biomolecular Modeling | 2-1-0-3 |
| 12. | BSE 702 | Applied Genetic Engineering | 2-1-0-3 |
| 13. | CH 704 | Chemistry at Surfaces and Interfaces | 2-1-0-3 |
| 14. | CH 706 | Photochemistry | 2-1-0-3 |
| 15. | CH 711 | Bio-organic and Medicinal Chemistry | 2-1-0-3 |
| 16. | CH 720 | Asymmetric Synthesis | 2-1-0-3 |
| 17. | MA 706 | Numerical Linear Algebra | 2-1-0-3 |
| 18. | PH 650 | Numerical Methods | 2-1-0-3 |
| 19. | PH 781 | Theory of complex systems | 2-0-2-3 |
| 20. | HS 671 | Human Factors and Higher Cognitive Processes | 2-0-2-3 |
| 21. | EE 619 / EE 419 | Biomedical Optics | 2-1-0-3 |
| 22. | EE 701 | Time frequency analysis | 2-1-0-3 |
| 23. | ME 607 / ME 407 | Biofluid Mechanics | 2-1-0-3 |
| 24. | ME 418 / ME 618 | Computational Fluid Dynamics | 2-1-0-3 |

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|---|---|---|
| 1. | Course Code | **BSE 600** |
| 2. | Title of the Course | **Physics and Mathematics for Biologists** |
| 3. | Credit Structure | L-T-P-Credits<br>(2-1-0-PP/NP) |
| 4. | Name of the Concerned Department | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Objectives of the course | The course would provide comprehensive introduction to basics of the field related to biological science. |
| 7. | Course Syllabus | **Introductory Calculus**: Limit, Continuity, Differentiation, Integration and Ordinary Differential Equations.<br><br>**Properties of Matter**: Elasticity, Hydrostatic, Surface tension, Microscopic consideration for study of properties of matter, Atomic and Molecular structure, Structure of solids, amorphous solids, Structure of single crystals, Broad classification of solids<br><br>**Thermal Physics**: Laws of Thermodynamics and its application in Biological system, Temperature and related topics, Internal energy, Heat and First law of Thermodynamics, The ideal monatomic gas, Application of first law to Ideal Gases, Entropy and the second law<br><br>**Fundamental Electromagnetism**: Charge and Current, Coulomb’s law, Electric field, Electrostatic potential, Guass’s law for Electronics, Magnetic effects on study currents, Forces on current in a magnetic field, Forces on charges in Electric and Magnetic field, Electromagnetic induction<br><br>**X-ray crystallography**: A basic introduction to x-ray crystallography, Crystal growth, evaluation and mounting, Symmetry and space group determination<br><br>**Optics**: geometrics optics, ray tracing, diffraction and scattering some topics related to nonlinear and quantum optics. |
| 8. | Suggested Books | 1. H. Neil, Calculus: A Complete Introduction, 1$^{st}$ ed., John Murray Learning, 2013, ISBN-10: 144419111X.<br>2. D. Halliday, R. Resnick, J. Walker, Fundamentals of Physics, 9$^{th}$ ed., Wiley, 2010, ISBN-10: 0470469080.<br>3. H. D. Young, R. A. Freedman, University Physics, 13$^{th}$ ed., Addison-Wesley, 2011, ISBN-10: 0321696867.<br>4. M. W. Zemansky, Heat and Thermodynamics, 8$^{th}$ ed., McGraw Hill India, 2011, ISBN-10: 0070700354.<br>5. A. Besier, Concepts of Modern Physics, 6$^{th}$ ed., McGraw Hill Education, 2002, ISBN-10: 0072448482. |

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|---|---|---|
| 1. | Course Code | **BSE 601** |
| 2. | Title of the Course | **Advanced Molecular Biology** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of biology |
| 6. | Scope of the Objective | The course will give an overview of advances and recent discoveries in the area of Molecular Biology, in addition to fundamentals in the area. |
| 7. | Course Syllabus | Structure of genetic material, Central dogma; Replication: eukaryotic and prokaryotic replication, mechanism and control, Nucleosomes: eukaryotic and prokaryotic genome packing, heterochromatin, euchromatin; Transcription: mechanism of RNA transcription in prokaryotes and eukaryotes; model systems of transcriptional control: lac operon, lambda phage; promoters, enhancers, repressors; antitermination and attenuation; post-transcriptional regulation and RNA processing: processing of heterogeneous nuclear RNA: splicing, capping, polyadenylation; Translation: universal genetic code, degeneracy of codons, mechanisms of initiation, elongation and termination of translation, wobble hypothesis, genetic code in mitochondria; Mutations: nonsense, missense, frameshift and point mutations; suppression; DNA repair: photoreactivation, excision, mismatch and SOS repair; Recombination: mechanism of homologous recombination in prokaryotes, site specific recombination, insertion sequences, transposons; Epigenetics, DNA methylation, chromatin modification and gene regulation. |
| 8. | Suggested Books | **Text Books**<br>1. Robert F., Weaver, Molecular Biology, 4th ed., McGraw-Hill, 2003. [ISBN-10: 0071275487 \| ISBN-13: 978-0071275484]<br>2. B. Lewin., Genes IX. 9th ed., Jones and Bartlett Publishers, 2007. [ISBN-10: 0763740632 \| ISBN-13: 978-0763740634]<br>3. H. Lodish et al., Molecular Cell Biology. 6th ed., W. H. Freeman, 2007. [ISBN-10: 0716776014 \| ISBN-13: 978-0716776017]<br>**Reference Books or Journals**<br>4. Alberts et al., Molecular Biology of the Cell, 4th ed., Garland Publishing, Inc., 2002.<br>5. Tropp B.E., Molecular Biology: Genes to Proteins, 3rd ed., Jones & Bartlett Publishers, 2007 [ ISBN-10: 0763709166 ISBN-13: 978-0763709167<br>6. Selected articles from the journal Nature, Science, Cell, etc. |

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| 1. | Course Code | **BSE 602** |
| 2. | Title of the Course | **Modern NMR Spectroscopy** |
| 3. | Credit Structure | L-T-P-C<br>1-2-0-3 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Objective | This course intends to give an overview of fundamentals and advances in the area of NMR Spectroscopy which relates to **structure biology**. |
| 7. | Course Syllabus | NMR phenomenon; parameters; chemical shifts; spin-spin coupling; Bloch equation; the rotating frame of References; pulses; free induction decay; Fourier transform; signal to noise ratio; signal averaging; sampling; spin echoes; measuring T1 and T2; application to biology; $^{13}C$ NMR; gated decoupling; assignments; DEPT; heteronuclear correlation; nuclear Over hauser effect; steady state NOE; transient NOE; internuclear distances; applications to biomolecular structure determination; multiple-pulse NMR; polarisation transfer; One, Two and multi-dimensional experiments; COSY; TOCSY; NOESY; ROESY; chemical exchange; application to Biological molecules: proteins; nucleic acid and sugars etc. NMR of biologically relevant nuclei. NMR in Bio-medicine: MRI and fMRI; NMR in Metabolomics |
| 8. | Suggested Books | **Text Books**<br>1. Edwin D. Becker; High Resolution NMR. Academic Press, 1968.<br>2. J. K. M. Sanders and B. K. Hunters; Modern NMR Spectroscopy. Oxford Univ. Press, 1987<br>3. E. Derome; Modern NMR Techniques for Chemistry Research. Pergamon Press, 1987.<br>4. K. Wuthrich; NMR of Proteins and Nucleic Acids. Wiley-Interscience, 1986.<br>5. KVR Chary & G. Govil; NMR in Biological System, Springer, 2008.<br>**Reference from Journals/Book**<br>1. Teng Quincy; Structural Biology: Practical NMR Applications, Springer, 2010<br>2. B. D. Nageswara Rao, Marvin D. Kemple; NMR as a structural tool for macromolecules: current status and future directions; Plenum Press, 1996<br>3. David G. Gadian; NMR and its applications to living systems, Oxford science publications, 2008<br>4. Selected articles from the journal Nature, Science, Cell, etc. |

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| 1. | Course Code | **BSE 603** |
| 2. | Title of the Course | **Analytical Biochemistry** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | Nil |
| 6. | Scope of the Objective | This course intends to give knowledge about the analytical techniques which used to be carried out in regular practices during research work. |
| 7. | Course Syllabus | **Spectroscopy Techniques:** Buffers; Methods of cell disintegration; Enzyme assays and controls; Detergents and membrane proteins; Dialysis, Ultrafiltration and other membrane techniques, UV- Visible and Fluorescence Spectroscopy; Theory and application of Circular Dichroism; M.S., NMR.<br>**Chromatography Techniques:** TLC and Paper chromatography; Chromatographic methods for macromolecule separation – Gel permeation, Ion exchange, Hydrophobic, Reverse-phase and Affinity chromatography; HPLC and FPLC; Criteria of protein purity<br>**Electrophoretic techniques:** Theory and application of Polyacrylamide and Agarose gel electrophoresis; Capillary electrophoresis; IEF & 2D Electrophoresis; Disc gel electrophoresis; Gradient electrophoresis; Pulsed field gel electrophoresis (PFGE)<br>**Centrifugation:** Basic principles; Mathematics & theory (RCF, Sedimentation coefficient etc.); Types of centrifuge - Micro centrifuge, High speed & Ultracentrifuges; Preparative centrifugation; Differential & density gradient centrifugation; Applications (Isolation of cell components); Analytical centrifugation; Determination of molecular weight by sedimentation velocity & sedimentation equilibrium methods<br>**Advanced Techniques:** Protein crystallization; Theory and methods; API-electrospray and MALDI-TOF; Mass spectrometry; Enzyme and cell immobilization techniques; DNA & Peptide Synthesis and sequencing. |
| 8. | Suggested Books | **Text Books**<br>1. D. Holme & H. Peck; Analytical Biochemistry. Longman, 1983.<br>2. T.G. Cooper; The Tools of Biochemistry. Wiley Intersciences, 1977.<br>3. R. Scopes; Protein Purification - Principles & Practices. Springer Verlag, 1982.<br>4. R.C. Price, Proteins. Lafbax Academic Press 1996.<br>5. Freifelder D., Physical Biochemistry, Application to Biochemistry and Molecular Biology, 2nd Edition, W. H. Freeman & Company, San Fransisco, 1982<br>6. Keith Wilson and John Walker, Principles and Techniques of Practical Biochemistry, 5$^{th}$ Edition, Cambridge University Press, 2000.<br>**References**<br>1. D. Holme & H. Peck, Analytical Biochemistry, 3rd Edition, Longman, 1998.<br>2. R. Scopes, Protein Purification - Principles & Practices, 3rd Edition, Springer Verlag 1994.<br>3. Selected readings from Methods in Enzymology, Academic Press. |

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| 1. | Course Code | **BSE 604 / IBSE 404** |
| 2. | Title of the Course | **Biomedical Imaging** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the Course | This course will give a comprehensive introduction to the fundamental and major aspects of biomedical imaging systems used currently. The fundamental physics and engineering of each imaging modality will be discussed. |
| 7. | Course Syllabus | Radiation and interaction with matter, principle of diagnostic biomedical optical imaging.<br><br>Radiation dosimetry, risk and protection.<br><br>Radiography, mammography and fluoroscopy.<br><br>Principle of ultrasound imaging and current status.<br><br>Image analysis, image processing, image reconstruction theory, computed tomography system.<br><br>Magnetic Resonance Imaging (MRI): principle of nuclear magnetic resonance, MR imaging, functional MR imaging, application of MR imaging.<br><br>Single Photon Emission Computed Tomography (SPECT) principle, Positron Emission Tomography (PET). |
| 8. | Suggested Books | **Text / Reference Books**<br>1. J. T. Bushberg et al, The essential physics of medical imaging, 2nd edition. [ISBN-10: 0683301187 \| ISBN-13: 978-0683301182]<br>2. Richard R. Carlton, Principle of radiographic imaging: An art and a science. [ISBN-10: 1439058725 \| ISBN-13: 978-1439058725]<br>3. James G. Fujimoto and Daniel Farkas, Biomedical optical imaging, 1st edition. [ISBN-10: 0195150449]<br>4. Andrew G. Webb, Introduction to biomedical imaging, 1st edition. [ISBN-10: 0471237663 \| ISBN-13: 978-0471237662] |

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| 1. | **Course Code** | **BSE 605/ BSE 405** |
| 2. | **Title of the Course** | **Molecular Biophysics** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | Open to all graduates, with the prior permission of course instructor. |
| 6. | Scope of the Course | This course is designed to teach the basics of Physics, sufficient for BSBE graduate students. The fundamental physics of Biological phenomena will be discussed. It will also prepare students to learn and apply biophysical approaches to understand biochemical, biotechnological and medical problems. |
| 7. | Course Syllabus | Review of calculus and its application in biology. Introduction to thermodynamics and role in biology. Discussion about various stages of evolution. Single cell machinery to multi-cellular organs.<br><br>Structure of biomolecules. Elements of building blocks for macromolecules. Weaker interatomic interactions. Hydrogen bond and hydrophobic interactions. Amphiphilic molecular behavior in aqueous environments. Introduction to X-ray crystallography.<br><br>Structures and physics of amino acids and proteins. Conformational transitions of proteins (folding and unfolding of proteins), Ramachandran plot. Physics of nucleic acid, membranes and membrane physics. Modeling membranes as elastic materials.<br><br>Dynamics of biomolecules: diffusion, vibrations versus conformational transitions. Interaction of biomolecules with electromagnetic radiation.<br><br>General characteristic of a cell. Cytoskeletal organizations and constituents molecules and their mechanism. Ion channels and ion pumps, osmotic pressure of cells.<br><br>Cellular energetics: chloroplast and mitochondria. Cells as thermodynamic machines. Active transport.<br><br>Review of fundamentals of electricity and magnetism. Bioelectricity, heart dynamics, anatomy of nerve cells, conducting properties of neurons. Structure and function of synapse. |
| 8. | Suggested Books | **Text / Reference Books**<br>1. P. Nelson, **Biological Physics**, (Updated edition), W. H. Freeman, New York, December 16, 2013. [ISBN-10: 0716798972 \| ISBN-13: 978-0716798972]<br>2. W. Bialik, **Biophysics: Searching for Principles**, Princeton University Press, October 28, 2012. [ISBN-10: 0691138915 \| ISBN-13: 978-0691138916]<br>3. J. Tuszynski, and M. Kurzynski, **Introduction to Molecular Biophysics,** (First edition), CRC Press, New York, February 26, 2003. [ISBN-10: 0849300398 \| ISBN-13: 978-0849300394] CRC Series in Pure and Applied Physics<br>4. C. R. Cantor and P. R. Schimmel, **Biophysical Chemistry, Part I: The conformation of biological macromolecules** (Their Biophysical Chemistry), (First edition), W. H. Freeman, New York, March 15, 1980. [ISBN-10: 0716711885 \| ISBN-13: 978-0716711889]<br>5. C. R. Cantor and P. R. Schimmel, **Biophysical Chemistry, Part 2: Techniques for the study of biological structure and function**, (First edition), W. H. Freeman, New York, April 15, 1980. [ISBN-10: 0716711907 \| ISBN-13: 978-0716711902]<br>6. C. R. Cantor and P. R. Schimmel, **Biophysical Chemistry, Part 3: The behavior of biological macromolecules**, (First edition), W. H. Freeman, New York, June 15, 1980. [ISBN-10: 0716711923 \| ISBN-13: 978-0716711926] |

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|---|---|---|
| 1. | **Course Code** | **BSE 606** |
| 2. | **Title of the Course** | **Molecular Virology and Viral Pathogenesis** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | Basic Biology and Basic Biochemistry (Undergraduate level). |
| 6. | Scope of the Course | The course is designed to provide graduate students a broad background view on virus history, classification, structure, life cycle, virus-host interactions. The course is designed primarily in the context of animal virology. There will be emphasis on viral reverse genetics in designing successful vaccines. The course further aims provide a brief career road map to the students to become a successful virologist. |
| 7. | Course Syllabus | Virus history: Discovery of viruses, Major viral epidemics in human history (e.g. Influenza, HIV, Polio, SARS, Ebola), Milestones in virology research, Emerging infectious viral diseases. Virus classifications.<br>Nano life: A quick view on virus structure and classification: General characteristics of viruses, diversity, shapes, sizes, and components of genomes. Virus life cycle in host cell. Assembly and packaging of virus particles. Strategies how virus packages its genome and exits the living cell.<br>Virus-host interaction: Concepts of co-evolution of viruses and humans. Virus entry, replication. Consequences of virus infection. Mechanisms to invade host defense. Strategies on counter attack. Overview on anti-viral therapy.<br>Reverse Genetics: Reverse genetics in virology: Generation of recombinant virus from cDNA. Focus on negative strand RNA viruses recovery and genome manipulations. Customizing and designing viral vaccine candidates through reverse genetics.<br>Virotherapy: Use of viruses for treatment of diseases. Creating oncolytic virus for cancer treatment. Gene therapy through viral vector mediated gene expression. Viral Immunotherapy: Principles and implications. |
| 8. | Suggested Books | Reference Books<br>1. B. Fields. Fields virology. Philadelphia: Wolters Kluwer/Lippincott WilliaM.S. & Wilkins Health, 2013. ISBN-13: 978-0781702539, ISBN-10: 0781702534<br>2. N. Acheson. Fundamentals of molecular virology. Hoboken NJ: John Wiley & Sons, 2011. ISBN-13: 978-0470900598, ISBN-10: 0470900598<br>3. A. Cann. Principles of molecular virology. AM.S.terdam: Elsevier Academic Press, 2012. ISBN-13: 978-0123849397, ISBN-10: 012384939X<br>4. N. Maclachlan. Fenner's veterinary virology. AM.S.terdam: Elsevier Academic Press, 2010. ISBN-13: 978-0123751584, ISBN-10: 0123751586<br>5. L. Norkin. Virology : molecular biology and pathogenesis. Washington DC: ASM Press, 2009. ISBN-13: 978-1555814533, ISBN-10: 1555814530.<br><br>Journal Reference:<br>Journal of Virology: Published by American Society of Microbiology, USA. |

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|---|---|---|
| 1 | **Course Code** | **BSE 607** |
| 2 | **Course Title** | **Bioremediation: Principles & Practices** |
| 3 | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4 | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5 | Pre-requisite, if any | Basic knowledge of biology |
| 6 | Scope of the course | This course is designed to introduce students to basic principles of biotechnology to address environmental pollution issues. In addition, this course gives latest applications and development of biotechnology for environmental remediation to simulate students' interest in environmental sustainability. |
| 7 | Course Syllabus | Status and role of biotechnology in environmental protection and management.<br>**Bioremediation:** Introduction, Current bioremediation practices and applications, Factors affecting the process of bioremediation (Environmental, Physical and Chemical factors).<br>**Bioremediation systems, processes and types:** Solid, Liquid and Slurry phase bioremediation; Bioaugmentation and Biostimulation of microbial activities; Microbial systems of bioremediation; Phytoremediation and Root zone treatment; Bioremediation of toxic metal ions, Volatile Organic Compounds (VOCs), Oil spills.<br>**Wastewater treatment:** Sources and classification of water pollutants, Principles of biological treatment, Aerobic and anaerobic wastewater treatment systems.<br>**Bioreactors**: Rotating Biological Contactors, Fluidized Bed Reactors, Inverse Fluidized Bed Biofilm Reactor, Membrane Bioreactor, High Rate Algal Ponds, Upflow Anaerobic Sludge Blanket Reactor.<br>**Future perspectives**: Scope and Development of environmentally friendly processes.<br>**Field visit**: Sewage treatment plant/Industrial effluent treatment plant for practical exposure. |
| 8 | Suggested Readings | 1. I. L. Pepper, C. P. Gerba, T. J. Gentry, **Environmental Microbiology,** Third Edition, Academic Press, San Diego, California, 2014 (ISBN-10: 0123946263 / ISBN-13: 978-0123946263).<br>2. M. J. Hammer Sr., M. J. Hammer Jr., **Water and wastewater technology,** Seventh Edition, Pearson Education Inc., New Jersey, USA, 2011 (ISBN-10: 0135114047 / ISBN-13: 978-0135114049).<br>3. G. Tchbanoglous, H. D. Stensel, R. Tsuchihashi, F. Burton, Metcalf and Eddy, **Wastewater Engineering: Treatment and Resources Recovery,** Fifth Edition, Tata McGraw Hill Publishing Companies Ltd., New Delhi, India, 2013 (ISBN-10: 0073401188 / ISBN-13: 978-0073401188).<br>4. N. F. Gray, **Biology of Wastewater Treatment,** Second Edition, Imperial College Press, London, 2004 (ISBN 10: 1860943322 / ISBN 13: 9781860943324).<br>5. Selected articles from Journals - Nature Biotechnology, Hazardous Materials, Biodeterioration and Biodegradation, Desalination etc. |

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|---|---|---|
| 1. | **Course Code** | **BSE 608** |
| 2. | **Title of the course** | **Advanced Drug Delivery Systems** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Department | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | Basic Biology |
| 6. | Scope of the course | The course will cover newer advances in drug delivery systems and recent trends for development characterization and applications of delivery systems to solve healthcare problems. |
| 7. | Course Syllabus | Introduction to drug delivery systems, Controlled release systems, Influence of drug properties and routes of drug administration on the delivery<br>Oral controlled drug delivery systems and their mechanisms, Examples and Case Studies<br>Controlled drug delivery systems: Micro-particles, liposomes, niosomes, polymeric nanoparticles, solid lipid nanoparticles, carbon nanotubes, implants etc., Examples and Case Studies<br>Transdermal drug delivery systems: Principles of skin permeation, Factors affecting percutaneous absorption of drugs, Development and evaluation of transdermal devices, Examples and Case Studies<br>Targeted drug delivery systems: active and passive targeting, Enhanced permeation and Retention (EPR) effect, receptor mediated endocytosis, prodrug based drug targeting, brain targeting, tumour targeting. Examples and Case Studies |
| 8. | Suggested Reading | 1. P.V. Devarajan, S. Jain, Targeted Drug Delivery: Concepts and Design, Springer International Publishing Switzerland, 2015, [ISBN: 978-3-319-11355-5]<br>2. J. R. Robinson, V. H. L. Lee, Controlled Drug Delivery: Fundamentals and Applications. Taylor and Francis UK, 1987, [ISBN: 978-0824775889]<br>3. J. Siepmann, R. A. Siegel, M. J. Rathbone, Fundamentals and Applications of Controlled Release Drug Delivery, Springer Switzerland**,** 2012, [ISBN 978-1-4614-0880-2]<br>4. A. S. Narang, R. I. Mahato Targeted Delivery of Small and Macromolecular Drugs, CRC Press USA, 2010, [ISBN: 9781420087727]<br>5. C. A. Lorenzo, A. Concheiro, Smart Materials for Drug Delivery, RSC Publishing UK, 2013, [ISBN: 978-1-84973-552-0]<br>6. Selected articles from journals like Journal of Controlled Release, International Journal of Pharmaceutics, Journal of Pharmaceutical Sciences etc. |

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| 1. | Course Code | **BSE 609** |
| 2. | Title of the course | **Microbiology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | The course will cover the fundamental of Microbiology |
| 7. | Course Syllabus | **History and Microbial Diversity**<br>The historical foundations and development of microbiology; An overview of microbial world; Microbial diversity - Prokaryotic and eukaryotic microbial diversity; The bacteria and the archaea; Principles of bacterial taxonomy Molecular methods in taxonomy; Intraspecies classification of bacteria. Morphology and structure of bacteria; Surface structures and inclusions of bacteria; Viruses- unique properties, morphology and structure; Virion, Viroids and Prions; Viral replication. Viral diversity –bacterial, plant and animal viruses; Fungi –properties and classification.<br>**Microbial Growth and Culturing**<br>Factors influencing microbial growth. Environmental and nutritional factors; Nutritional types of bacteria; Microbial locomotion – flagellar motility, gliding motility and amoeboid motion; Chemotaxis, Phototaxis and other taxes. Cultivation of bacteria- culture media and methods; Measurement of bacterial growth. Bacterial growth curve; Binary fission, Growth cycle, Microbial growth at different temperature, pH and oxygen level; Continuous cultures; Maintenance and transport of cultures.<br>**Identification of bacteria and Sterilisation methods**<br>Identification of bacteria. Staining reactions; Cultural, physiological and biochemical characteristics; Sterilisation – Principles and methods, physical and chemical methods; Disinfectants – modes of action; Testing of disinfectants; Antibiotics – mechanism of action; Drug resistance in bacteria; Antibiotic sensitivity tests.<br>**Microbial genetics**<br>Genetic materials in bacteria; Bacterial chromosome; Extrachromosomal genetic elements; Plasmid, Transposons; Mutation, DNA repair, Mutant selection; Mechanism of gene transfer – transformation, transduction and conjugation.<br>**Microbial metabolism**<br>Microbial metabolism; Central pathways, Glycolysis, Pentose phosphate pathway, Entner Doudoroff pathway, TCA cycles, Electron transport chain, Aerobic and anaerobic respiration; Fermentation. Anaplerotic reaction; Peptidogycan synthesis, Bacterial photosynthesis. |
| 8. | Suggested Books | 1. G. J. Tortora, B. R. Funke, C. L. Case, Microbiology: An Introduction, 11th ed., Benjamin Cumings, 2012, ISBN-10: 0321733606.<br>2. J. G. Black, Microbiology: Principles and Explorations, 8th ed., Wiley, 2012, ISBN-10: 0470541091.<br>3. M. J. Pelczer, Microbiology: Concepts and Applications, 6th ed., McGraw Hill, 1993, ISBN-10: 0070492581.<br>4. L. M. Prescott, J. P. Harley, D. A. Klein, Microbiology, 6th ed., McGraw Hill, 2004, ISBN-10: 0697293904. |

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| 1. | Course Code | **BSE 610** |
| 2. | Title of the course | **Cell and Developmental Biology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | The course will cover the fundamental of Cell and Developmental Biology |
| 7. | Course Syllabus | **Cell structure:** Ultra structure of prokaryotic and eukaryotic cells,<br>**Cell Organelles**: Structure and function of: Endoplasmic reticulum, Golgi complex, Types of vesicles - transport and their functions, Lysosomes. Nucleus - Internal organization, Nuclear pore complex, Nucleosomes Chromatin. Mitochondrial Genome, Structure and Function<br>**Cell Metabolism:** Oxidative in the Mitochondrion – The Role of Mitochondria in the formation of ATP – Translocation of Protons and the Establishment of a proton-motive force – The Machinery for ATP formation – Peroxisomes. Genome studies of Mitochondria. Chloroplast structure and function – An overview of photosynthetic Metabolism, Cytoskeleton – components of Cytoskeleton, Microtubules, Intermediate filaments – Microfilaments,<br>**Cellular Transport and Cell Signaling**: Protein trafficking, Cell Signaling: Hormones and Receptors, Intracellular signaling in Development and Disease, Transport across Cell Membranes, Protein Sorting: Organelle Biogenesis and Protein secretion, Stem Cell Biology, Cancer, Regulation of Cell Death; Apoptosis, Circadian Rhythms.<br>**Developmental Biology**: Introduction to genomes and differential gene expression, mechanism of differentiation, fertilization, self-adhesion, cell-adhesion, stem cells, early amphibian development, neurulation, neural tube pattern, neural crest. Organ developments |
| 8. | Suggested Books | 1. H. Lodish, A. Berk, P. Matsudaira, C. Kaiser, M. Krieger, M. Scott, L. Zipursky, J. Darnell, Molecular Cell Biology, $5^{th}$ ed., W.H Freeman and Company, 2003, ISBN-10: 9780716743668.<br>2. S. F. Gilbert, M. J. F. Barresi, Developmental Biology, $11^{th}$ ed., Sinauer Associates Inc., 2016, ISBN-10: 1605356042.<br>3. G. M. Cooper, R. E. Hausman, The Cell: A Molecular Approach, $5^{th}$ ed., Sinauer Associates Inc., 2009, ISBN-10: 0878933972.<br>4. B. Alberts, A. Johnson, J. Lewis, D. Morgan, M. Raff, K. Roberts, P. Walter, Molecular Biology of the Cell, $6^{th}$ ed., Garland Sciences, 2014, ISBN-10: 0815344643.<br>5. J. Hardin, G. Bertoni, Becker's World of the Cell, $9^{th}$ ed., Pearson/Benjamin Cummings, 2015, ISBN-10: 0134145798 \| ISBN-13: 978-0134145792.<br>6. G. Karp, Cell Biology, $7^{th}$ ed., Wiley, 2013, ISBN-10: 1118318749. |

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| 1. | Course Code | **BSE 611** |
| 2. | Title of the course | **Biochemistry** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | The course will cover the fundamentals of Biochemistry |
| 7. | Course Syllabus | **CARBOHYDRATES**<br>**Oligosaccharides and Polysaccharides:** Glycosidic bonds; Classification: glycoproteins, glycolipids; Nature of carbohydrate moiety attached; Functions: as cell recognition factors, in intracellular targeting; Purification and Characterization of oligosaccharides from cell membranes; Homopolysaccharides, Heteropolysaccharides; Purification and Characterization of polysaccharides from biological systems.<br>**Metabolism of carbohydrates:** Introduction, Aerobic and anaerobic pathways: Glycolysis and its regulation, Gluconeogenesis and its regulation. TCA cycle - Regulation, Glyoxylate cycle, amphibolic and anaplerotic reactions. Electron Transport chain, Oxidative phosphorylation, and production of ATP, Inhibitors of ETC and ATP synthesis, Photosynthesis – 'light' and 'dark' reactions<br>**PROTEINS and NUCLEIC ACIDS:** Protein structure and function**;** Fibrous protein: (Collagen), Membrane Protein (ATP synthetase); Protein structure and molecular approach to medicine: introduction (Sickle cell anaemia, p53 and its role in Cancer).<br>**Nucleic acid structure and function:** Supercoiling of the DNA molecule; topoisomers and superhelixes; Higher orders of DNA Structure: Chromatin Structure: Histones and Nucleosomes; Tandem repeats (Satellites, minisatellites, and microsatellites), Interspersed repeats (LINE, SINEs) Single copy genes; RNA Structure: Types of RNA; structure of mRNA, tRNA and rRNA, Si RNA, micro RNA with emphasis on importance of structure to its function.<br>**LIPIDS:** Structure and function of Glycerophospholipids and Glycosphingolipids, CDP-diacylglycerol, Lung surfactants. Eicosanoids: Prostaglandins, Leukotrienes and Thromboxanes: Chemistry, formation and physiological function.<br>**Steroids:** Steroids in animal system: Glucocorticoids, mineralocorticoids and Sex hormones (Site of biosynthesis, functions and mechanism of action; Sterols in Plant system: Phytohormones: Brassinosterroids (functions); Sterols in microbial system. |
| 8. | Suggested Books | 1. D. L. Nelson, M. M. Cox, Lehninger Principles of Biochemistry, 4th ed., W. H. Freeman; 2004, ISBN-10: 0716743396.<br>2. J. M. Berg, J. L. Tymoczko, L. Stryer, Biochemistry: International Edition, 7th ed., W. H. Freeman, 2011, ISBN:071676766X ISBN-13: 9780716767664, 978-716767664<br>3. D. Voet, J. G. Voet, C. W. Pratt, Fundamentals of Biochemistry: Life at the Molecular Level, 4th ed., Wiley, 2015, ISBN-10: 0470547847.<br>4. L. A. Moran, R. A. Horton, G. Scrimgeour, M. Perry, D. Rawan, Principles Of Biochemistry, 5th ed., Pearsarson, 2011, ISBN-10: 0321707338.<br>5. R. A. Dean, J. A. Spencer, K. M. Christopher, Biochemistry: Concepts and Connections, 1st ed., Pearson Education, 2017, ISBN-10: 9332585458. |

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| Course Code | **BSE 612** |
| Title of the Course | **Immunology and Immunotechnology** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Department | Biosciences and Biomedical Engineering |
| Pre–requisite, if any | Open to all graduates, with the prior permission of course instructor. |
| Scope of the Course | This course deals with immune systems and their components at the cellular and humoral levels. Furthermore, this course deals with the practical aspects such as the production and engineering of antibodies, the application of antigens, the design of (recombinant) vaccines, strategies for immune intervention, etc. |
| Course Syllabus | **Introduction to immunology**. Cells & organs of immune system-lymphoid cells, B and T lymphocytes, null cells. Mononuclear cells- phagocytosis, antimicrobial and cytotoxic activities. Granulocytes- neutrophils, eosinophils and basophils. Mast cells, dendritic cells. Organs of immune system-primary and secondary lymphoid organs.<br><br>**Immunoglobulins:** Structure and function-basic and fine structures of immunoglobulins. Isotypes, allotypes and idiotypes Classification of immunoglobulins. Genetic control of antibody response. Generation of antibody diversity. Theories of antibody formation. Clonal selection theory.<br><br>Antigen-antibody interaction- strength of antigen-antibody interaction, cross reactivity, precipitin reactions. Radioimmunoassays (RIA). Enzyme linked immunosorbent assay (ELISA). Western blotting. immunoelectron microscopy. Complement proteins, complement features, classical and alternative pathways.<br><br>**Major histocompatibilty complex** (**MHC**): Structure and its significance. Transplantation immunity- immunological basis of graft rejection, xenotransplantation. Clinical manifestation of graft rejection. General and specific immuno suppressive therapy. Clinical transplantation. Hypersensitivity- type I, II, III, and IV hypersensitivity.<br><br>**Autoimmunity**: Basis of autoimmune disorders, mechanism for the induction of autoimmunity. Treatment of autoimmune diseases. Immune response to infectious diseases. Antigen presentation via Class I and Class II pathways. Th1/ Th2 polarities, NK Effector Mechanism. Apoptosis.<br>Monoclonal antibodies- production role and advantages of monoclonal antibodies. Detailed account on the application and uses of monoclonal antibodies. Humanization of antibodies.<br><br>**Cancer Immunology:** Role of cytotoxic T lymphocytes in cancer immunology. AIDS pathogenesis, immunology of retroviruses, role of chemokines in management of AIDS. Vaccine technology, active and passive immunity, development of vaccine against infectious diseases. |
| Suggested Books | 1. T. J. Kindt, R. A. Goldsby, B. A. Osborne. Immunology, 6th ed., W. H. Freeman, 2006, ISBN-10: 0716767643.<br>2. A. K. Abbas, A. H. Lichtman, Cellular and Molecular Immunology, 8th ed., Saunders, 2014, ISBN-10: 0323222757.<br>3. D. K. Male, J. Brostoff, D. E. Roth, I. M. Roitt, Immunology, 8th ed., Elsevier, 2012, ISBN-10: 0323080588.<br>4. T. Doan, R. Melvold, S. Viselli, C. Waltenbaugh, Immunology, 2nd ed., Lippincott Williams & Wilkins, 2012, ISBN-10: 8184737637. |

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| **Course code** | **BSE 613/ BSE 413** |
| **Title of the course** | **Omics Technologies** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course is designed for the students with the background in biology, chemistry and computer science. This course will emphasize at molecular level changes through the studies of Genomics, Transcriptomics, Proteomics, Metabolomics, Glycomics and Lipidomics. The goal of this course is to explain the details of modern OMICS technologies and their applications which control structure, function, and dynamics of organisms. |
| Course Syllabus | OMICS: Introduction of omics, types of omics, methods to study, experimental approaches, bioinformatics algorithm. Genomics: Gene, Genome and their genomics, Status of genomics project, genome annotation, genome database, Prediction for transcription factor binding sites, Bioinformatic analysis for miRNA target and motif search, Single nucleotide polymorphisms (SNP) in bio-medical research. Transcriptomics: Principle and applications of experimental techniques: micro-arrays, Expressed Sequence Tag (EST), Serial analysis of gene expression (SAGE), tissue arrays. Data analysis and normalization through bioinformatics methods. Publicly available micro-arrays expression data. Proteomics: Principle and applications of proteomics technologies: 2D-electrophoresis, MALDI-TOF mass spectrometry, yeast 2-hybrid system. Protein-protein interactions, Protein-DNA interaction, Protein-RNA interaction. Computational prediction of interactions, protein databases. Metabolomics: Principles and applications of technologies in metabolomics: High-performance liquid chromatography (HPLC), Gas Chromatography, Mass Spectrometry, Nuclear Magnetic Resonance. Metabolic pathways resources, Metabolic health, and complications. Glycomics and Lipidomics: Principles and applications. Instrumentation and arrays to understand these structural changes in leaving organism. |
| Suggested Books | 1. C. Simo, A. Cifuentes, V. Garcia-Canas, ***Fundamentals of Advanced Omics Technologies***, From Genes to Metabolites, Elsevier, United States of America, 2008, 978-0-44462-651-6<br>2. D. Barh, K. Blum, M.A. Madigan, ***OMICS:*** **Biomedical Perspectives and Applications**, CRC Press, United States of America, 2017, 978-1-43985-008-4<br>3. B. Mayer, ***Bioinformatics for OMICS Data***, Springer, United States of America , 2011 , 978-1-61779-027-0<br>4. E.C. Soo, J.P.M. Hui, ***Metabolomics in Glycomics***, Springer, United States of America, 2009, 978-1-60761-453-1 |

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| Course Code | **BSE 614** |
| Title of the course | **General Physiology** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Department | Biosciences and Biomedical Engineering |
| Pre–requisite, if any | None |
| Scope of the course | The course will cover the fundamentals of Physiology |
| Course Syllabus | **Introduction to Physiology:** The scope of human physiology, Elementary tissues- epithelial tissue, connective tissue, muscle tissue, nervous tissue, homeostasis, blood buffers, acid base balance, hormones<br><br>**Muscle physiology:** Muscles classification, skeletal muscle, smooth muscle, muscle contraction, membrane excitation, neuromuscular junction, and rigor mortis<br><br>**Renal physiology**: Kidney, nephron, renal circulation, GFR, renal regulation of water and electrolyte balance<br><br>**Cardiovascular Physiology:** Heart, cardiac muscle, action potential in cardiac muscle, cardiac cycle, heart sounds, conducting mechanism, heart beat and regulation, cardiac output, ECG, blood pressure, role of baro and chemo receptors in blood pressure regulation, composition and functions of blood, plasma proteins and functions, cellular content of blood- haematopoiesis, haemoglobin, haemostasis, blood groups, blood transfusion, lymph<br><br>**Respiratory physiology:** Organization of respiratory system, respiratory membrane, pulmonary ventilation, pulmonary volumes and capacities, alveolar ventilation, surfactants, exchange of gases, transport of gases, regulation of respiration, hypoxia, cyanosis, hypercapnia, dyspnea, apnea, periodic breathing, artificial respiration<br><br>**Digestive physiology:** Salivary gland and secretion, gastric gland and secretion, secretion of pepsinogen, HCl secretion and regulation, pancreas, liver, bile |
| Suggested Books | 1. E. P. Widmaier, H. Raff, K. T. Strang, Vander's Human Physiology- The Mechanism of Body Function. 12$^{th}$ ed., McGraw Hill, 2010, ISBN-10: 0077350014.<br>2. J. E. Hall, M. Vaz, A, Kurpad, T. Raj, Text Book of Medical Physiology, 2$^{nd}$ ed., Elsevier Health-INR, 2016, ISBN-10: 8131244660.<br>3. J. B. West, Physiological Basis of Medical Practice, 12$^{th}$ ed., Lippincott Williams & Wilkins, 1990, ISBN-10: 0683089471.<br>4. W. F. Ganong, Review of Medical Physiology, 25$^{th}$ ed., McGraw Hill Education, 2016, ISBN-10: 007182510X.<br>5. K. Sembulingam, P. Sembulingam, Essentials of Medical Physiology, 7$^{th}$ ed., Jaypee Brothers Medical Publishers, 2016, ISBN-10: 9385999117. |

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| **Course code** | **BSE 615** |
| **Title of the course** | **Chemical Biology** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| Pre-requisite, if any | Basic Biology and Chemistry (Undergraduate level) |
| Scope of the course | This course is designed to build a bridge between Chemistry and Biology. Understanding the chemical logic behind biology is extremely important as it allows us to predict consequences in physiological context. Emphasis will be given on understanding the fundamental concepts for using the chemical toolbox to uncover the functions of living systems at both mechanistic and molecular level. |
| Course Syllabus | Introduction to Chemical Biology? Difference between Biochemistry and Chemical Biology; Metabolic regulations; Warburg effect; Activity-based protein profiling to study orphan enzymes and its importance in drug discovery; Bio-orthogonal approaches in biology; Protein-protein interaction; Stable-isotope labeling for probing metabolism; Metabolomics-assisted proteomics; Quantitative proteomics; Chemo-proteomic platform; Incorporation of unnatural amino acids; Chemical toolbox to study protein post-translational modifications; Targeted protein degradation in live cells; Native chemical ligation: A tool for chemical protein synthesis; Small molecules in important biological discoveries; Introduction to PyMOL. |
| Suggested Books | 1. N. Civjan, ***Chemical Biology:*** **Approaches to Drug Discovery and Development to Targeting Disease**, Wiley-Blackwell, United States of America, 2012, 1118101189<br>2. D. Reed, ***Chemistry for Biologists***, Pearson Education, United Kingdom, 2013, 1408280825<br>3. D. V. Vranken, G. A. Weiss, ***Introduction to Bioorganic Chemistry and Chemical Biology***, Garland Science, United States of America, 2012, 0815342144<br>4. C. Walsh, ***Posttranslational Modification of Proteins:*** **Expanding Nature_s Inventory**, Roberts & Company Publishers, United States of America, 2005, 0974707732 |

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| 1. | Course Code | **BSE 616** |
| 2. | Title of the course | **Infectious Diseases and Medical Microbiology** |
| 3. | Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| 4. | Name of the Concerned Department | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | This course provides a basic understanding of issues related to infectious diseases, mechanism and pathophysiology. |
| 7. | Course Syllabus | **General Principles of Infection**: How diseases are caused by micro-organisms, Host factors, Virulence, Susceptibility, host defence, macrophages, cytokines, complement system, cell mediated immunity, Disease transmission mechanisms.<br><br>**Microbial agents causing infections**: Gram positive and gram-negative bacteria, anaerobic bacteria, spirochetes, rickettsia, fungi, viruses, algae, helminths etc.<br><br>**Diagnosis and Prevention of infection**: Bacterial, Fungal, Viral and Parasitic infections, Immunization, Molecular techniques for detection, Immuno-diagnosis, Imaging of infections<br><br>**Treatment of Infectious Diseases**: Antimicrobial agents, Antivirals including anti-retrovirals, Approaches for treatment of Sepsis, systemic infections, Eye infections, Pulmonary infections, GI infections, Sexually transmitted infections, skin and soft tissue infections, Orthopaedic, neurological, urological, hepatic infections and surgical infections. |
| 8. | Suggested Books | 1. S. L. Gorbach, J. G. Bartlett, N. R. Blacklow, Infectious Diseases, 3rd ed., Lippincott Williams & Wilkins, 2004, ISBN-10: 0781733715.<br>2. W. F. Wright, Essentials of Clinical Infectious Diseases, 1st ed., Demos Medical Publishing, 2013, ISBN-10: 1936287919.<br>3. D. Schlossberg, Clinical Infectious Disease, 1st ed., Cambridge University Press, 2008, ISBN-10: 0521871123.<br>4. P. G. Engelkirk, J. L. Duben-Engelkirk, Laboratory Diagnosis of Infectious Diseases: Essentials of Diagnostic Microbiology, 1st ed., Lippincott Williams & Wilkins, 2007, ISBN-10: 0781797012. |

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| **Course code** | **BSE 617/ BSE 417** |
| **Title of the course** | **Biomolecular Modeling** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| Pre-requisite, if any | NA |
| Scope of the course | This course is designed for the students with the background in biology, chemistry, physics, or computer science and who are interested in learning biomolecular modeling. The goal of the course is to introduce the principles of biomolecular modeling and to develop practical skills for using existing modeling software. |
| Course Syllabus | Elements of thermodynamics and statistical mechanics: laws of thermodynamics, entropy, ensembles in statistical mechanics: microcanonical, canonical, and grandcanonical ensembles, Partition function, Maxwell-Boltzmann distribution, Phase space. Introduction to stochastic phenomena: Gaussian noise, Brownian motion, diffusion (Fokker-Planck equation), Euler algorithm for Brownian motion. Molecular Mechanics: introduction, Morse potential, Harmonic Oscillator Model for molecules, Energy due to stretch, bend, stretch-bend, torsional strain, van der Waals and Dipole-Dipole interactions. Types of Force fields: AMBER, CHARMM, GROMOS, OPLS, Merck Molecular Force Field, Consistent Force Field, MM2, MM3, and MM4 force fields, force field optimizations. Potential Energy Surface:- Convergence Criteria, Optimization Criteria, Unidirectional Search, Finding Minimum Point, Gradient based Methods- Steepest Descent and Conjugate Gradient Methods Molecular Dynamics Simulations: Introduction, Newtonian dynamics, Integrators- Leapfrog and Verlet algorithm, Thermostats and barostats, Implicit and explicit solvation models, periodic boundary conditions, Ewald's summation for electrostatistics, radial distribution functions, pair correlation function. Biased sampling: umbrella sampling and steered MD simulations. Free energy calculations: molecular recognitions, protein-drug interactions, Molecular Mechanics-Poisson-Boltzmann (Generalized Born) Surface Area (MMPBSA/MMGBSA), Free Energy Perturbation, Thermodynamic Integration (TI). |
| Suggested Books | 1. R. Leach, **Molecular Modeling, Principles and Applications**, Pearson Education, India, 2009 and 978-8131728604<br>2. Frenkel, B. Smit, **Understanding Molecular Simulation, From Algorithms to Applications**, Academic Press, USA, 2001 and 978-0122673511<br>3. K. I. Ramachandra, G. Deepa, K. Namboori, **Computational Chemistry and Molecular Modeling-Principles and Applications**, Springer, New York, 2010 and 978-3642095986<br>4. T. Schlick, **Molecular Modeling and Simulation-An interdisciplinary Guide**, Springer, New York, 2010 and 978-1441963505 |

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| Course Code | **BSE 618** |
| Title of the course | **Biostatistics and Bioinformatics** |
| Credit Structure | L-T-P-Credits<br>2-0-2-3 |
| Name of the Concerned Department | Biosciences and Biomedical Engineering |
| Pre–requisite, if any | None |
| Scope of the course | In this course we will explore the use of statistical methodologies in designing, analyzing, interpreting, and biological experiments and observations. The course will cover descriptive statistics, probability, hypothesis testing and statistical interference, analysis of variance, correlation, and regression techniques. |
| Course Syllabus | **Biostatistics:** Introduction to Biostatics: Variable and attribute; Population vs. sample; Census vs. sample survey; Arrangement of data; Frequency distribution. Graphical presentation of data. Measure of central tendency: Arithmetic mean; Mode; Median. Measure of dispersion: Variance; Standard deviation; Standard error of mean; Standard score. Testing of hypothesis and goodness of fit: Null hypothesis; Level of significance; Probability, Normal distribution, Error of inference, Student's t-test, Fisher's t-test, Chi-square test. Correlation, Regression and Analysis of variance (ANOVA)<br>**Bioinformatics:** Introduction to Bioinformatics with historical background, major developments. Biological data and databases, data query and data mining; Nucleic acid and protein sequence databases,<br>**Sequence analysis**: Basic concept of sequence similarity, identity, and homology; Scoring matrices: basic concept of a scoring matrix, matrices for nucleic acid and protein sequences, PAM, and BLOSUM series, matrix derivation method and principles.<br>**Sequence alignment**: Basic concept of sequence alignment, Needleman and Wunsch, Smith and Waterman algorithms for pairwise alignments, gap penalties, applications to nucleic acid and protein sequences, basic concepts of various approaches for multiple sequence alignment (M.S.A), algorithm for CLUSTALW and PileUp and their application for sequence analysis, etc.<br>**Biological network**: Basic concepts of network, Protien-protien interaction networks, gene regulatory networks, signal transduction networks, etc.<br>**Simulation methods**: Monte Carlo (MC) and Molecular Dynamics (MD) simulations of biological macromolecules. |
| Suggested Books | 1. N. T. J. Bailey, Statistical Methods in Biology, 3rd ed., Cambridge University Press, 1995, ISBN-10: 0521498457.<br>2. B. Rosner, Fundamentals of Biostatistics, 8th ed., Cengage Learning Custom Publishing, 2015, ISBN-10: 130526892X.<br>3. D. W. Mount, Bioinformatics: Sequence and Genome Analysis, 2nd ed., Cold Spring Harbor Laboratory Press, 2005, ISBN-10: 8123912412.<br>4. T. K. Attwood, D. J. Parry-Smith, Introduction to Bioinformatics, Prentice Hall, 1999, ISBN-10: 058232788.<br>5. B. Bergeron, Bioinformatics Computing, 1st ed., Pearson Education, 2015, ISBN-10 9332549419. |

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| Course Code | **BSE 651** |
| Title of the Course | **Biochemistry Lab** |
| Credit Structure | L-T- P-Credits<br>0-0-4-2 |
| Name of the Concerned Department | Biosciences and Biomedical Engineering |
| Pre–requisite, if any | Basic biochemistry courses at the undergraduate level |
| Scope of the Course | This course aims to introduce basic laboratory techniques in biochemistry through experiments that will be conducted as Experimental Projects. |
| Course Syllabus | 1. To prepare an Acetic-NaAcetate buffer system and validate the Henderson-Hasselbach equation.<br>2. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law.<br>3. Titration of Amino Acids and separation of aliphatic, aromatic, and polar AA by TLC.<br>4. An enzyme purification theme (such as E. Coli alkaline phosphatase):<br>(a) Preparation of cell-free lysates,<br>(b) ammonium sulfate precipitation,<br>(c) Ion-exchange chromatography,<br>(d) Gel filtration,<br>(e) Affinity chromatography,<br>(f) Generating a purification table,<br>(g) Assessing purity by SDS0PAGE gel electrophoresis,<br>(h) Assessing purity by 2D-gel electrophoresis, and<br>(i) Enzyme kinetic parameters: $K_m$, $V_{max}$, and $K_{cat}$. |
| Suggested Books | 1. D. Holme, H. Peck, Analytical Biochemistry, 3rd ed., Longman, 1998, ISBN-10: 058229438X.<br>2. R. K. Scopes, Protein Purification -Principles & Practices, 3rd ed., Springer International Edition, 2014, ISBN-10: 8132214838.<br>3. D. Freifelde, Physical Biochemistry: Application to Biochemistry and Molecular Biology, 2nd ed., W. H. Freeman, 1983, ISBN-10: 0716714442.<br>4. K. Wilson, J. Walker, Principles and Techniques of Practical Biochemistry, 5th ed., Cambridge University Press, 2000, ISBN-10: 052165873X. |

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| **Course Code** | **BSE 652** |
| **Title of the Course** | **Genetic Engineering Lab** |
| Credit Structure | L-T-P-Credits<br>0-0-6-3 |
| Name of the Concerned Department | Biosciences and Biomedical Engineering |
| Pre–requisite, if any (for the students) | Basic Biology and Basic Biochemistry (Undergraduate level). |
| Course Objective | The emphasis of the lab is on understanding the principles behind experiments, the ability to design and execute experiments and time management. The purpose of various steps and project planning will be discussed. |
| Course Syllabus | 1. Isolate genomic DNA from *Bacillus subtilis* (or equivalent organism) genome<br>2. PCR amplification of *flgM* gene and analysis by agarose gel electrophoresis<br>3. Preparation of plasmid pET-28a from *E. coli* DH5a and gel analysis<br>4. Restriction digestion of vector (gel analysis) and insert with *Nco*I and *Xho*I<br>5. Vector and insert ligation, b. Transformation in *E. coli* DH5a.<br>6. Plasmid isolation and confirming recombinant by PCR and RE digestion.<br>7. Transformation of recombinant plasmid in BL21(DE3).<br>8. Induction of FlgM protein with IPTG and analysis on SDS-PAGE.<br>9. Purification of protein on Ni-NTA column and analysis of purification by SDS-PAGE.<br>10. Random primer labeling of *flgM* with Dig-11-dUTP<br>11. Southern hybridization of *B. subtilis* genome with probe and non-radioactive detection. |
| Suggested Reading | 1. T. Maniatis, E.F. Fritsch, J. Sambrook, Molecular Cloning: A Laboratory Manual. 3rd ed., Cold Spring Harbor Laboratory Press, 2002, ISBN-10: 0879695773.<br>2. C. Hardin, J. Edwards, A. Riell, D. Presutti, W. Miller, D. Robertson, Cloning, Gene Expression and Protein Purification: Experimental Procedures and Process Rationale, 1st ed., Oxford University Press, 2001, ISBN-10: 0195132947.<br>3. M. A. Innis, D.H. Gelfand, J. J. Sninsky, PCR Applications: Protocols for Functional Genomics, 1st ed., Academic Press, 1999, ISBN-10: 0123721865.<br>4. D. J. Park, PCR Protocols, 3rd ed., Humana Press, 2011, ISBN-10: 1607619431.<br>5. S. B. Primrose, R. M. Twyman, Principles of Gene Manipulation and Genomics, 7th ed., Wiley India, 2014, ISBN-10: 8126548398. |

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| Course Code | **BSE 659** |
| Title of the Course | **Microbiology Lab** |
| Credit Structure | L-T- P-Credits<br>0-0-4-2 |
| Name of the Discipline | Biosciences and Biomedical Engineering |
| Pre–requisite, if any | Basic biology courses undergraduate level |
| Scope of the Course | This course aims to introduce basic laboratory techniques in microbiology (Bacteriology, Virology, Immunology) through experiments that will be conducted as Experimental Projects. |
| Course Syllabus | 1. Introduction to Light Microscopy, Laboratory Procedure for Microscopic Examination<br>2. Introduction to laboratory sterilization technique, Media Preparation; Bacterial Culture Media preparation and sterilization<br>3. Bacterial Isolation, Culturing Techniques and Microscopic Examination of Bacterial Morphology, Structures, Motility.<br>4. Antigen-Antibody Reactions; Agglutination and Precipitation Techniques<br>5. Introduction to virological methods and techniques. Animal cell culture techniques, cell propagation, cell counting, maintenance<br>6. Quantification of virus by plaque assay. Reverse transcription PCR techniques<br>7. Enzyme-Linked Immunosorbent Assay (ELISA) assay for viral antigen detection, Western Blot<br>8. Cell staining and immunoflurescence techniques, Image acquisition through epiflurescence techniques |
| Suggested Books | 1. M. R. Green, J. Sambrook, Molecular Cloning: A Laboratory Manual, 4$^{th}$ ed., Cold Spring Harbor Laboratory Press, 2012, ISBN-10: 9781936113422.<br>2. A. Oller, Microbiology Lab Manual, Spi Lab Edition, Kendall Hunt Pub Co., 2016, ISBN-10: 1465295380.<br>3. J. G. Cappuccino, C. T. Welsh, Microbiology: A Laboratory Manual, 11$^{th}$ ed., Pearson, 2016, ISBN-10: 0134098633. |

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| Course Code | **BSE 698** |
| Title of the Course | **PG Seminar Course** |
| Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| Name of the Concerned Department | Center for Biosciences and Biomedical Engineering |
| Pre–requisite, if any | Nil |
| Course Objective | To develop confidence and presentation skills of the student |
| Course Syllabus | In this course a PG student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her PG Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| Suggested Books | Books and research publications in various relevant journals/conference proceeding, etc. |

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| 1. | Course Code | **BSE 702** |
| 2. | Title of the Course | **Applied Genetic Engineering** |
| 3. | Credit Structure | L-T-P-C<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | Basic knowledge of molecular biology |
| 6. | Scope of the Course | The course is intended to give students an overview of various genetic engineering techniques and its applications. |
| 7. | Course Syllabus | Concept of recombinant DNA technology and purpose, basic methodology, use of plasmids, restriction endonucleases, linkers, adaptors, ligation; Transformation, methods in screening recombinant DNA; methods for labelling DNA, modifying enzymes, hybridization techniques: northern, Southern and colony hybridization; Restriction maps and mapping techniques; PCR technology, primer design; Construction of cDNA libraries in plasmids, Gene amplification, RT-PCR and quantitative RT-PCR; Strategies for maximizing gene expression, prokaryote expression vectors and their applications in expression, quantitation, purification; Inclusion bodies, approaches to solubilisation; Cloning in M13 mp vectors, application to DNA sequencing, site-directed mutagenesis; PCR-based mutations; Vectors: cosmid vectors, yeast artificial chromosome; selection and screening recombinant phage, in vitro packaging, genomic libraries and cDNA cloning; principles and application of di-hybrid systems; Cloning and expression in mammalian cells, methods of selection and screening, application of reporter genes; Applications in mammalian genetic engineering, Biopharmaceuticals, Transgenics in animals and plants, restriction fragment length polymorphism, DNA fingerprinting, human genetic diseases; Gene targeting, human gene therapy, Automated DNA sequencing, Man-made antibodies, phage display; Basic principles of transcriptomics and proteomics. |
| 8. | Suggested Books | **Text Books**<br>1. W. Old & Primrose; Principles of Gene Manipulation. 6th ed., S. B. University Press, 2001. [ ISBN-10: 0632059540 ISBN-13: 978-0632059546]<br>2. T. Maniatis, E. F. Fritsch & J. Sambrook; Molecular Cloning: A Laboratory Manual. CSHL, 3rd ed., 2002. [ ISBN-10: 0879695773 \| ISBN-13: 978-0879695774]<br>3. M.A. Innis, D.H. Gelfand, J.J. Sninsky & T.J. White. PCR Protocols. Academic Press, 1990. [ ISBN 0-12-372181-4]<br>**Reference Books or Journals**<br>1. C Hardin, J Edwards, A Riell, D Presutti, W Miller and D Robertson; Cloning, Gene Expression and Protein Purification: Experimental procedures and process rationale. Oxford University Press, 2001. [ ISBN-10: 0195132947 ISBN-13: 978-0195132946] |

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|---|---|---|
| | | 2. K.E. Davies et al., Genome Analysis - A Practical Approach, 1988. [ ISBN-10: 1852211105 ISBN-13: 978-1852211103]<br>3. Selected articles from the journal Nature, Science, Cell, etc. |

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|---|---|---|
| 1. | Course Code | **BSE 797 (Autumn Semester)**<br>**BSE 798 (Spring Semester)** |
| 2. | Title of the Course | Ph.D. Seminar Course |
| 3. | Credit Structure | L-T-P-Credits<br>0-2-0-2 |
| 4. | Name of the Concerned Discipline | Biosciences and Biomedical Engineering |
| 5. | Pre–requisite, if any | None |
| 6. | Scope of the course | |
| 7. | Course Syllabus | In this course a Ph.D. student has to present seminar/presentation or a series of presentations on a topic(s) chosen by him/her in consultation with his/her Ph.D. Thesis Supervisor/ Faculty Advisor. The frequency of seminar/presentation will be decided by the Course Coordinator. |
| 8. | Textbook | None |
| 9. | Other references | Books and research publications in various journals |

# Course Structure
# of
# PG and Ph.D. Program in
# Discipline of Astronomy, Astrophysics and
# Space Engineering
# and Syllabi of Courses

# Course Structure of 2-year M.Sc. and M.Sc. + Ph.D. Dual Degree Program in Astronomy (From AY 2018-19)

**Minimum Educational Qualification (MEQ):** Bachelor‘s degree in Physics or Mathematics or CSE or EE or ME **AND** JAM qualification in Physics.

**Qualifying Examination:**
**(a) International Students:** Valid score of TOEFL or IELTS, AND valid score of GRE.
**(b) Indian Students:** Valid JAM qualification in Physics.

**Eligibility Requirement (ER):** As per the brochure of Joint Admission test for M.Sc. (JAM).

**Categories of Admission:**
**(a) International Students:** (i) International self-financed **(ISF)** students; (ii) International students sponsored by non-government organizations or by a reputed industry **(ISW)**; (iii) International students sponsored by foreign government or its organizations or through mutual collaborative programs of India with other countries **(GSW)**
**(b) Indian Students:** Not Applicable

**Duration of the Program:** Two years on full-time basis.

### Course Structure for two-year Full-time M.Sc. Program in Astronomy

**1st Year: Semester-I**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| PH 601 | Electrodynamics | 2-1-0 | 3 |
| PH 611 | Fundamental of Quantum Mechanics | 3-1-0 | 4 |
| PH 651 | Mathematical Methods | 2-1-0 | 3 |
| AA 601 | Astrophysical Fluids and Plasma | 2-1-0 | 3 |
| AA 651 | Astronomy Laboratory-I | 0-0-8 | 4 |
| AA 671N/ AA 471N | Relativity and Cosmology | 2-1-0 | 3 |
| | | **Total minimum credits during the semester** | **20** |
| **Additional course (as per the requirement basis)** | | | |
| HS 641 | English Communication Skills | 2-0-2 | PP/NP |

**1st Year: Semester-II**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| AA 672N/ AA 472N | Galactic and Extragalactic Astronomy | 2-1-0 | 3 |
| AA 674N/ AA 474N | Radio Astronomy | 2-1-0 | 3 |
| AA 652 | Astronomy Laboratory-II | 0-0-8 | 4 |
| AA 698 | PG Seminar Course | 0-2-0 | 2 |
| ZZ XXX | Elective-I | 2-1-0 | 3 |
| ZZ XXX | Elective-II | 2-1-0 | 3 |
| | | **Total minimum credits during the semester** | **18** |

**2nd Year: Semester-III**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| AA 799 | M.Sc. Research Project (Stage-I) | 0-0-36 | **18** |

**2nd Year: Semester-IV**

| Course code | Course Title | Contact Hours (L-T-P) | Credits |
|---|---|---|---|
| AA 800 | M.Sc. Research Project (Stage-II) | 0-0-36 | **18** |
| | | **Total minimum credits during the program** | **74** |

**Courses from Astronomy for Elective- I and II @**

| Course code | Course Name | Contact Hours (L-T-P) | Credit |
|---|---|---|---|
| AA 602 | Advanced Topics in Astronomy and Astrophysics | 2-1-0 | 3 |
| AA 604 / AA 404 | Spacecraft and Payload Attitude Dynamics, Control and Pointing | 2-1-0 | 3 |
| AA 606 | Random Signals and Applied Kalman Filtering | 2-1-0 | 3 |
| AA 608 | Astronomical Data Analysis | 2-1-0 | 3 |
| AA 676/ AA 476 | Satellite Based Navigation Systems | 2-1-0 | 3 |
| AA 678/ AA 478 | Space Weather | 2-1-0 | 3 |

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines, after consultation with DPGC Convener / HoD / Supervisor

**NOTE:**

1. Request for conversion from M.Sc. to M.Sc. + Ph.D. dual degree will be considered after evaluating the research potential of the promising and motivated PG students at the end of the **third semester of their program.** The confirmation of conversion of M.Sc. program and to M.Sc. + Ph.D. dual degree program is done during 4th semester with subject to successfully qualifying CSIR/UGC-JRF or equivalent fellowship to enable receiving Ph.D. scholarship.
2. The enhancement in the scholarship from M.Sc. to Ph.D. will be from the beginning of the fifth semester or from the date on which all requirements for the award of M.Sc. degree are fulfilled AND candidate successfully qualifies CSIR/UGC-JRF or equivalent fellowship, whichever is later**.**
3. **If the** student opts for Dual Degree Program but cannot complete the requirements of a Ph.D., an **exit option** with the M.Sc. degree can be earned **before the specified date during the 4th semester** of the normal M.Sc. Program by getting the M.Sc. Research Project examined in the standard manner as per the requirements for the award of an M.Sc. degree.

# Course Structure for Ph.D. Program in Astronomy, Astrophysics and Space Engineering (w.e.f. AY 2018-19)

**(for AY 2016-17 and 2017-18 referred as Centre of Astronomy)**

## (A) Semester-I (Autumn / Spring)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-I | x-x-x-3 |
| 2 | ZZ xxx | Elective-II | x-x-x-3 |
| 3 | ZZ xxx | Elective-III | x-x-x-3 |
| 4 | AA 797* / AA 798* | Ph.D. Seminar Course | 0-2-0-2 |

## (B) Semester-II (Spring / Autumn)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | ZZ xxx | Elective-IV | x-x-x-3 |
| 2 | ZZ xxx | Elective-V | x-x-x-3 |
| 3 | ZZ xxx | Elective-VI | x-x-x-3 |
| 4 | AA 798* / AA 797* | Ph.D. Seminar Course | 0-2-0-2 |

**Astronomy Courses for Elective I -VI** (In addition to these courses, a student can also choose from the Ph.D. courses being offered by the other disciplines.)

| Sr. No. | Course code | Course Title | L-T-P-Credits |
|---|---|---|---|
| 1 | AA 671N/ AA 471N/ IPH 471N/ PH 671N | Relativity and Cosmology | 2-1-0-3 |
| 2 | AA 672N/ AA 472N | Galactic and Extragalactic Astronomy | 2-1-0-3 |
| 3 | AA 674N/ AA 474N/ IPH 474N/ PH 674N | Radio Astronomy | 2-1-0-3 |
| 4 | AA 676/ AA 476 | Satellite Based Navigation Systems | 2-1-0-3 |

**NOTE:**

1. A Ph.D. student having **B.Tech./ B.E./ M.Sc.** or **equivalent qualification** admitted to Ph.D. Program in an Engineering discipline shall do 6-8 courses of at least 3 credits each and 1-2 Ph.D. Seminar courses of at least 2 credits each. Minimum number of courses will be 6 Ph.D. level courses and one Ph.D. seminar course (minimum coursework of 20 credits).

2. A Ph.D. student having **M.Tech./ME//MPhil** qualification has to do one semester coursework (with 2-3 Ph.D. level courses) Minimum number of courses will be 2 Ph.D. level courses and one Ph.D. seminar course (i.e. *(minimum coursework of 8 credits)*.

* Ph.D. Seminar course can be taken either in Autumn or in Spring Semester or both as suggested by the Faculty Advisor/ Thesis Supervisor.

| | | |
|---|---|---|
| 1. | Course Code | **AA 601** |
| 2. | Title of the Course | **Astrophysical Fluids and Plasma** |
| 3. | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. | Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| 5. | Pre–requisite, if any | |
| 6. | Scope of the Course | This course aims to introduce students to the principles of astrophysical fluids with a focus of applying to astrophysical sources. The course also further extends to introduce the concept of plasma that are prevalent in astrophysical environments. |
| 7. | Course Syllabus | **Introduction to Fluids:** Fluids as continuous medium, Local thermal equilibrium. Flow and velocity field, convective derivative. Equations of fluid dynamics (mass, momentum and entropy) for ideal fluids. Condition on equation of state for hydrostatic equilibrium. Convective instability and Schwarzschild's criterion. **Properties of flows:** Equations of fluid dynamics in conservation form. Streamlines and Bernoulli's equation with applications. Kelvin's circulation theorem, Vorticity in 2D and 3D flows, Rotating fluids: Coriolis force, geostrophic flows. *e.g:* Solar Wind and Bondi accretion/Accretion disc, von Ziepel's theorem, Taylor-Proudman theorem. **Linear Waves and Instability**: Sound waves: wave equation, dispersion relation. Gravity waves: derive the dispersion relation; discuss internal and surface gravity waves, Rayleigh-Taylor & Kelvin-Helmholtz instabilities e.g.: Inertial waves in a steadily rotating flow. **Navier-Stokes (NS) equation:** Non-ideal fluids: discuss at elementary kinetic theory level the origins of dissipation and transport, Derive equation for viscous energy conservation and entropy production. Boundary layers. Scaling in the NS equations: Reynolds number, Stokes flow past a sphere at low Re, transition to turbulence, phenomenological treatment of Kolmogorov cascade. **Supersonic flow:** De-laval nozzle, shock properties, Rankine-Hugoniot jump conditions, Cooling length and time, isothermal shocks. Sedov-Taylor blast wave, Supernova shocks: Adiabatic and momentum conserving phases of evolution. **Convection:** Thermal diffusivity and its effect on the entropy equation. Conductive and convective transport of heat equation. Mixing length theory and transport of heat, application to plane-parallel atmospheres and stars. Rayleigh-Benard convection. **Introduction to Plasmas** Particle orbit theory and adiabatic invariants. 2-component plasmas. Debye shielding and length in a plasma in thermal equilibrium. Cold plasma oscillations. **Magnetohydrodynamics** Derivation of induction equation, magnetic diffusion, flux freezing. Lorentz force and momentum equation. Alfven, fast and slow waves. Elements of dynamo theory, Parker spiral, Pulsar magnetospheres, Magneto-rotational instability. **Collisionless plasmas** Coulomb collision times. 6-dim phase space, distribution functions. Vlasov equation. Landau damping e.g.: Connections with stellar systems. |

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| 8. | Suggested Books | 1. Clarke, C.J. & Carswell, R.F., ***Principles of Astrophysical Fluid Dynamics***, Cambridge University Press (2014), ISBN: 9781107666917<br>2. Landau, L. D. & Lifshitz, E. M, ***Fluid Mechanics*** Volume 6 (Course of Theoretical Physics), Butterworth-Heinemann; $2^{nd}$ edition (17 August 1987), ISBN 9780750627672<br>3. Shu, Frank, ***The Physics of Astrophysics: Gas Dynamics: 2 (A Series of Books in Astronomy)***, University Science Books (1994), ISBN 9781891389672<br>4. J. P. Hans Goedbloed, and Stefaan Poedts, ***Principles of Magnetohydrodynamics: With Applications to Laboratory and Astrophysical Plasmas***, Cambridge University Press, 2004, ISBN 9780521626071<br>5. A. R. Choudhari, ***The Physics of Fluids and Plasmas: An Introduction for Astrophysicists***, Cambridge University Press, 1998, ISBN 9780521555432<br>6. Shore, Steven, ***An Introduction to Astrophysical Hydrodynamics***, Academic Press (2012), ISBN 978-0124120075<br>7. P.G. Drazin, and W.H. Ried, ***Introduction to Hydrodynamic Instability*** $2^{nd}$ |

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|---|---|
| Course Code | **AA 602** |
| Title of the Course | **Advanced Topics in Astronomy and Astrophysics** |
| Credit Structure | L-T-P-Credits<br>2-1-0-3 |
| Name of the Concerned Discipline / | Astronomy, Astrophysics and Space Engineering |
| Pre–requisite, if any | |
| Scope of the Course | This is a topical course. |
| Course Syllabus | Selected topics in any areas of astronomy and astrophysics like -<br>1. Star and Planet formation.<br>2. Space Plasmas.<br>3. Gravitation and Gravitational Wave Astronomy.<br>4. Compact Objects and Transients.<br>5. Dark Matter and Dark Energy.<br>6. Astronomical Detectors. |
| Suggested Books | 1. T. Padmanabhan, ***Gravitation: Foundations and Frontiers***, Cambridge University Press, ISBN-13: 978-0521882231<br>2. C. W. Misner, K.S. Thorne and J.A. Wheeler, ***Gravitation***, Princeton University Press (October 24, 2017) , ISBN-13: 978-0691177793<br>3. Claus Grupen, G. Cowan, S. Eidelman, T. Stroh; ***Astroparticle Physics***, ISBN-13: 978-3540253129<br>4. P. R. Saulson, ***Fundamentals of Interferometric Gravitational Wave Detectors***, World Scientific Pub Co Inc; 2 edition (February 16, 2017), ISBN-13: 978-9813143074<br>5. Kaaret, P; ***X-ray Polarimetry***; Link : https://arxiv.org/abs/1408.5899<br>6. Padmanabhan, ***Theoretical Astrophysics: Vols. I, II and III*** - Cambridge University Press; South Asian edition (11 October 2010), ISBN-13: 978-1107400610<br>7. Stuart Shapiro, Saul, Teokolsky, ***Black Holes, White Dwarfs and Neutron Stars: The Physics of Compact Objects,*** Wiley-VCH, ISBN-13: 978-0471873167<br>8. P. Armitage, ***Astrophysics of Planet Formation,*** Cambridge University Press; 1 edition (October 24, 2013), ISBN-13: 978-1107653085<br>9. Mark Krumholz, ***Star Formation (World Scientific Series in Astrophysics)*** World Scientific Publishing Company (July 11, 2017) ISBN-13: 978-9813142022 10. D. H. Perkins - Particle Astrophysics - OUP Oxford, ISBN-13: 978-0198509516 |

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|---|---|
| Course Code | **AA 604 / AA 404** |
| Title of the Course | **Spacecraft and Payload Attitude Dynamics, Control and Pointing** |
| Credit Structure | L-T- P-C 2-1-0-3 |
| Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| Pre-requisites (if any) | |
| Course Syllabus | Three-axis Spacecraft Attitude dynamics; quaternions and other representations. Multi-body spacecraft with articulated antennas, sensors, and solar arrays. Design of spacecraft controllers with reaction wheels, magnets, single- and double-gimbaled control moment gyros as actuators. Three-axis large angle manoeuvres. Payload controllers for acquiring, precision pointing, and high-accuracy tracking of landmarks and moving objects of interests for remote sensing and communication. Pointing error budget. Image motion compensation to remove image blur. Solar array controllers for tracking the Sun using micro-stepper motors. Flexible spacecraft dynamics and control. Dynamics and control of spinning spacecraft: stability, precession and nutation. Control of spin-axis attitude during $\Delta$V-firing for changing orbits; active nutation control; dual-spin stabilization; Rhumb-line manoeuvre. Dynamics and precision pointing of bias momentum spacecraft: stability**;** control using two momentum wheels and a reaction wheel. Reaction jet attitude control and nonlinear controllers: pulse-width-pulse-frequency modulators; minimum-fuel-minimum-time single-axis and three-axis control. Control of spacecraft with liquid propellants: sloshing-control interaction. |
| Suggested Books | 1. Hughes, P.C., ***Spacecraft Attitude Dynamics***, John Wiley,1986, ISBN: 9780486439259<br>2. Sidi, M.J., ***Spacecraft Dynamics and Control***, Cambridge University Press, 1997, ISBN: 9780521787802<br>3. Agrawal, B., ***Design of Geosynchronous Spacecraft***, Prentice Hall, 1986, ISBN: 9780132001144<br>4. Bryson, A.E., ***Control of Spacecraft and Aircraft***, Princeton University Press, 1994, ISBN: 9780691087825<br>5. Wie, B., ***Space Vehicle Dynamics and Control***, AIAA Education Series, 1998, ISBN: 9781563479533<br>6. Markley, F.,L., ***Fundamentals of Spacecraft Attitude Determination and Control***, Springer – 2014, ISBN: 9781493908011<br>7. Smit, G. N., Spacecraft and Payload Pointing, AIAA 2015, ISBN: 9781884989230 |

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|---|---|
| Course Code | **AA 606** |
| Title of the Course | **Random Signals and Applied Kalman Filtering** |
| Credit Structure | L-T- P-C<br>2-1-0-3 |
| Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| Pre–requisite, if any | |
| Course Syllabus | Probability and random variables: a review; Mathematical description of random signals; Gauss-Markov Process; Linear dynamic systems with random inputs, steady-state analysis; state-space modeling, Cholesky decomposition; Basic concepts in estimation; Linear estimation in static systems; Discrete Kalman filter basics; estimation for kinematic models; auto-correlated process noise; cross-correlated measurement and process noise; auto-correlated measurement noise; smoothing; Multiple Model adaptive Kalman filter; delayed-state filter; linearization; nonlinear filtering; the Extended Kalman Filter; simultaneous state and parameter estimation; Complementary filter: error model, total model; inertial navigation; position determination with GPS; the observables; receiver clock model; Kalman filter applications to the GPS; integer ambiguity resolution; tropospheric delay estimation; aided inertial navigation with conventional sensors and GPS. Particle filters, terrain navigation. |
| Texts/References: | 1. Brown, R. G., and Hwang, P. Y. C., ***Introduction to Random Signals and Applied Kalman Filtering with Matlab Exercises***, 4$^{th}$ ed., John Wiley, 2012, ISBN: 9780470609699<br>2. Farrell, J. A., ***Aided Navigation – GPS with High Rate Sensors***, McGraw Hill 2008, ISBN: 9780071493291<br>3. Bar-Shalom, Y., et al, ***Estimation with Applications to Tracking and Navigation***, Wiley 2001, ISBN: 9780471416555 |

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|---|---|
| Course Code | **AA 608** |
| Title of the Course | **Astrostatistics** |
| Credit Structure | L-T- P-Credits 2-1-0-3 |
| Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| Pre–requisite, if any | |
| Course Syllabus | **Introduction**<br>Fundamentals of measuring radio signals, noise theory, Time Series Analysis. Spectral Fitting. Sources of error – systematic vs. random errors.<br>Nyquist Sampling and its applications. Data compression.<br>**Applied Inference & Entropic Information Theory**<br>Stochastic Processes, Markov Chains, Monte Carlo methods: descriptions and applications to Astronomy<br>Entropy in Signal Processing and Information Theory<br>**Parameter Estimation and Model-fitting**<br>Maximum Likelihood and Clustering, Model fitting: Chi-square minimization, Least Squares. Confidence Intervals.<br>Random Inference, Decision Theory, Bayesian Inference and Sampling: The Metropolis-Hastings algorithm, marginalization applied to M-H Algorithm, the Special Case of Markov Chain Monte Carlo methods,<br>Application of above methods to simple astronomical examples |
| Suggested Books | 1. Babu, J.G. , Feigelson, E.D., ***Astrostatistics***, Chapman & Hall (1996)<br>2. Ivezic, Z., Connolly, A.J., Vander Plas, J.T., Gray, A., Statistics, Data Mining, And Machine Learning in Astronomy, Princeton University Press (2014)<br>3. Chattopadhyay, A.K., Chattopadhyay, T., ***Statistical Methods for Astronomical Data Analysis***, Springer (2014)<br>4. Hilbe, J.M., ***Astrostatistical Challenges for the New Astronomy***, Springer (2012)<br>***5.*** C. Lin, T.S. Kalkur, M. Morin, ***Design of RF CMOS Low Noise Amplifiers***, Lambert Academic Publishing (2010)<br>6. Johnson, C . R . Sethares, C. A., Klein, A.G., ***Software Receiver Design***, Cambridge University Press (2011)<br>7. Shannon, C. Weaver, W.A., ***The Mathematical Theory of Communication***, University of Illinios Press (1949)<br>8. MacKay, D.J.C., ***Information Theory, Inference and Learning Algorithms***, Cambridge University Press (2003)<br>9. Papoulis, A., Probability, ***Random Variables and Stochastic Processes***, McGraw Hill, 2002 |

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|---|---|---|
| 1. | Course Code | **AA 651** |
| 2. | Title of the Course | **Astronomy Laboratory I** |
| 3. | Credit Structure | L-T- P-Credits<br>0-0-8-4 |
| 4. | Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| 5. | Pre–requisite, if any | |
| 6. | Course Syllabus | **Introduction to Practical Scientific Computing**<br>Python programming with the use of numerical and scientific libraries (numpy, scipy, matplotlib).<br>**X-ray Data Analysis**<br>CIAO software platform, Chandra X-ray Observatory Data Analysis, CCD device study<br>**Use of Archival data for application to Astronomical systems**<br>Introduction to tools for data retrieval & analysis from the Virtual Observatory, Stellar Type & Spectra – constructing the HR Diagram, Age and characteristics of Open Clusters (Pleiades Cluster), Shape and thickness of the disk of the Milky Way galaxy, Estimating the mass of Jupiter using the orbits of its moons, Distance to the Crab Nebula, Proper motion of Barnard's Star, Measuring the Cosmological Parameters from supernovae type I as standard candles or the period-luminosity relation of Cepheids.<br>**Radio Astronomy Experiments**<br>Any three (3) out of the following experiments:<br>Faraday Rotation, Measuring the Beam Pattern of an antenna – using a signal generator, and then a natural source (the sun), detection of HI line in the galaxy, Superheterodyne receiver characterization |
| 7. | Suggested Books | 1. Sarazin, C. L., ***X-ray Emission from Clusters of Galaxies***, Cambridge University Press; 1 edition (June 18, 2009) ISBN: 978-0521113137<br>2. Horowitz, P.; Hill, W., ***The Art of Electronics***, CUP, 3rd ed. (April 2015) ISBN: 978-0521809269 |

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|---|---|
| Course Code | **AA 652** |
| Title of the Course | **Astronomy Laboratory II** |
| Credit Structure | L-T- P-Credits 0-0-8-4 |
| Name of the Discipline of Center | Astronomy, Astrophysics and Space Engineering |
| Pre–requisite, if any | None |
| Course Syllabus | **Radio Astronomy Data Analysis**<br>Visibilities, van-Cittert Zernicke theorem, the concept of a Dirty Map, Deconvolution<br>Calibration: Band pass, Phase and Amplitude<br>Self-calibration: Amplitude, Phase and Amplitude + Phase<br>High Dynamic Range Imaging<br>**Optical Observations**<br>Four (4) experiments out of the following:<br>1. Measuring distance to Moon by parallax method.<br>2. Measuring limb-darkening of Sun.<br>3. Measuring relative sensitivity of B, V, and R bands of a photometer with Sun<br>4. Measuring extinction of the atmosphere in B, V, and R bands.<br>5. Characterising a CCD camera for gain, read-noise, linearity, and flat-field.<br>6. Estimating atmospheric seeing by measuring differential motion.<br>**Advanced Data Analysis Techniques in Astronomy**<br>Bayesian Statistical Inference, Regression and Model Fitting, Classification, Time Series Analysis |
| Suggested Books | 1. Thomason, Moran, Swenson, ***Interferometry and Synthesis in Radio Astronomy***, Wiley-VCH, 2nd ed., 2001. ISBN:0471254924<br>2. Wilson and Rohlfs, ***Tools of Radio Astronomy***, Springer, 6th ed. (2014) ISBN: 978-3642399497<br>3. Kraus, J. D., ***Radio Astronomy***, Cygnus-Quasar Books, 2nd ed. (1986) ISBN: 978-1882484003<br>4. Ivezic, Z., Connolly, A.J., Vander Plas, J.T., Gray, A., ***Statistics, Data Mining, And Machine Learning in Astronomy***, Princeton University Press, 1st ed. (2014) ISBN: 978-0691151687 |

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|---|---|---|
| 1 | Course Code | **AA 671N/ AA 471N/ PH 671N/ IPH 471N** |
| 2 | Title of the Course | **Relativity and Cosmology** |
| 3 | Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4 | Name of the Discipline | Astronomy, Astrophysics and Space Engineering |
| 5 | Pre–requisite, if any | |
| 6 | Scope of the Course | This course aims to introduce students to cosmology through an understanding of the General Theory of Relativity. Special emphasis will be placed on linear perturbation theory in the early universe, leading to the formation of the cosmic microwave background, as this illustrates basic undergraduate physics in the context of the frontiers of research in cosmology. |
| 7 | Course Syllabus | **1. Special Relativity:** Michaelson-Morley Experiment, Galilean vs. Lorentz transformations, Lorentz invariance, scalars in special relativity, relativistic dynamics, acceleration in special relativity<br>**2. Cosmology:** Olber's paradox; difficulty with Newtonian cosmology; brief introduction to general theory of relativity, especially the line element; Schwarzschild metric, horizon, orbits, Hawking radiation; FRW metric as a consequence of cosmological principle; redshift, angular and luminosity distances; evolution of scale factor from Newtonian cosmology; density parameter; LCDM cosmology; flatness and horizon problems, basics of inflation theory; thermal history of the Universe, big bang nucleosynthesis; microwave background.<br>**3. Structure formation:** Jeans instability in an expanding background; initial perturbation and anisotropies in CMBR, formation of dark matter halos, galaxy formation and star formation; millennium simulation; Sunyaev-Zeldovich effect; neutral hydrogen and other elements in the IGM, Lyman α forest and damped clouds; reionization, AGN/star-formation history of the universe; Gunn- |

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| 8 | Suggested Books | 1. S. Dodelson, ***Modern Cosmology***, Academic Press, 2003, ISBN: 0-1221-9141-2.<br>2. S. Carroll, ***Spacetime and Geometry: An Introduction to General Relativity***, 2003, ISBN: 0-8053-8732-2.<br>**3.** J. A. Peacock, ***Cosmological Physics***, Cambridge University Press, 1998, ISBN: 9780521422703.<br>**4.** P. J. E. Peebles, ***Principles of Physical Cosmology***, Princeton University Press, 1993, ISBN: 0-6910-1933-9.<br>5. P. J. E. Peebles, ***Large-Scale Structure of the Universe***, Princeton University Press, 1980, ISBN: 0-6910-8240-5. 6. D. H. Lyth, & A. R. Liddle, ***The Primordial Density Perturbation***, Cambridge University Press, 2008, ISBN: 0-5218-2849-X.<br>6. S. Weinberg, ***Cosmology***, Oxford University Press, 2008, ISBN: 0-1985-2682-7.<br>7. R. Durrer, ***The Cosmic Microwave Background***, CUP 2008.<br>8. S. Weinberg, ***The First Three Minutes***, Basic Books, 1993, ISBN: 0-4650-2437-8. |

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| 1. Course Code | **AA 672N / AA 472N** |
| 2. Title of the Course | **Galactic and Extragalactic Astronomy** |
| 3. Credit Structure | L-T- P-Credits 2-1-0-3 |
| 4. Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| 5. Pre–requisite, if any | |
| 6. Scope of the course | |
| 7. Course Syllabus | **Types of galaxies:** spirals, ellipticals and irregulars, Hubble pitchfork classification. Milkyway components: gas, stars, magnetic field and cosmic rays; satellites; 21 cm line, rotation curve, dark matter; Jeans instability and star formation, Phases and components of interstellar medium; HII regions; Radiative transfer, optical depth, Free-free emission, Scattering from dust, Optical depth, cosmic rays. **Galactic dynamics:** orbits in axisymmetric potentials, epicyclic limit; Oort's A & B constants, local differential rotation, collisionless Boltzmann equation, Jean's equations, Distribution Functions DFs, isothermal models gas in galaxies. **Evolution of Galaxies:** starbursts, galaxy formation models; color-magnitude diagram for galaxies; initial mass function; **Active Galaxies:** observations of active galaxies and quasars, unified model, radio lobes and jets; relativistic apparent superluminal motion, Doppler boosting, blazars; properties of accretion flows around supermassive black holes; M-σ relation for central black holes; Sgr A*, the Galactic center black hole. **Extragalactic distance scales**: classification of clusters, the local group, superclusters, hot intercluster gas, mass estimates from virial theorem applied to galaxies and hydrostatic equilibrium of hot gas; structure on largest scales. |
| 8. Suggested Books | 1. Mo, H.; van den Bosch, F.; White, S, ***Galaxy Formation and Evolution***, Cambridge University Press, 2010. ISBN 978-0-521-85793-2.<br>2. Schneider, P., ***Extragalactic Astronomy and Cosmology: An Introduction***, Springer 2006. ISBN 978-3-540-33174-2.<br>3. Phillipps, S., ***The Structure and Evolution of Galaxies***, John Wiley & Sons, Ltd, 2005; ISBN 978-0-470-85507-X.<br>4. Longir, Malcolm S., ***Galaxy Formation***, Springer, 2008. ISBN<br>5. James Binney, Scott Tremane, ***Galactic Dynamics***, Princeton University Press; Second edition (January 27, 2008), ISBN: 978-0691130279<br>6. Sparke, L.; Gallagher, J., ***Galaxies in the Universe: An Introduction*** ($2^{nd}$ Edition), Cambridge University Press, 2007. ISBN 978-0-521-67186-6.<br>7. Binney, J.; Merrifield, M., ***Galactic Astronomy***, Princeton University Press, 2008. ISBN 978-0-691-02565-7. |

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| 1. Course Code | **AA 674N/ PH 674N/ AA 474N/ IPH 474** |
| 2. Title of the Course | **Radio Astronomy** |
| 3. Credit Structure | L-T- P-Credits<br>2-1-0-3 |
| 4. Name of the Discipline / Centre | Astronomy, Astrophysics and Space Engineering |
| 5. Pre–requisite, if any | |
| 6. Scope of the course | This course is intended to introduce the concepts of radio astronomy. |
| 7. Course Syllabus | **Review of Electromagnetic theory:** Maxwell's equations and basics of electric and magnetic fields, Basic Electromagnetic Theory and radiation of electromagnetic waves, E & B Field Measurable quantities and Polarization.<br>**Radio Universe and Antenna:** The Radio Universe and the<br>Atmospheric Radio Window Brightness, Flux density and antenna fundamentals-<br>I, Effects of the earth's atmosphere, Basics of Radiative<br>Transfer, Antenna fundamentals – II, Antenna Fundamentals–III.<br>**Radio Interferometry:** Introduction, Uses and Advantages, Essential Ingredients of an interferometer.<br>**Radiometers:** from Voltages to Spectra, Galactic Astrophysics and observations.<br>**Non-thermal Radiative Processes:** Astrophysics with 21 cm emission, Synchrotron emission and Polarisation, Faraday Rotation, Inverse Compton |
| 8. Suggested Books | 1. Thomason, Moran, Swenson, ***Interferometry and Synthesis in Radio Astronomy***, Wiley-VCH, 2nd ed., 2001. ISBN:0471254924<br>2. Wilson and Rohlfs, ***Tools of Radio Astronomy***, Springer, 6th ed. (2014) ISBN: 978-3642399497<br>3. Kraus, J. D., ***Radio Astronomy***, Cygnus-Quasar Books, 2nd ed. (1986) ISBN: 978-1882484003<br>4. J. Tinbergen, ***Astronomical Polarimetry***, Cambridge University Press (August 22, 2005), ISBN: 978-0521018586 |

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| 1. | Course Code | **AA 676/ AA 476** |
| 2. | Title of the Course | **Satellite Based Navigation Systems** |
| 3. | Credit Structure | L-T-P-Credit<br>2-1-0-3 |
| 4. | Name of the Concerned Discipline | Center of Astronomy |
| 5. | Pre–requisite | None |
| 6. | Scope of the course | This is a contemporary course on GPS-Aided Geostationary Augmented Navigation (GAGAN) and Navigation with Indian Constellation (NAVIC) satellite-based navigation systems of the country and how they will be used for navigation of land, air and space vehicles. |
| 7. | Course Syllabus | Review of satellite-based navigations: GPS (Global Positioning System), IRNSS (Indian Regional Navigation Satellites System). GPS measurements and error sources; Code phase and carrier phase measurements. Ionospheric and tropospheric delay models; receiver clock error model; User range error; Combining code and carrier phase measurements – carrier-aided smoothing. Differential GPS, local-area DGPS, relative positioning; wide-area DGPS; Indian navigation system GAGAN (Geostationary Augmented GPS Aided navigation). Position, velocity and time estimation with pseudorange and pseudorange rate measurements. Precise positioning with carrier phase, with integer ambiguity resolution using code measurements and dual- and three-frequency measurements; LAMBDA method. Differential GPS-aided INS for flight vehicles: Code and carrier double-differencing, triple-differencing. Integration of differenced observables with inertial navigation (INS); GPS-Aided INS for precise aircraft landing. Tightly coupled GPS/INS integration for missiles and launch vehicle navigation. Absolute and relative navigation with GRAPHIC technique for satellites rendezvous. Unmanned Aerial Vehicle (UAV) and Micro Air Vehicle (MAV) navigation. Spinning sounding rocket navigation. Submarine navigation |
| 8. | Suggested Books | 1. Brown and Hwang, **Introduction to Random Signals and Applied Kalman Filtering**, John Wiley, 2012, 4th edition, ISBN : 0470609699<br>2. Rogers, R.M., **Applied Mathematics in Integrated Navigation Systems**, 3rd Ed., AIAA Education Series, 2007, ISBN: 1563479273<br>3. Farrell, J.L., **GNSS Aided Navigation and Tracking**, American Literary Press, 2007, ISBN : 1561679798<br>4. Farrell, J. A., **Aided Navigation: GPS with High Rate Sensors**, McGraw Hill, 2008, ISBN : 0071493298<br>5. Farrell, J.A. and Barth, M., **The Global Positioning System and Inertial Navigation**, McGraw-Hill, 1999, ISBN : 007022045X<br>6. Misra, P., and Enge, P., **GPS – Signals, Measurements and Performance**, Second Edition, Ganga-Jamuna Press, 2006, ISBN: 0970954425 |

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| **Course code** | **AA 678/ AA 478** |
| **Title of the course** | **Space Weather** |
| Credit Structure | L - T - P - Credits<br>2-1-0-3 |
| Name of the Concerned Discipline | Astronomy |
| Pre-requisite, if any | NA |
| Scope of the course | This course gives an overview of the space weather systems involving the Sun, Heliosphere, Magnetosphere and Ionosphere. |
| Course Syllabus | 1. Introduction – Definition of Space Weather(Sun, Heliosphere, Magnetosphere, Ionosphere)<br>2. Solar interior, solar magnetism, structure of solar atmosphere<br>3. Solar Activity: Flares, Coronal Mass Ejections and Solar Energetic Particles, Solar Wind Formation and Acceleration, Heliospheric Structure<br>4. Magnetospheric structure, magnetospheric storms and substorms, Geomagnetic Storms– Geomagnetic Variations, Geomagnetic Activity Indices, Geomagnetic Storms<br>5. Ionosphere – Description of the ionospheric layers, anomalous features of the F-region, ionospheric irregularities, short-term and long-term behavior of the ionospheric layers, sporadic-E, ionospheric models.<br>6. Space Weather Measurement Systems–Ionospheric Sounding Systems, Radar, Transionospheric Propagation Systems, GPS.<br>7. Space Weather Effects on Telecommunication Systems – outline of ionospheric effects, integrated propagation effects – refraction, phase and group path variation, Doppler shift, Faraday rotation, absorption, differential effects – scintillations, mitigation scheme. |
| Suggested Books | 1. Gerd W. Prolss, ***Physics of the Earth's Space Environment - An Introduction,*** Springer Publications, Heidelberg, 2004, ISBN-10 : 3540214267<br>2. M.G. Kivelson and C.T. Russel, ***Introduction to Space Physics,*** Cambridge Univ. Press, Cambridge, 1995, ISBN-10, 0521457149<br>3. M. Kallenrode, ***Space Physics: An Introduction to Plasma and Particles in the Heliosphere and Magnetosphere***, Springer Publications, Heidelberg, 2004, ISBN, 3-540-20617-5<br>4. M. Moldwin, ***An Introduction to Space Weather,*** Cambridge Univ. Press, Cambridge, 2008, ISBN 9780511801365 |