Indian Institute of Technology Indore

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

April 2025

[After incorporating decisions of the 53rd meeting of the Senate held on 23 April 2025]

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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 to AY 2024-25)

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.

1st Year: Semester-I **Course Structure of M. Tech. Program**

Course code	Course Title	Contact hours (L-T-P)	Credits
MM 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.

Course Structure of M.Tech. / M.Tech. + Ph.D. Dual Degree Program in Materials Science and Engineering (From AY 2025-26 onwards)

Minimum Educational Qualification: *"Four-year bachelor's degree or five-years integrated degree (with the first division*) in Metallurgical Engineering and Materials Science/ Physics/ Chemistry/ Nanoscience/ Nanotechnology/ Engineering Science/ Engineering Physics/ Metallurgy/Mechanical/Chemical/Caramics/polymer/Electrical/Electronics/Energy Science and Engineering.*

OR

Two years master's degree (with first division*) in Chemistry/Physics/Material Science/ Nanoscience/ Nanotechnology discipline.

**as defined by the awarding Institute/University for Indian applicants and equivalent to International applicants, as assessed by the institute.*

Qualifying Examination:

(c) International Students: Valid score of TOEFL or IELTS, AND valid score of GRE

(d) Indian Students: Valid GATE qualification in MT/ME/CH/CY/PH/EC/EE/XE.

Categories of Admission:

(c) 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)**

(d) 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.

Note: Candidates in the SW, DF and IS categories will not be provided with any scholarship.

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

Course Structure of M. Tech. Program

1st Year: Semester-I

Course code	Course Title	Contact hours (L-T-P)	Credits
MM 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.

Course Structure of M.Tech. program with specialization in Metallurgy Engineering (with an option to convert M.Tech. + Ph.D. dual degree Program) (for batch graduated in AY 2019-20 and AY 2020-21)

Metallurgical Engineering (with an option to convert M.Tech. + Ph.D. dual degree Program) (from the batch graduated in AY 2021-22)

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/ Engineering Sciences.

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.

1st 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

1st 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.	MM 605	Green Hydrogen: Materials and Technologies	2-1-0-3
2.	MSE 601	Surface Science and Engineering	2-1-0-3
3.	MSE 605	Computational Techniques in Materials Engineering	3-1-0-3
4.	MSE 607	Materials for Devices	2-1-2-4
5.	MM 661	Material Science and Engineering	2-1-0-3
6.	ME 650	Materials Characterization Techniques	2-0-2-3
7.	ME 660/ ME 460	Technology of Surface Coatings	2-1-0-3
8.	MSE 607	Materials for Devices	2-1-2-3
9.	MSE 610	Design of Materials for Surface Protection and Corrosion Control	2-1-0-3
10.	MSE 612	Laser Based Surface Processing and Characterization	2-1-0-3
11.	MSE 614	Micro/Nano Fabrication of Nanostructures	2-1-0-3
12.	MSE 616	High Temperature Materials and Coatings	2-1-0-3
13.	MSE 618	Organic Paint Coatings	2-1-0-3
14.	MSE 620	Modeling and Management of Corrosion	2-1-0-3
15.	MSE 622	Tribology and Wear	2-1-0-3
16.	MSE 624	Interface Effect in Electronic Devices	2-1-0-3
17.	MSE 626	Surface Metrology	2-1-0-3

18.	MSE 628	Wear friction and abrasion of surface	2-1-0-3
19.	ME 738	Composite Materials	2-1-0-3
20.	ME 640/ ME 440	Smart Materials and Structures	2-1-0-3
21.	ME 648/ ME 448	MEM.S. and micro-systems	2-1-0-3
22.	ME 658	Laser based Measurements and micro-manufacturing	2-1-0-3
23.	MSE 610	Design of Materials for Surface Protection and Corrosion Control	2-1-0-3
24.	MSE 612	Laser Based Surface Processing and Characterization	2-1-0-3
25.	MSE 614	Micro/Nano Fabrication of Nanostructures	2-1-0-3
26.	EE631	Organic Electronics	3-0-0-3
27.	EE 629	Nanotechnology and Nanoelectronics	3-0-0-3
28.	EE 605	Nanotechnology	3-0-0-3
29.	PH 725	Characterization of surfaces and interfaces of materials	2-0-2-3
30.	PH613	Developments in early 20th century in Physics	2-1-0-3
31.	PH721	Advance Materials	2-1-0-3
32.	ME 640/ ME 440	Smart Materials and Structures	2-1-0-3
33.	ME 648/ ME 448	MEMS and micro-systems	3-0-1-3
34.	ME 658	Laser based Measurements and micro-manufacturing	2-1-0-3
35.	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.

Course Code	**MM 602/ MM 402**
Title of the Course	**Design and Selection of Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
Scope of the Course	To develop a systematic procedure for selecting materials and processes that best matches the requirements of industries.
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.
Suggested Books	1. M.F. Ashby, **Materials Selection in Mechanical Design**, 4th Edition, Elsevier, San Francisco, 2011; ISBN: 978-1-85617- 663-7. 2. Cambridge Engineering Selector (CES EduPack), Granta Design Limited, Cambridge, UK, 2010, www.grantadesign.com. Cases studies provided by the instructor. 3. W.D. Callister, **Materials Science for Engineering: An Introduction**, 7th Edition, Wiley, 2007. ISBN: 978-0-471-73696- 7.

Course Code	**MM 603**
Title of the Course	**Applied Surface Science**
Credit Structure	L - T - P – Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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
Suggested Books	1. John B. Hudson, Surface Science: An Introduction, Elsevier Science & Technology, Oxford, United Kingdom, 1992, ISBN: 978-0-471-25239-9 2. H. Luth, Surfaces and Interfaces of Solids (2nd Ed.), Springer- Verlag Berlin Heidelberg, New York (USA), 1993, ISBN: 978-3- 662-10159-9 3. Andrew Zangwill, Physics at Surfaces, Cambridge University Press, Cambridge (UK), 1988, ISBN: 978-0-521-34752-5 4. M. Prutton, Introduction to Surface Physics, Clarendon Press, Gloucestershire (UK), 1994, ISBN: 978-0-198-53476-1 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 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

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

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Course Code	**MM 605/ MM 405**
Title of the Course	**Green Hydrogen: Materials and Technologies**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre-requisite, if any	Fundamental knowledge of materials science, materials synthesis/fabrication, materials characterization and electrochemistry
Scope of the Course	The course provides the learning on various aspects of green hydrogen energy: fundamentals of materials and technologies for green hydrogen production, storage and its applications.
Course Syllabus	**1. HYDROGEN ENERGY OVERVIEW:** Green hydrogen in global energy scenarios. **2. METHODS AND TECHNOLOGIES FOR GREEN HYDROGEN PRODUCTION:** Water-electrolysis: mechanisms of oxygen evolution reaction and hydrogen evolution reaction. Solar driven water splitting: photocatalytic & Photoelectrochemical, Biological and bio-electrochemical, Thermochemical, Electrolyzer Technologies: alkaline water electrolyser, proton exchange membrane, solid oxide electrolyzer, anion exchange membrane, proton conducting ceramic. **3. MATERIALS FOR GREEN HYDROGEN PRODUCTION**: Catalytic materials based on different electrolyzer technologies, solar driven water splitting, thermochemical and bio electrochemical water splitting. Materials challenges and research scope. **4. HYDROGEN STORAGE**: Physical storage technologies, Materials storage: metal hydrides, metal alanates, amino borane, metal amides, amine metal borohydrides, chemical hydrogen storage, carbon materials, nanostructured adsorbents.
Suggested Books	• K. S. V. Santhanam, R. J. Press, Massoud J. Miri, A. V. Bailey, G. A. Takacs : *Introduction to Hydrogen Technology*: 2nd Edition : John Wiley and Sons Ltd : USA : 2017 : 9781119265573. • Bent Sorensen and Giuseppe Spazzafumo, *Hydrogen And Fuel Cells*, Acad Pr, 2018, ISNB: 9780081007082 • Mario Pagliaro and Athanasios G. Konstandopoulos, *Solar Hydrogen: Fuel of The Future,* RSC, 2012, ISBN: 781849731959 • Paulo Emilio Miranda, *Science and Engineering of Hydrogen-Based Energy Technologies*, Academic Press, 2018 ISBN: 9780128142516 • Kent Olsen, *Advanced Concepts of Hydrogen Storage Technology*, Clanrye International, 2015, ISNB: 9781632400178

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

Course Code	**MM 641**
Title of the Course	**Advanced Physical Metallurgy**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course teaches advanced concepts in crystallography, crystal defects, advanced heat-treatments, and related phase transformations.
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.
Suggested Books	1. C. Hammond, **The Basics of Crystallography and Diffraction**, Oxford University Press, 2009, ISBN-13: 978-0199546459. 2. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, **Physical Metallurgy Principles**, 4th Edition, Cengage Learning, 2003,ISBN-13: 978-0495082545. 3. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Inc. New York, 1988, ISBN-13: 978-1259064791. 4. D. A. Porter, E. E. Kenneth, M. Sherif, **Phase Transformations in Metals and Alloys**, CRC press, 2009,ISBN-13: 978-1420062106. 5. R. E. Smallman, A. H. W. Ngan, **Physical Metallurgy and Advanced Materials**, 7th Edition, Elsevier, 2007,ISBN: 9780750669061.

Course Code	**MM 642/ MM 442**
Title of the Course	**Quality Assurance in Metallurgy**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
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.
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.
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. 2. ASTM International: **https://www.astm.org/Standard/standards-and-publications.html** 3. A. J. Duncan**, Quality Control and Industrial Statistics**, Richard D. Irwin, Inc,1974, ASIN: B01LQEKJ2M.

Course Code	**MM 643**
Title of the Course	**Advanced Mechanical Metallurgy**
Contact Hours	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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. Deformation processing: Mechanics of Forming, Deformation mechanism maps. Conventional metal forming processes (Rolling, extrusion, drawing, forging, sheet metal forming). Advances in conventional forming techniques. **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. Powder processing – mechanism of sintering, spark plasma sintering, microwave processing of materials Additive Manufacturing processes: Laser-Sintering and industrial 3D printing.
Suggested books	1. K. Sindo,**Transport Phenomena and Materials Processing**, Wiley-Interscience, 1996, ISBN: 9780471076674. 2. H. Tschätsch, **Metal Forming Practice: Processes - Machines – Tools**, Springer, 2005, ISBN-10: 3642069770. 3. I. Gibson, D. Rosen, B. Stucker, **Additive Manufacturing Technologies**, Springer, 2014, ISBN-10: 1493921126. 4. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Inc. New York, 1988, ISBN-13: 978-1259064791.

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Course Code	**MM 644**
Title of the Course	**Integrated Computational Materials Engineering (ICME)**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Computational techniques in Materials Engineering
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.
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.
Suggested Books	1. N. Provatas, K. Elder, **Phase-Field Methods in Material Science and Engineering**, Wiley-VCH, 2010, ISBN: 9783527407477. 2. J.G. Lee, **Computational Materials Science: An Introduction**, CRC Press, Taylor and Francis group, 2012, ISBN: 9781439836163. 3. D. Raabe, **Computational materials science: the simulation of materials microstructures and properties**, Wiley-VCH, 1998, ISBN: 9783527295418. 4. R. Lesar, **Introduction to computational materials science: Fundamentals to Applications**, Cambridge University Press, 2013, ISBN-10: 0521845874. 5. W.A. Stauss, **Partial Differential equation: An Introduction**, Wiley Publications, 2007, ISBN: 9780470473184. 6. M.F. Horstemeyer, **Integrated Computational Materials Engineering (ICME) for Metals**, Wiley Publications, 2012, ISBN: 9781118022528.

Course Code	**MM 645**
Title of the Course	**Multiphysics Modelling**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Computational techniques in Materials Engineering, Advanced structural and mechanical metallurgy
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.
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; 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; 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.
Suggested Books	1. J.N. Reddy, **Principles of Continuum Mechanics**, Cambridge University Press; 1stEdition, 2010, ISBN: 0521513693 2. J.G. Simmonds**, A brief on Tensor Analysis**, Springer, 1982, ISBN: 978-1-4419-8522-4 3. M. Kaviany, **Principles of Heat Transfer**, 2002,ISBN: 9781468404128. 4. COM.S.OL Multiphysics Manual.

Course Code	**MM 646**
Title of the Course	**Advances in Iron and Steel Metallurgy**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
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.
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.
Suggested Books	1. R. H. Tupkary, V. R. Tupkary, **Modern Iron Making**, Khanna Publications, Delhi, 2004, ISBN-13: 9788174090215. 2. A. Ghosh, A. Chatterjee, **Ironmaking and Steelmaking**, PHI Pvt. Ltd., 2008,ISBN-13: 978-8120332898. 3. V. Kudrin, **Steel Making**, Mir Publisher, Moscow, 1985. ISBN: 5030008594 9785030008592. 4. Bashforth, **Manufacture of Iron and Steel**. Vol I and II, Asia Publishing House, 1996, ISBN: 9781504122511.

Course Code	**MM 647/ MM 447**
Title of the Course	**Metallurgical Thermodynamics and Phase Transformations**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
Scope of the Course	To develop critical thinking and analytical problem solving skills related to macroscopic thermodynamics and kinetics in Metallurgy and Materials Engineering.
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.
Suggested Books	1. D. R. Gaskell and D. E. Laughlin, **Introduction to thermodynamics of materials,** Sixth Edition, CRC Press, 2017, ISBN-13: 978-1498757003. 2. D. A. Porter, and K. E. Eastering, Phase Transformations in Metals and Alloys, Chapman & Hall, London, New York, 1992, ISBN: 0442316380. 3. R. W. Balluffi, S. M. Allen, W. C. Carter, **Kinetics of Materials**, Wiley, New York, 2005, ISBN: 9780471246893. 4. D. V. Ragone, **Thermodynamics of Materials**, Vol 1-2, Wiley, New York, 1994, ISBN: 978-0-471-30885-0. 5. Bashforth, **Manufacture of Iron and Steel**. Vol I and II, Asia Publishing House, 1996, ISBN: 9781504122511.

Course Code	**MM 648/ MM 448**
Title of the Course	**Solidification and Phase Field Modeling**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Discipline of Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
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.
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.
Suggested Books	1. G. J. Davies, **Solidification and Casting**, Applied Science Publishers Ltd, London, 1973, ISBN: 0-853345562. 2. W. Kurz, D.J. Fisher, **Fundamental of Solidification**, Trans Tech Publications, Switzerland, 1992, ISBN: 0-878495223. 3. M.E. Glicksman, **Principles of Solidification**, Springer, New York, 2010, ISBN: 9781441973436. 4. J.A. Dantzig, M. Rappaz, **Solidification**, EPFL Press, Switzerland, 2016, ISBN: 9780849382383. 5. D. M. Herlach, D.M. Matson, **Solidification of Containerless Undercooled Melts**, Wiley-VCH, 2012, ISBN:9783527331222. 6. S. BulentBiner, **Programming Phase-Field Modeling**, Springer, 2017,ISBN: 9783319411941.

Course Code	**MM 649/ MM 449**
Title of the Course	**Advance Welding Technology**
Contact Hours	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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
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) 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. 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). 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
Suggested books	1. M. Robert, **Joining of Materials and Structures**, 1st Edition, Elsevier, 2004,**ISBN:** 9780750677578. 2. S. Kou, **Welding Metallurgy**, 2nd Edition, Wiley, 2002, ISBN: 9780471434917. 3. H. Granjon**, Fundamentals of Welding Metallurgy**, 1st Edition, Elsevier, 1991, ISBN: 9781855730199.

Course code	**MM 650/ MM 450**
Title of the course	**Ferrous and Non-Ferrous Alloys**
Credit Structure	L - T - P - Credits 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 2. R. E. Smallman, A. H. W. Ngan, ***Physical Metallurgy and Advanced Materials***, Elsevier, USA, 2007, ISBN, 9780750669061 3. G. Lutjering, J.C. Williams, ***Titanium***, Springer-Verlag, Berlin, 2003, ISBN, 9783540713975 4. R.C. Reed, ***The Superalloys, Fundamentals and Applications***, Cambridge University Press, UK, 2006, ISBN-13, 978-0521070119

Course Code	**MM 651/ MM 451**
Title of the Course	**Non-destructive Evaluation**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
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.
Course Syllabus	**Introduction**: Need for inspection, types of inspection system, Quality of inspection, Reliability of defect detection and benefits of NDE. **Visual Inspection**: Basic principles and applications, borescope; rigid chamber scopes; endoscope; videoscope; robotic crawlers. **Liquid Penetrant Inspection**: Physical principles, procedures of testing, penetrant testing materials, applications and limitations. **Magnetic Particle Testing**: Principle of MPT, Magnetization techniques, procedure used for testing a component, equipment used for MPT, applications and limitations. **Ultrasonic Testing**: Basic principles of sound beam, ultrasonic transducers, type of display, inspection methods, identification of defects, immersion testing, applications and limitations. **Acoustic Emission Testing (AET)**: Principles, technique, Instrumentation and applications. **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. **X-ray and Neutron Radiography**: Basic principles, electromagnetic radiation sources, effect of radiation in film, radiographic imaging, inspection techniques, applications and limitations. Shearography, Vibrothermography, Thermography, Laser Interferrometry, Acoustic microscopy, Microwave Testing: Working principles and applications. Case study; Statistical methods for quality control.
Suggested Books	1. B. Raj, T. Jayakumar, M. Thavasimuthu, **Practical Non-destructive Testing**, 3rd Edition, Narosa, New Delhi, 2007, ISBN: 9788173197970. 2. ASM handbook committee, **Nondestructive Evaluation and Quality Control**, Metals Handbook, Vol. 17, ASM International, ISBN: 0871700077. 3. J. Prasad, C. G. Nair, **Nondestructive Test and Evaluation of Materials,** McGraw-Hill Education, 2008, ISBN: 9780070077461.

Course Code	**MM 652/ MM 452**
Title of the Course	**Thermomechanical Processing**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Discipline of Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
Scope of the Course	This course deals with advanced thermomechanical processing to understand the development of unique microstructure.
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.
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 2. B.S. Altan, Severe Plastic Deformation: Towards Bulk Production of Nanostructured Materials, Nova Publishers, New York, 2006, ISBN: 1-59454-508-1. 3. M.J. Zehetbauer, R.Z. Valiev, Nanomaterials by Severe Plastic Deformation, Wiley-VCH, Germany, 2004, ISBN: 9783527604944. 4. A. Rosochowski, Severe Plastic Deformation Technology, Whittles Publishing, UK, 2017, ISBN: 9781849950916. 5. Y. T. Zhu, V. Varyukhin, Nanostructured Materials by High-Pressure Severe Plastic Deformation, Springer, Netherlands, 2006, ISBN-10: 1402039212. 6. T. C. Lowe, R. Z. Valiev, Investigations and Applications of Severe Plastic Deformation, Springer, Netherlands, 2000, ISBN: 9780792362814.

Course Code	**MM 653/ MM 453**
Title of the Course	**Non-equilibrium Processing of Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
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.
Course Syllabus	**Introduction:** Thermodynamics and kinetics of metastable phase formation. **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. **Nanostructured materials:** Classification, preparation, structure, stability, properties, application and future direction. **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.
Suggested Books	1. C. Suryanarayana, **Non-equilibrium Processing of Materials**, Elsevier, 1999, ISBN: 0080426972. 2. B.S. Murty, J.W. Yeh, S. Ranganathan, **High Entropy Alloys**, Elsevier, UK, 2014, ISBN: 9780128002513. 3. R. E. Smallman, A. H. W. Ngan, **Physical Metallurgy and Advanced Materials**, 7th Edition, Elsevier, 2007, ISBN: 9780080552866. 4. R.C. Reed, **The superalloys: fundamentals and applications**, Cambridge University Press, 2006, ISBN-13: 9780511245466. 5. Dimitris C. **Lagoudas**, **Shape Memory Alloys Modeling and Engineering Applications**, Springer, 2008, ISBN: 9780387476841.

Course Code	**MM 654/ MM 454**
Title of the Course	**Advanced Foundry Technology**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Discipline of Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
Scope of the Course	This course introduces students to different foundry techniques, different alloy systems by casting routes, casting defects.
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.
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. 2. A. Ghosh, A.K. Mallik, **Manufacturing Science**, Affiliated East-West Press Pvt. Ltd., India, 2010, ISBN-10: 8176710636. 3. P.L. Jain, **Principles of Foundry Technology,** 5th Edition, Mcgraw Hill Education, 2009, ISBN: 9780070151291. 4. A.K. Chakrabarti, **Casting Technology and Cast Alloys**, PHI Learning Pvt. Ltd., 2005, ISBN: 9788120327795. 5. B. Ravi, **Metal Casting: Computer - Aided Design and Analysis**, Phi Learning Pvt. Ltd, 2010, ISBN: 9788120327269, 8120327268. 6. D. Kumar, S.K. Jain, **Foundry Technology**, Cbs Publisher, 2007, ISBN: 9788123902906. 7. P. Beeley, **Foundry Technology**, Butterworth-Heinemann, 2001, ISBN: 0750645679. 8. O.P. Khana, **Foundry Technology**, Dhanpat Rai Publications, 2011, ISBN: ISBN-10: 8189928341. 9. K.P. Sinha, D.B. Goel, **Foundry Technology**, Standard Publishers Distributors, 2006, ISBN: 8186308121. 10. G. Sutradhar, **Principles of Foundry Process Design**, New Age International Pvt. Ltd, 2010, ISBN 10: 8122434053.

Course Code	**MM 656**
Title of the Course	**Experimental Techniques in Materials**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	The course is intended to teach the students an overview of the various characterization techniques used in metallurgy and materials.
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). Experimental methods in materials properties measurements: Mechanical, Electrical, Thermal, Magnetic, and optical.
Suggested Books	1. C. Suryanarayana, **Experimental Techniques In Materials And Mechanics**, CRC press, 2011, ISBN-10: 1439819041. 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. 3. **Characterization of Materials**, 10th Edition, Metals Handbook, Vol. 9, American Soc. of Metals, Metals Park, Ohio, 1986, ISBN: 9780871700162. 4. M.V. Heimendahl, **Electron Microscopy of Materials-An Introduction**, Academic Press, 1980, ISBN:0127251502. 5. B.D. Cullity, **Elements of X-Ray Diffraction,**Pearson, 2001, ISBN:10: 0201610914.

Course Code	**MM 657/ MM 457**
Title of the Course	**Advances in Energy Storage Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Discipline of Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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. **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. **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. **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.
Suggested Books	1. E. R. Leite, **Nanostructured Materials for Electrochemical Energy Production and Storage**, Springer, 2009, ISBN: 978-0-387-49323-7. 2. B. E. Conway, **Electrochemical Supercapacitors Scientific Fundamentals and Technological Applications**, Springer, 1999, ISBN: 9781475730586. 3. D. Linden, T. B. Reddy, **Handbook of Batteries,** 3rd Edition, McGraw-Hill, 2002, ISBN-13: 9780071359788. 4. C. G. Granqvist**, Handbook of Inorganic Electrochromic Materials**, Elsevier, 1995, ISBN: 9780080532905.

Course Code	**MM 659**
Title of the Course	**Introduction to Soft Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
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. The course will illustrate the broad overview of design, synthesis, characterization, properties, recent advancements and potential applications of soft materials.
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.
Suggested Books	1. I. W. Hamley, **Introduction to Soft Matter: Polymers, Colloids, Amphiphiles and Liquid Crystals**, Willey, 2000, ISBN: 0471899518. 2. R. G. Weiss, P. Terech, **Molecular Gels: Materials with Self-Assembled Fibrillar,** Networks, 2006, ISBN: 9781402036897. 3. M. Tokita, K. Nishinari, **Progress in Colloid and Polymer Science,** Vol 136, 2009, ISBN: 9783642008658.

Course Code	**MM 663**
Title of the Course	**Failure Analysis and Life Assessment**
Contact Hours	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline/School	MEM.S.
Pre–requisite, if any	None
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.
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 Classification of different types of failures; Description and origin of processing defects: Metal working defects, casting defects, heat treatment defects and weld defects; Basic of fracture, fracture mechanism map, Fatigue failures, Creep failures. Environmental assisted failures (corrosion, stress corrosion cracking, hydrogen embrittlement, failures at elevated temperatures), Failure of coatings, Failure due to wear 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. Safety design approaches in safety critical industries (Nuclear, aerospace, automotive industries).
Suggested books	1. A. J. McEvily, **Metal Failures: Mechanisms, Analysis, Prevention**, John Wiley & Sons, New York, 2002,ISBN: 9781118163962. 2. **J.S. Zhang, High Temperature Deformation and Fracture of Materials**, Elsevier,**2010,** ISBN: 9780857090799. 3. **Failure Analysis and Prevention,** ASM Handbook Volume 11, 2002, ISBN: 9780871707048.

Course Code	**MM 665**
Title of the Course	**Surface Engineering of Metallic Materials**
Contact Hours	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
Course Syllabus	Introduction to surface engineering, Need for engineered surface. Definition and principles of conventional surface hardening methods. Surface hardening methods involving no change in the chemical composition of the surface and methods involving change in chemical composition of the surface. 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) Application of advanced techniques such as ion and electron beam towards creating new engineered surface. Advanced and high quality surface modification processes- chemical vapor deposition (CVD), physical vapor deposition (PVD). Effect of process variables to obtain high quality surface modification. Evaluation of mechanical properties of coatings and surface modified components Recent trends in surface engineering for components in structural and engineering applications – case studies
Suggested books	1. P. Martin, **Introduction to Surface Engineering and Functionally Engineered Materials**, John Wiley & Sons, 2011, ISBN: 9780470639276. 2. T. Burakowski, T. Wierzchon, **Surface Engineering of Metals**, CRC Press,1998, ISBN: 9780849382253. 3. H. Dong, **Surface Engineering of Light Alloys**, Woodhead Publishing, 2010, ISBN: 9781845695378. 4. J. Takadoum, **Materials and Surface Engineering in Tribology**, John Wiley & Sons, 2007,ISBN: 9781848210677.

Course Code	**MM 667**
Title of the Course	**Advanced Composites**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	The course covers the advanced topics pertaining to the processing of various composites and the mechanics associated with them.
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
Suggested Books	1. **Composites**, Engineered Materials Handbook, Vol.1, ASM International, Ohio, 1988, ISBN-10: 0871702797. 2. K.K. Chawla, **Composite Materials Science & Engineering**, Springer-Verlag, New York, 1987, ISBN: 9781475729665. 3. F.L. Matthews, R.D. Rawlings, **Composite Materials: Engineering and Science**, Chapman & Hall, London, 1994, ISBN: 9781855734739. 4. **Structure and Properties of Composites, Materials Science and Technology**, Vol.13, Wiley-VCH, Germany, 1993, ISBN 3:527268316.

Course Code	**MM 669**
Title of the Course	**Crystallographic Texture in Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Advanced structural and Mechanical Metallurgy
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.
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.
Suggested Books	1. U. F. Kocks, C. Tomé, H.-R. Wenk(Eds.),**Texture and Anisotropy,** Cambridge University Press, UK, 1998, ISBN-10: 052179420X. 2. V. Randle, O. Engler, **Texture Analysis: Macrotexture, Microtexture& Orientation Mapping**, Gordon & Breach, AM.S.terdam, Holland, 2000, ISBN: 9056992244. 3. M. Hatherly, W.B. Hutchinson, **An Introduction to Textures in Metals**, 1979, ISBN:0901462055.

Course Code	**MM 671**
Title of the Course	**Dynamic Behavior of Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Advanced structural and Mechanical Metallurgy
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.
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.
Suggested Books	1. M. Andre,J. Meyers, **Dynamic Behaviour of Materials**, Wiley, 1994, ISBN: 9780471582625. 2. W.W. Chen, B. Song, **Split Hopkinson (Kolsky) Bar: Design, Testing and Applications**, Springer, 2011, ISBN: 9781441979827. 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.

Course Code	**MM 673**
Title of the Course	**Science of Ceramics**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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
Suggested Books	1. M. W. Barsoum ,**Fundamental of Ceramics**, McGraw Hill, 1997, ISBN:9780750309028. 2. D. W. Richerson, **Modern Ceramic Engineering**, Mercel Dekker, 1992, ISBN: 9781574446937. 3. M. N. Rahman, **Ceramic Processing and Sintering**, Mercel Dekker, 2003, ISBN: 9780824709884.

Course code	**MM 674/ MM 474**
Title of the course	**Fluorescence Phenomenon**
Credit Structure	L - T - P - Credits 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 2. J. R. Albani, ***Principles and Applications of Fluorescence Spectroscopy***, Blackwell Publishing, Lowa, USA, 2007, 9781405138918 3. E. Wehry, ***Modern Fluorescence Spectroscopy***, Plenum Press, New York and London, 1976, 9781468425833 4. O. S. Wolfbeis, *Fluorescence Spectroscopy,* New Methods and Applications : Springer-Verlag : Berlin, Heidelberg : 1993 : 9783642773747

Course Code	**MM 675/ MM 475**
Title of the Course	**Advanced Fracture Mechanics**
Contact Hours	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
Course Syllabus	Introduction to Fracture Mechanics, Theory of Elasticity and Plasticity, Mohr's circle, equivalent stress, stress tensors. 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. Linear elastic fracture mechanics, elastic plastic fracture mechanics, fracture toughness and test methods, J-integral, R-Curve, CTOD. 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. Creep of materials, mechanisms of creep, creep curve, deformation mechanism maps, and basic equations governing creep. Creep-fatigue interaction, Damage tolerant design.
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.** 2. G. E. Dieter, **Mechanical Metallurgy**, 3rd Edition, McGraw-Hill, 2017, ISBN: 0071004068. 3. **T. L. Anderson, Fracture Mechanics: Fundamentals and Applications**, 4th Edition, CRC Press, 2017, ISBN-10: 1498728138. 4. **R. J. Sanford,** Principles of Fracture Mechanics**, 1st Edition, Pearson, 2002,** ISBN-10: 0130929921.

Course code	**MM 676**
Title of the course	**Advance Computational Methods for Materials**
Credit Structure	L - T - P - Credits 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 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 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 4. C. Kittle, ***Introduction to Solid State Physics***, Wiley, 8th edition, 2012, 978-8126535187

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Course Code	**MM 677/ MM 477**
Title of the Course	**High Temperature Deformation of Materials**
Contact Hours	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course provides basic understanding of d the various deformation mechanisms that take place under given stress and temperature.
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.
Suggested books	1. W. D. Callister, **Materials Science and Engineering: An Introduction**, 7th Edition, John Wiley & Sons, 2014, ISBN: 9781118324578. 2. J. S Zhang, **High Temperature Deformation and Fracture of Materials**, 1st Edition, Elsevier,2010, ISBN: 9780857090805. 3. M. A. Meyers, K. K. Chawla, **Mechanical Behavior of Materials**, Cambridge University Press, 1999, ISBN: 9780521866750. 4. G. E Dieter, **Mechanical Metallurgy**, 1st Edition, McGraw Hill Education, 1976, ISBN: 9780070168916.

Course Code	**MM 679 / MM 479**
Title of the Course	**Fundamentals and Engineering of Solar Energy Devices**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Discipline of Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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. **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* η*,* 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. **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. Over view of potential hazards, Solar energy storage/utilization (*Batteries, Supercapacitor, Display devices, Emitters, and Generators etc.*), Status and prospective of *PV technology*.
Suggested Books	1. A. McEvoy, T. Markvart, L. Castaner, **Solar Cells: Materials, Manufacture and Operation,** 2nd Edition, Elsevier, 2013, ISBN: 9780080993799. 2. T. Soga, **Nanostructured Materials for Solar Energy Conversion**, Elsevier, 2006, ISBN: 9780444528445. 3. D. Yogi Goswami, **Principles of Solar Engineering,** 3rd Edition, CRC Press, 2015, ISBN: 9781466563780. 4. A. L. Fahrenbruch, R. Bube, **Fundamentals of Solar Cells**, Elsevier, 1983, ISBN: 9780323145381. 5. C. J. Chen, **Physics of Solar Energy,** John Wiley & Sons, Inc., 2011, ISBN: 9780470647806. 6. P. Wurfel, **Physics of Solar Cells: From Basic Principles to Advanced Concepts,** 2nd Edition, Wiley-VCH, 2005, ISBN:9783527408573. 7. L Fraas, L. Partain, **Solar Cells & Their Applications,** 2nd Edition, John Wiley & Sons, 2010, ISBN: 9780470446331.

	8. M. A. Green, **Third Generation Photovoltaics: Advanced Solar Energy Conversion**, Springer, 2005, ISBN: 9783540265634.

Course code	MM 681/ MM 481
Title of the course	**High Pressure Materials Processing**
Credit Structure	L - T - P - Credits 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 2. K. D. Timmerheld, ***High-Pressure Science and Technology***, Springer, Berlin, Germany, 1979, 9780306400698 3. M. I. Eremets, ***High Pressure Experimental Methods***, Oxford University Press, United Kingdom, 1996, 9780198562696 4. R. V. Eldic and F. G. Kramer, ***High Pressure Chemistry, Synthetic, Mechanistic, and Supercritical Applications***, Wiley, New York, 2002, 9783527612635

Course Code	**MM 683/ MM 483**
Title of the Course	**Analysis and Modelling of Welding**
Contact Hours	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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. Introduction to micro-segregation, Solute redistribution, Microscale, Microstructure evolution. Solute transfer at Macroscale. Defects in fusion welds, Effects of dilution, Weld Cladding. Distortion in welding, Dissimilar welding, Solutions to Dissimilar welding. Numerical solutions to thermal field and fluid flow in welding.
Suggested books	1. S. Kou, **Welding Metallurgy**, 2nd Edition, John Wiley & Sons, 2002, ISBN: 9780471434917. 2. R. W. Messler, **Principles of Welding: Processes, Physics, Chemistry and Metallurgy**, Wiley-VCH, 1999, ISBN-13:978-0471253761. 3. J. F. Lancaster, **Metallurgy of Welding**, Abington Publishing, England, 1999, ISBN: 1855734281. 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. 5. S. V. Patankar, **Numerical Heat Transfer and Fluid Flow**, McGraw-Hill Book Company, New York,1980, ISBN: 0070487405.

Course Code	**MM 685/ MM 485**
Title of the Course	**Materials Degradation**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
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.
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.
Suggested Books	1. ASM committee, **ASM Handbook on Corrosion,**9th Edition, Vol 13, 1992, ISBN: 9780871707079. 2. J. R. David, **Corrosion: understanding the basics,** ASM international, Materials Park, Ohio, 2000,ISBN-10: 0824799178. 3. A. M. El-Sherik, **Trends in Oil and Gas Corrosion Research and Technologies,** Woodhead Publishing. 2017, ISBN: 9780081011058.

Course code	MM 686/ MM 486
Title of the course	**Applied Photoelectrochemistry**
Credit Structure	L - T - P - Credits 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. 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. 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. 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 2. Yurii Pleskov, ***Semiconductor Photoelectrochemistry***, Springer, New York, USA, 2012, 9781468490800 3. Mary D Archer and Arthur J Nozik, ***Nanostructured and Photoelectrochemical Systems for Solar Photon Conversion***, World Scientific, London, 2008, 10 1860942555 4. R. Krol and M. Grätzel, ***Photoelectrochemical Hydrogen Production***, Springer, USA, 2011, 9781461413806

Course code	MM 688/ MM 488
Title	**Electroceramics**
Credit Structure	L - T - P – Credits 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 2. L. L. Hench and J. K. West, ***Principles of Electronic Ceramics***, Wiley-Interscience, New Jersey, United States, 1990, 978-0471618218 3. A. J. Moulson and J. M. Herbert, ***Electroceramics , Materials, Properties, Applications***, John Wiley & Sons, West Sussex, England, 2003, 978-0470864975 4. Anthony R. West, ***Solid State Chemistry and its Applications,***2nd Edition, Wiley, New Delhi, India, 2014, 978-1119942948 5. Nava Setter (editor), ***Electroceramic***-Based MEM.S., Springer US, 2005, ISBN: 978-1441936042

Course Code	**MM 730/ MM 430**
Title of the Course	**Two Dimensional Materials and Electronic Devices**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre-requisite, if any	Basic knowledge in nanomaterials fabrication, characterization, devices integration and electronic devices.
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.
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.
Suggested Books	1. M. Aliofkhazraei, and N. Ali, *Two-Dimensional Nanostructures,* CRC Press, 2012, ISBN:9781439866658 2. J.H. Warner, F. Schaffel, M. H. Rummeli and A. Bachmatiuk, *Graphene : Fundamentals and Emergent Applications*, Elsevier,2013, ISBN: 9780123945938 3. V. Skakalova, A. B. Kaiser, *Graphene: Properties, Preparation, Characterisation and Devices,* Woodhead Publishing, 2014, ISBN: 9780857095084 4. F. Iacopi, J. J. Boeckl and C. Jagadish; *2D Materials*, Academic Press, 2016, ISBN:9780128043370 5. Kolobov, Alexander V., Tominaga, Junji, *Two-Dimensional Transition-Metal Dichalcogenides* , Springer, 2016, ISBN: 9783319314501 6. M. Raghu, *Graphene Nanoelectronics: from Materials to Circuits*, Springer, 2012, ISBN: 9781461405481 7. M. Houssa, A. Dimoulas and A. Molle, *2D Materials for Nanoelectronics,* CRC Press , 2016, ISBN: 9781498704175

Course Code	**MSE 601**
Title of the Course	**Surface Science and Engineering**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards science and surface engineering
Course Syllabus	Concept of Surfaces, surface reactions, interaction, surface energy, surface tension, surface diffusion. Design of surface layers based on mathematical modeling, rational application of surface layers. 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 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. Stereometric-physico-chemical parameters types of surface degradation. surface modification techniques conventional methods of surface property alteration, functional coatings, advanced methods – basic principles,
Suggested Books	1. G. Cao, Y. Wang, **Nanostructure and Nano materials, synthesis, properties and applications**, World scientific Publishing Co., 2011, ISBN:978-9814324557. 2. Bhusan, **The Handbook on Nanotechnology,** Springer series, ISBN: 978-3-540-29855-7. 3. R. Kelsall, I. W. Hamley and M. Geoghegan, **NanoScale Science and Technology,** ISBN :9780470850862. **4.** L. Chi, **Nano Technology-Volume 8: Nanostructured Surfaces**, Wiley Publication, ISBN:9783527317394. **5.** R. K. Leach, **Fundamental Principles of Engineering Nanometrology**, Elesevier publication, ISBN 978-0-08-096454-6.

Course Code	MSE 605
Course Title	**Computational Techniques in Materials Engineering**
Credit Structure	L-T-P-Credit 3-1-0-4
Name of the Concerned Discipline	Material Science and Engineering
Pre-requisite, if any	Nil
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.
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. **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 **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.
Suggested Books	▪ K. E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989. ▪ Numerical Methods for Engineers, Steven Chapra and Raymond Canale, McGraw-Hill, 6thedition. ▪ S D Conte and C. De Boor, Elementary Numerical Analysis: An Algorithmic Approach, McGraw Hill 1980. ▪ J. Stoer and R. Bulirsch, Introduction to Numerical Analysis, 2nd ed., Texts in Applied Mathematics, Vol. 12, Springer Verlag, New York, 1993. ▪ D. C. Montgomery and G. C. Runger, "Applied Statistics and Probability for Engineers", 3rd ed., John Wiley & Sons Inc, ISBN 0-471-20454-4. ▪ J. W. Barnes, "Statistical Analysis for Engineers and Scientists", McGRAW-HILL, Inc., 2001 ▪ W.A. Strauss, "Partial Differential equation: An Intrduction", Wiley Publications, Inc., 2007 ▪ J. G. Lee, "Computational Materials Science: An Introduction" CRC Press, Taylor and Francis group, 2012. ▪ M. K. Jain, S. R. K. Iyengar and R. K. Jain, "Numerical Methods" (for scientific and engineering computation), New Age International, sixth edition.

	▪ S. S. Rao, "Finite Element Method in Engineering", Elsevier, 2004.

Course Code	**MSE 610**
Title of the Course	**Design of Materials for Surface Protection and Corrosion Control**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards design and protection of structures towards corrosion
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.
Suggested Books	1. Fontana, G. Mars, Greene and D. Norbert, **Corrosion Engineering**, McGraw-Hill, New York, 1967, ISBN: 978-0070214637. 2. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, Edited, ISBN: 0-87170-705-5. 3. M. Cartier, **Handbook of Surface Treatment and Coatings,** Tribology in Practice S. (Hardback), ISBN-13: 9781860583759 ISBN-10: 186058375X. 4. J. Baghdachi, T. Provder, **Smart Coatings: Vol-2,** ACS Symposium (Hardback), ISBN-13: 9780841272187, ISBN-10: 0841272182. 5. G. Franz, **Low Pressure Plasmas and Microstructuring Technology** (Hardback), ISBN-13: 9783540858485, ISBN-10: 3540858482

Course Code	**MSE 612**
Title of the Course	**High Temperature Corrosion-Resistant Materials and Coatings**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards design and protection of structures towards high temperature corrosion
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.
Suggested Books	1. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, ISBN: 0-87170-705-5. 2. M. Cartier, **Handbook of Surface Treatment and Coatings,** Tribology in Practice S., (Hardback), ISBN-13: 9781860583759, ISBN: 186058375X. 3. A. S. Khanna, **Introduction to High Temperature Corrosion**, ASM Publication, 2002, ISBN: 978-0871707628. 4. A. A. Tracton, **Coatings Technology: Fundamentals, Testing, and Processing Techniques** (Hardback) CRC Press Inc., ISBN: 9781420044065. 5. A. A. Tracton, **Coatings Materials and Surface Coatings** (Hardback), CRC Press ISBN: 9781420044041.

Course Code	**MSE 614**
Title of the Course	**Corrosion-Resistant Paints and Coatings**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards coatings on resistance against corrosion
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.
Suggested Books	1. A. S. Khanna, **High Performance organic Coatings**, CRC, Woodhead Publications, 2008, ISBN 978-1-84569-265-0. 2. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, Edited, ISBN: 0-87170-705-5. 3. M. Cartier, **Handbook of Surface Treatment and Coatings,** Tribology in Practice S. (Hardback), ISBN-13: 9781860583759, ISBN-10: 186058375X. 4. J. Baghdachi, T. Provder, **Smart Coatings Vol.2,** ACS Symposium (Hardback), ISBN-13: 9780841272187, ISBN-10: 0841272182.

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Course Code	**MSE 616**
Title of the Course	**Wear, Friction and Abrasion of Surfaces**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards tribology and wear
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.
Suggested Books	1 M. Cartier, **Handbook of Surface Treatment and Coatings**, Tribology in Practice S. (Hardback), ISBN: 9781860583759. 2. G. Franz, **Low Pressure Plasmas and Microstructuring Technology**, Hardback, ISBN 13: 9783540858485, ISBN: 3540858482. 3. V. Raghavan, **Materials Science and Engineering**, PHI Learning Private Limited, New Delhi, 2009, ISBN: 8120324552. 4. W. D. Callister, **Materials Science and Engineering**, Wiley India (P) Ltd. , ISBN: 9788126510764.

Course Code	**MSE 618**
Title of the Course	**Corrosion in Oil and Gas Industries**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards suitable application of corrosion
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. 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.
Suggested Books	1. A. S. Khanna, **Introduction to High Temperature Corrosion**, ASM Publication, 2002, ISBN: 978-0871707628. 2. Evans, R. Ulick, **An Introduction to Metallic Corrosion**, Edward Arnold, London, UK, 1948, ISBN: 9780713120530. 3. Fontana, G. Mars, Greene and D. Norbert, **Corrosion Engineering**, McGraw-Hill, New York, 1967, ISBN: 0070214611. 4. D. Stephen, Cramer, S. Bernard and Jr. Covino, **ASM Corrosion Fundamentals and Testing**, ASM International, Edited, ISBN: 0-87170-705-5.

Course Code	**MSE 620**
Title of the Course	**Modeling and Management of Corrosion**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards modeling of corrosion
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 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.
Suggested Books	1. R. A. Adey, Modelling of Cathodic Protection Systems (Advances in Boundary Elements), ISBN-10: 1853128899, ISBN-13: 9781853128899. 2. A. S. Khanna, High Performance Organic Coatings, CRC, Woodhead Publications, 2008, ISBN: 978-1-84569-265-0. 3. A. S. Khanna, Introduction to High Temperature Corrosion, ASM Publication, 2002, ISBN: 978-0871707628. 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) 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.

Course Code	**MSE 641**
Title of the Course	**High Temperature Oxidation and Corrosion**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To expose students towards high temperature corrosion
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.
Suggested Books	A. S. Khanna, Introduction to High Temperature Corrosion, ASM Publication, 2002, ISBN: 978-0871707628. Evans, R. Ulick, An Introduction to Metallic Corrosion, Edward Arnold, London, UK, 1948, ISBN: 9780713127584. Fontana, G. Mars, Greene and D. Norbert, **Corrosion Engineering**, McGraw-Hill, New York, 1967, ISBN: 978-0070214637. D. Stephen, Cramer, S. Bernard and Jr. Covino, ASM Corrosion Fundamentals and Testing, ASM International, Edited, ISBN: 0-87170-705-5.

Course Code	**MSE 698**
Title of the Course	**PG Seminar Course**
Credit Structure	L-T-P-Credits 0-2-0-2
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
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.
Textbook	None
Other references	Books and research publications in various relevant journals/conference proceeding, etc.

Course Code	**MSE 724**
Course Title	**Thin FilM.S. and Devices Fabrication**
Credit structure	L-T- P-Credits 2-1-2-4
Name of the Concerned Discipline	Materials Science and Engineering
Pre–requisite, if any	None
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.
Course Syllabus	**Introduction and Overview:** Basic Physics, Chemistry and Materials science **Steps in thin film formation:** Thermal accommodation, binding, surface diffusion, nucleation, island growth, coalescence, *etc.* **Thin Controlling Parameters:** Environment, Temperature, Concentration, *etc.* **Film Deposition:** Vacuum and kinetic theory of gasses, Evaporation, Sputtered deposition, Cathodic Arc Deposition, Ion Beam, Molecular Beam, Wet chemical, Electrochemical, Hydrothermal, *etc.* **Thin Film Characterization:** Imaging techniques, structural technique, chemical technique, optical technique, electrical/magnetic technique, mechanical technique. **Chemical Mechanical Polishing/Planarization (CMP):** Chemical process and Mechanical process, Working principals, Usage in semiconductor fabrication, Limitations of CMP, Applications, *etc*. **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. **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.*

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Suggested Books	1) L I. Maissel and R. Glang, **Handbook of Thin Film Technology,** McGraw-Hill, 1970. 2) M. Ohring, **Materials Science of Thin FilM.S.**, Academic Press (2nd Edition) 2001, ISBN-13:978-0125249751. 3) J. L. Vossen and W. Kern, **Thin Film Processes,** Academic Press (January 11, 1979) ISBN-13:978-0127282503. **4) M. H. Francombe, Handbook of Thin Film Devices,** Academic Press (Volume-I-V) 2000, ISBN:978-0122653209. 5) Z. Cao, **Thin Film Growth: Physics, Materials Science and Applications,** Woodhead Publishing; 1 edition (August 1, 2011) ISBN-13: 978-1845697365. 6) F. C. Matacotta and G. Ottaviani**, Science and Technology of Thin FilM.S.,** World Scientific Publishing Co. 1995, ISBN: 978-9810221935. 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

Course Code	**MSE 725**
Course Title	**Single Crystal Growth Techniques**
Credit structure	L-T- P-Credits 2-1-2-4
Name of the Concerned Discipline	Centre for Materials Science and Engineering
Pre–requisite, if any	None
Scope of the Course	To provide basic knowledge about importance of materials synthesis and growth of single crystals to students.
Course Syllabus	Crystal growth from solids: nucleation and crystallization, e.g. in metals and glass ceramics. 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*.
Suggested Books	1) G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer Handbook of Crystal Growth, 2010, ISBN: 9783540747611. 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. 3) H. K. Henisch, Crystal Growth in Gels, Courier Dover Publications, 1996, ISBN: 9780486689159 4) A. Holden and P. Morrison, **Crystals and Crystal Growig, MIT Press, 1982, ISBN:** 9780262580502. 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.

Course Code	**MSE 797 (Autumn Semester)** **MSE 798 (Spring Semester)**
Title of the Course	Ph.D. Seminar Course
Credit Structure	L-T-P-Credits 0-2-0-2
Name of the Concerned Discipline	Materials Science 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 journals