Indian Institute of Technology Indore

Course Structure
of
PG and Ph.D. Program in Mathematics
and
Syllabi of Courses (AY 2015-16)

April 2026

[After incorporating decisions of the 62nd meeting of the Senate held on April 20, 2026]

Curriculum for M.Sc. and M.Sc. + Ph.D. dual degree Program in Mathematics from AY 2015-16 to AY 2024-25

Minimum Education Qualification (MEQ): Bachelor's degree with Mathematics as a subject for at least two years/four semesters.

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

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

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

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

Course Structure for 2-Year Full-time M.Sc. (Mathematics) Program
1st Year: Semester-I

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 611	Analysis-I	3-1-0	4
MA 621	Ordinary Differential Equations	2-1-0	3
MA 641	Linear Algebra	3-1-0	4
MA 673	Fundamentals of Discrete Mathematics	2-1-0	3
MA 675 / ME 675	Probability and Statistical Methods	2-0-2	3
		Total minimum credits during the semester	**17**
Additional Course (as per requirement basis)			
HS 641	English Communication Skills	2-0-2	PP/NP

1st Year: Semester-II

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 610	Complex Analysis	3-1-0	4
MA 612	Analysis-II	3-1-0	4
MA 620	Partial Differential Equations	2-1-0	3
MA 640	Algebra-I	3-1-0	4
MA 680	Computational Techniques	3-0-2	4
		Total minimum credits during the semester	**19**

2nd Year: Semester-III

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 603	Topology-I	3-1-0	4
MA 631	Functional Analysis	3-1-0	4
MA 643	Algebra-II	2-1-0	3
MA 651	Numerical Analysis	2-1-0	3
MA 671 / ME 671 / ME 471	Operations Research	2-0-2	3
MA 799 **OR** ZZ xxx	M.Sc. Research Project (Stage-1) **OR one Elective course in lieu** [Elective-I]	0-0-6 **OR** x-x-x	3
Total minimum credits during the semester			**20**

2nd Year: Semester-IV

Course Code	Course Title	Contact Hours (L-T-P)	Credits
ZZ xxx	Elective I **OR** [Elective II]	x-x-x	3
ZZ xxx	Elective II **OR** [Elective III]	x-x-x	3
MA 800 **OR** ZZ xxx ZZ xxx ZZ xxx	M.Sc. Research Project (Stage-2) **OR** Three elective courses [i.e. Electives IV-VI]	0-0-18 **OR** x-x-x x-x-x x-x-x	9
Total minimum credits during the semester			**15**
Total minimum credits during the program			**71**

@ In addition to this course list, a student can also opt from the PG courses being offered by the other disciplines. An M.Sc. student can also choose elective courses from Ph.D. course curriculum of Mathematics except the courses MA 741: Algebra, MA 711: Analysis, MA 720: Differential Equations, MA 703: Topics in Analysis.

NOTE:

1. During the second semester, students will choose their research project guide(s) and continue their research project work in the third and fourth semesters.

2. Students will submit a dissertation after the completion of their research project work as per the time schedule mentioned in the PG course curriculum.

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

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

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

Curriculum for M.Sc. and M.Sc. + Ph.D. dual degree Program in Mathematics
(From AY 2025-26 onwards)

Minimum Education Qualification (MEQ): Bachelor's degree with Mathematics as a subject for at least two years/four semesters.

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

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

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

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

1st Year: Semester I

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 611N	Analysis-I	2-1-0	3
MA 613	Algebra-I	2-1-0	3
MA 641N	Linear Algebra	2-1-0	3
MA 619	Probability and Statistics	2-0-2	3
MA 607	Fundamentals of Operations Research	2-0-2	3
MA 609	Object Oriented Programming	1-0-2	2
Total minimum credits during the semester			17
Additional Course (as per the requirement basis)			
HS 641	English Communication	2-0-2	PP/NP

1st Year: Semester-II

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 610N	Complex Analysis	2-1-0	3
MA 621	Ordinary Differential Equations	2-1-0	3
MA 651N	Numerical Analysis	2-0-2	3
MA 618	Point Set Topology	2-1-0	3
MA 628	Basics of Data Structures and Algorithms	1-0-2	2
MA 6XX	Department Elective I	2-1-0	3
Total minimum credits during the semester			17

2nd Year: Semester-III

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 615	Partial Differential Equations	2-1-0	3
MA 617	Functional Analysis	2-1-0	3
MA 6XX	Department Elective II	X-X-X	3
MA 6XX	Department Elective III	X-X-X	3
ZZ XXX	Institute Elective I	X-X-X	3
MA 6XX	Flexicore I	X-X-X	3/2 (Half Semester)
MA 799	M.Sc. Project (Stage-I)	0-0-6	3
Total minimum credits during the semester			19.5

2nd Year: Semester-IV

Course Code	Course Title	Contact Hours (L-T-P)	Credits
MA 6XX	Department Elective IV	X-X-X	3
ZZ XXX	Institute Elective II	X-X-X	3

MA 6XX	Flexicore II	X-X-X	1.5 (3/2 Half Semester)
MA 800	M.Sc. Project (Stage-II)	0-0-18	9
		Total minimum credits during the semester	16.5

Courses from Discipline of Mathematics for the PG students in Mathematics @:

MA 623 Measure Theory
MA 652/ MA 452: Theory of Transforms
MA 654/ MA 454: Mathematical Modeling and Simulations
MA 656/ MA 456: Stochastic Approximation
MA 714: Advanced Complex Analysis
MA 734: Fourier Analysis on Euclidean Spaces
MA 736: Wavelet Analysis
MA 742: Commutative Algebra
MA 780: Mathematical Logic
MA 782: Theory of Computations
MA 422/ MA 622: Hyperbolic Geometry
MA 424/ MA 624: Algebraic Number Theory
MA 426/ MA 626: Theory of Modular Forms
MA 625 : Multivariable Calculus (2-1-0-1.5) (3/2 half semester)
MA 627 Fractal Geometry (2-1-0-1.5) (3/2 half semester)
MA 630 Basic Algebraic Topology (2-1-0-3)
MA 432/ MA 632 Introduction to Commutative Algebra (2-1-0-3)
MA 434/ MA 634 Introduction to Modal Logic and Applications (2-1-0-3)

Course Structure for Ph.D. program in Mathematics (during AY 2010-11 to 2012-13)

(A) Semester-I (Autumn / Spring)

Sr. No.	Course code	Course Title	L-T-P-Credits
1	MA 601	Topology	2-1-0-3
2	MA 703	Topics in Analysis	2-1-0-3
3	ZZ xxx	Elective-I	2-1-0-3
4	MA 797 */ MA 798*	Seminar Course	0-2-0-2

(B) Semester-II (Spring / Autumn)

Sr. No.	Course code	Course Title	L-T-P-Credits
1	MA 702	Conformal Mappings	2-1-0-3
2	MA 704	Probability Theory	2-1-0-3
3	MA 706	Numerical Linear Algebra	2-1-0-3
4	ZZ xxx	Elective-II	x-x-x-3
5	MA 798 * / MA 797*	Seminar Course ()	0-2-0-2

Mathematics course for the Elective-I and Elective-II *(in addition these courses students can take courses from the other disciplines / School)*

S.No.	Course Code	Course Title	L-T-P-Credits
1	MA 701	Experimental Designs and Data Analysis	2-1-0-3
2	MA 705	Applied Operator Theory	2-1-0-3
3	MA 707	Special Functions	2-1-0-3
4	MA 708	Ergodic Theory	2-1-0-3
5	MA 709	Advance Numerical Methods for Linear Control Systems	2-1-0-3
6	MA 710	Fractional Differential Equations	2-1-0-3
7	MA 712	Advanced Analysis	2-1-0-3

Note: M.Tech./MPhil qualified candidates have to do one semester coursework (with 2-3 PG level courses) while M.Sc./B.Tech./BE qualified candidates have to do two semester course work (with minimum 5 PG level courses).

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

Course Structure for Ph.D. program in Mathematics (for AY 2013-14)

(A) Semester-I (Autumn / Spring)

Sr. No.	Course Code	Course Title	L-T-P-Credits
1	MA 711	Analysis	2-1-0-3
2	MA 741	Algebra	2-1-0-3
3	ZZ XXX	Elective – I	x-x-x-3
4	MA 798* / MA 797*	Ph.D. Seminar Course	0-2-0-2

(B) Semester-II (Spring / Autumn)

Sr. No.	Course Code	Course Title	L-T-P-Credits
1	MA 720	Differential Equations	2-1-0-3
2	ZZ XXX	Elective – II	x-x-x-3
3	MA 798* / MA 797*	Ph.D. Seminar Course	0-2-0-2

Mathematics course for the Elective I-II
(In addition to these elective courses, students can take elective courses from other Disciplines also).

S. No.	Course Code	Course Title	L-T-P-Credits
1.	MA 601	Topology	2-1-0-3
2.	MA 701	Experimental Designs and Data Analysis	2-1-0-3
3.	MA 702	Conformal Mappings	2-1-0-3
4.	MA 703	Topics in Analysis	2-1-0-3
5.	MA 704	Probability Theory	2-1-0-3
6.	MA 705	Applied Operator Theory	2-1-0-3
7.	MA 706	Numerical Linear Algebra	2-1-0-3
8.	MA 707	Special Functions	2-1-0-3
9.	MA 708	Ergodic Theory	2-1-0-3
10.	MA 709	Advance Numerical Methods for Linear Control Systems	2-1-0-3
11.	MA 710	Fractional Differential Equations	2-1-0-3
12.	MA 712	Advanced Analysis	2-1-0-3

NOTE:

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

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

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Course Structure for Ph.D. program in Mathematics (from AY 2014-15)

(A) Semester I (Autumn / Spring)

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

(B) Semester-II (Spring / Autumn)

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

NOTE:

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

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

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

Mathematics courses for Electives I-VI

(In addition to these elective courses, students can take elective courses from other Disciplines also).

S. No.	Course Code	Course Title	L-T-P-Credits
1.	MA 601	Topology	2-1-0-3
2.	MA 605/ MA 405	Differential Equations in Population Dynamics	2-0-2-3
3.	MA 652/ MA 452	Theory of Transforms	2-1-0-3
4.	MA 653	Ramanujan's Mathematics	2-1-0-3
5.	MA 654/ MA 454	Mathematical Modeling and Simulations	2-1-0-3
6.	MA 701	Experimental Designs and Data Analysis	2-1-0-3
7.	MA 702	Conformal Mappings	2-1-0-3
8.	MA 703	Topics in Analysis	2-1-0-3
9.	MA 704	Probability Theory	2-1-0-3
10.	MA 705	Applied Operator Theory	2-1-0-3
11.	MA 706	Numerical Linear Algebra	2-1-0-3
12.	MA 707	Special Functions	2-1-0-3
13.	MA 708	Ergodic Theory	2-1-0-3
14.	MA 709	Advance Numerical Methods for Linear Control Systems	2-1-0-3
15.	MA 710	Fractional Differential Equations	2-1-0-3
16.	MA 711	Analysis	2-1-0-3
17.	MA 712	Advanced Analysis	2-1-0-3
18.	MA 715	Analytic Number Theory	2-1-0-3
19.	MA 720	Differential Equations	2-1-0-3
20.	MA 741	Algebra	2-1-0-3

Course Code	**MA 601**
Title of the Course	**Topology**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	An M. Sc. Level course in real and complex analysis
Scope of the course	
Course Syllabus	**Overview of General Topology:** Topological spaces, separation axioms, products, metrisation, function spaces, uniform spaces, topological groups **Overview of Algebraic Topology:** Paths, homotopy, fundamental group, category theory, chain complexes, homology and cohomology, simplicial and singular homology and cohomology, applications, cup product **Overview of Differential Topology:** Differentiable manifolds, tangent spaces, embeddings, differential forms, deRham cohomology
Suggested Books	1. James R. Munkres, Topology, Second Edition,Prentice Hall, 2000 2. James R. Munkres, Elements of Algebraic Topology,Addison-Wesley, 3. Edwin H. Spanier, Algebraic Topology, Springer, 1994 4. Marvin J. Greenberg and John R. Harper, Algebraic Topology – A First Course, Benjamin/Cummings, 1981 5. Victor Guillemin and Alan Pollack, Differential Topology, Prentice-Hall, 1974 6. John Milnor, Topology from the Differential Viewpoint, Princeto University Press, 1997 7. D. B. Fuks and V. A. Rokhlin, Beginner's course in Topology, Springer-Verlag 1984

Course Code	**MA 402/ 602**
Title of the Course	**Industrial Statistics**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	Understanding the concepts of quality control and system reliability techniques.
Course Outcomes	Techniques to apply these concepts in industrial problems such as pharma, automotive industry, etc.
Course Syllabus	• **Statistical Quality Control:** Product quality, need for quality control, the basic concept of process control, process capability and product control, theory of control charts, operation and uses of control charts, probability limits, specification limits, tolerance limits, 3-sigma limits, and warning limits, control charts for variables and attributes, modified control charts, acceptance sampling plans for attributes inspection, single and double sampling plans and their properties, and plans for inspection by variables for one-sided and two-sided specification. • **Reliability Theory:** Reliability concepts and measures, components and systems, coherent systems, reliability of coherent systems, life distributions, reliability function, hazard rate, mean residual life and mean time to failure, notions of ageing: IFR, IFRA, DMRL, NBU, and NBUE classes and their duals, reliability modellings in series/parallel systems and k-out-of-n systems.
Suggested Books	Text Books: 1. D. C. Montgomery, ***Introduction to Statistical Quality Control***, Seventh edition, Wiley, 2019, ISBN: 9781119399308. 2. J. Navarro, ***Introduction to System Reliability Theory***, Springer, 2022, ISBN: 9783030869526. Reference Books: 3. A. J. Duncan, ***Quality Control and Industrial Statistics***, Irwin, Homewood, 1986, ISBN: 9780256035353. 4. C. D. Lai, and M. Xie, ***Stochastic Ageing and Dependence for Reliability***. Springer, 2006, ISBN: 0387297421.

Course Code	**MA 603**
Title of the Course	**Topology-I**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Analysis-I
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in point set topology, countability, connected space, metrization theorem.
Course Syllabus	Topological spaces, Basis for a topology, The order topology, Subspace topology, Closed sets. Countability axioms, Limit points, Convergence of nets in topological spaces, Continuous functions, The product topology, Metric topology, Quotient topology. Connected spaces, Connected sets in R, Components and path components, Compact spaces, Compactness in metric spaces, Local compactness, One point compactification. Separation axioms, Uryshon's lemma, Uryshon's metrization theorem, Tietz extension theorem, The Tychonoff theorem, Completely regular spaces, Stone - Czech compactification.
Suggested Books	1. J. Munkres, *Topology* (2nd Edition), Prentice Hall, 2000. 2. J. Dugundji, *Topology*, Allyn and Bacon, Inc., 1966. 3. K. Janich., *Topology*, Springer, 1984. 4. M. A. Armstrong, *Basic Topology,* Springer, 1983. 5. K. D. Joshi, *Introduction to General Topology*, New Age International, 1983. 6. J. L. Kelley, *General Topology*, Springer, 1975. 7. C. D. Aliprantis and O. Burkinshaw, *Principles of Real Analysis* (3rd Edition), Academic Press, 1998.

Course Code	**MA 404/604**
Title of the Course	**Foundation of Approximation Theory**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite if any	Basic knowledge of calculus, linear algebra
Objective of the Course	This course introduces the basic terms and techniques of approximation theory.
Course Outcomes	Students would be able to understand the concept of approximations of functions by polynomials and trigonometric functions.
Course Syllabus	• **Density theorems:** Approximation of periodic function, Weierstrass Theorem, Stone-Weierstrass Theorem. • **Linear Chebyshev approximation:** Approximation in normed linear space, linear Chebyshev approximation of vector-valued functions, Chebyshev polynomials, strong uniqueness and continuity of metric projection, discrete best approximation, approximation by algebraic polynomials. • **Best approximation in normed linear spaces:** Approximative properties of sets, characterization and duality, continuity of metric projections.
Suggested Books	Text Books: 1. H. N. Mhaskar and D. V. Pai, ***Fundamentals of Approximation Theory***, *CRC Press*, 2007, ISBN: 0849309395. 2. M. J. D. Powell, ***Approximation Theory and Methods***, Cambridge University Press, 1981, ISBN: 0521224721. Reference Books: 3. K. G. Steffens, ***The History of Approximation Theory: From Euler to Bernstein***, Birkhauser, Boston, 2006, ISBN: 0817643532.

Course code	**MA 605/ MA 405**
Title of the course	**Differential Equations in Population Dynamics**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department/ Centre	Mathematics
Prerequisite, if any	Differential Equations and Numerical Methods
Scope of the course	The objective of the course is to present differential equation models arising in population dynamics, physical, mechanical and chemical systems, etc. The course will give an opportunity to apply several mathematical theories, methodologies and computational techniques of differential equations in the aforementioned areas. Current research advances in the field of modelling will also be discussed. After completing the course, students are expected to start research work in advanced topics.
Course Syllabus	**Introduction:** Mathematical models: Necessity, advantages and limitations; Brief history of population models, Different tools and modeling frameworks, Birth and death processes in population models. **Ordinary differential equations:** The Multhus, Verhulst, Lotka-Volterra, Rosenzweiz-MacArthur and Hestings-Powell models, Routh-Hurwitz criteria, Mean population density in cyclic and chaotic dynamics, Population harvesting, Resilience in Ecology, Hydra effects, Population genetic models, FitzHugh-Nagumo model. **Partial differential equations:** Fisher equation, Turing instability, Pattern formation, Spatiotemporal chaos, Reaction-diffusion in Ecological and Chemical systems, Diffusion in delayed predator-prey systems. **Delay differential equations:** Discrete and distributed delays in population dynamics, Hopfbifurcation and stability switching, Delayed harvesting in Nicholson blowflies model, Delayed dispersal in patchy environment, Mackey-Glass equation. **Impulsive differential equations:** Fixed-time and variable-time impulses, Impulses in biological control theory and epidemic models. **Applications of softwares:** Several measures will be quantified in all the models using computer simulations, and graphical representations will be provided to interpret the system dynamics.
Suggested Books	1. J. D. Murray, ***Mathematical Biology: I. An Introduction***, Springer, 2002: ISBN 978-0- 387-95223-9. 2. R. K. Upadhyay, S. R. K. Iyengar, ***Spatial Dynamics and Pattern Formation in Biological Populations***, Chapman and Hall/CRC, 2021: ISBN 9780367555504. 3. K. Gopalsamy, ***Stability and Oscillations in Delay Differential Equations of Population Dynamics***, Springer, 1992: ISBN 978-0-7923-1594-0. 4. V. Lakshmikantham, D. D. Bainov, P. S. Simeonov, ***Theory of Impulsive Differential Equations***, World scientific, 1989: ISBN 978-9971-5-0970-5.

Course Code	**MA 406/606**
Title of the Course	**Graph Theory**
Course Category	Department Elective
Credit Structure	L-T-P- Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of linear algebra
Objective of the Course	This course explores the theoretical development of graph theory and mathematical models based on it.
Course Outcomes	• Solving problems arising from computer science using graphs and trees. • Adapt and demonstrate state-of-the-art algorithms to real-life situations.
Course Syllabus	• Graphs and graph models, graph terminology and special types of graphs, path problems, incidence matrix, adjacency matrix, degree sequence of graphs, graph isomorphism, trees and its characterizations, spanning trees, algorithms for minimum weighted spanning trees, matching, perfect matching, augmenting path, bipartite matching, Hall marriage theorem, matching in general graphs, Tutte's theorem, Min-Max theorems, Konig-Egervary theorem. • Eulerian tour and seven bridges problem, Hamiltonian cycles and travelling salesman problem, necessary conditions for Hamiltonian graphs, sufficient conditions for Hamiltonian graphs, vertex coloring, edge coloring, Brook's theorem, network flows, max-flow min-cut theorem, Ford-Fulkerson algorithm, planar graphs, Euler's Formula, Kuratowski theorem, four color theorem.
Suggested Books	Text Books 1. D. B. West, ***Introduction to Graph Theory***, Pearson Education, 2015, ISBN: 0130144002. 2. J. A. Bondy, U. S. R. Murty, ***Graph Theory with Applications***, Elsevier Science Publishing Co., Inc., 1984, ISBN: 0444194517. Reference Books: 3. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, ***Introduction to Algorithms***, MIT press, 2009, ISBN: 026204630X 4. R. Diestel, ***Graph Theory***, Springer, 2006, ISBN: 3540261834. 5. A. M. Gibbons, ***Algorithmic Graph Theory***, Cambridge University Press, 1985, ISBN: 0521288819.

Course Code	**MA 607**
Title of the Course	**Fundamentals of Operations Research**
Course Category	Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Prerequisite, if any	Basic course in probability and statistics
Scope of the course (Objectives)	The course aims to provide students with a deep understanding of linear programming (LP), including problem formulation, solution methods (simplex, duality), sensitivity analysis, and applications in optimization. It emphasizes theoretical foundations, computational tools, and real-world problem-solving in engineering and data science.
Course Outcomes	Upon completing this course, students will be able to formulate and solve linear programming problems, apply the simplex method, duality theory, and sensitivity analysis, utilize integer programming techniques, and analyze optimization models, including game theory applications in decision-making and strategy.
Course Content	Introduction to Linear Programming: Origin, development, and scope of Linear Programming Problems (LPPs), General methodology of LPP, Applications of LPP in industry, business, and decision-making. Linear Programming Problems: Different types of models, formulation of linear programming problems (LPPs), product-mix problems, deterministic models, graphical methods for solving LPPs. Simplex Method: Standard form and basic feasible solutions, Computational procedure of the simplex algorithm, Big-M and two-phase methods for handling constraints. Special cases: Degeneracy, unbounded, and infeasible solutions, Industrial applications of the simplex technique. Duality and Sensitivity: Concept and formulation of dual problems, Complementary slackness theorem, sensitivity analysis, and Applications of duality in decision-making. Linear Optimization Techniques: Integer Programming Problems (IPPs): formulation and branch-and-bound method. Assignment Problems: mathematical formulation and Hungarian method. Transportation Problems: initial feasible solution and optimization methods (MODI method). Degeneracy in transportation problems and resolution techniques.

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	Game Theory: Introduction to game theory and its applications in business and industry, Min-max criterion and optimal strategies, solution methods for two-person zero-sum games: graphical and algebraic approaches, Game problems as special cases of linear programming. LAB based on the topics covered in this course.
Suggested Books	**Text Books:** 1. H.A. Taha, An Introduction to Operations Research (10th edition), Prentice Hall of India, 2001. ISBN: 9789352865277 2. M. S. Bazaraa, J. J. Jarvis, and H. D. Sherali. Linear programming and network flows (4th edition), John Wiley & Sons, 2011. ISBN: 9780470462720 **Reference Books** 3. F.J. Hillier, G.J. Lieberman, Introduction to Operations Research (7th edition), Holden Day Inc., 2001. ISBN: 9780072535105 4. H.M. Wagner, Principles of Operations Research (2nd edition), Prentice Hall of India, 1980, ISBN: 9788120301627

Course Code	**MA 408/608**
Title of the Course	**Mathematical Theory of Waves**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Differential Equations
Objective of the Course	To expose the students to the basic ideas that underline linear/non-linear wave motion. To derive important mathematical tools to deal with problems of wave theory. To consider simple examples of linear waves on strings, sound waves and water waves.
Course Outcomes	Upon completion of this course, students will know some of the most interesting wave phenomena that have physical significance, while at the same time, they will also be introduced to some of the deeper mathematical issues that are pertaining to wave motion.
Course Syllabus	● Introduction to waves: Classification, terminology, mathematical representation of waves. ● One-dimensional waves in solids and fluids: Waves in a string (free and forced vibrations), waves in a rod, steady-state waves, reflection and transmission of waves, water waves: Surface gravity waves, internal waves, sinusoidal waves on deep water, ripples, wave patterns, Fourier analysis of dispersive systems. ● Two-dimensional and three-dimensional waves: Basics of elasticity, waves in finite, infinite and semi-infinite media, waves in inhomogeneous media, motion of wave packets, dispersion and attenuation, phase velocity, group velocity. Non-linear waves: General effect of nonlinearity, non-linear Schrodinger equation, Riemann invariants, Piston problem, discontinues solutions and shock waves, wave localization phenomena.
Suggested Books	Text Books: 1. C. A. Coulson and Alan Jeffrey, Waves: A Mathematical Approach to the Common Types of Wave Motion, Longman Group Limited, 1977, ISBN: 9780582449541. 2. G. B. Whitham, Linear and Nonlinear Waves, Pure and Applied Mathematics, Wiley-Interscience, 1999, ISBN: 9780471359425. Reference Books: 3. R. Knobel, An Introduction to the Mathematical Theory of Waves, American Mathematical Society, 2000, ISBN: 9780821820391. 4. J. Lighthill, Waves in Fluids, Cambridge Mathematical Library, Cambridge, 2001, ISBN: 9780521010450.

Course Code	**MA 609**
Title of the Course	**Object Oriented Programming**
Course Category	Core
Credit Structure	L-T- P-Credits 1-0-2-2
Name of the Concerned Department	Mathematics
Pre-requisite, if any	NIL
Scope of the course (Objectives)	This course introduces the basics of C++ and its use. It covers flowcharts, and key concepts like classes, objects and inheritance, with practical use of functions, arrays, and pointers in solving mathematical problems.
Course Outcomes	● Understand and apply object-oriented concepts such as classes, objects, inheritance, and polymorphism. ● Write modular and efficient code in C++ using functions, arrays, and pointers. ● Develop structured programs that solve real-world problems using object-oriented principles.
Course Content	**Background of C++ programming basics:** Construction, syntax, variables, constants, data types, input/output, operators, expressions. **Conditional statements:** Loops: for, while, do; Decisions: if, if-else, switch statements, other statements related to looping: break, continue, go to **Structures:** A simple structure, definition, structure variable, accessing structure members, other structure features. **Functions:** Basics concepts, passing arguments to functions, returning values from functions, reference arguments, recursion, function call: call by value, call by reference **Objects and classes:** Basis concepts of creating classes and objects, constructors, destructors, structures and classes. **Arrays:** Array fundamentals, array elements, initializing arrays, multidimensional arrays, passing arrays to functions. **Inheritance and polymorphism:** Derived and base class, public and private inheritance, multiple inheritance, static and dynamic polymorphism. **Pointers:** Basic concepts, pointer variables, pointers and arrays, pointers and functions, pointers to objects, pointers to pointers.

Suggested Books	**Text Books:** 1. R. Lafore, Object-Oriented Programming in C++, Sams (4th edition), 2001. ISBN: 9780672323089 **2. Herbert Schildt, C++: The Complete Reference (4th edition), McGraw Hill Education, 2017. ISBN 978-0070532465** **Reference Books** 3. B. Stroustrup, Programming Principles and Practice Using C++ (2nd edition), Addison Wesley, 2014. ISBN: 9780321992789 4. U. Kirch-Prinz, P. Prinz, A Complete Guide to Programming in C++, Jones & Bartlett Learning, 2001. ISBN: 9780763718176

Course Code	**MA 610**
Title of the Course	**Complex Analysis**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Analysis-I
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Differentiability and analyticity of complex functions, conformal mappings, Complex integration, Classification of singularities and Residue theory.
Course Syllabus	Geometry and topology of the complex plane, Riemann sphere, Limits, Continuity, Differentiability, Analytic functions, Cauchy-Riemann equation, Harmonic functions, Multi-valued functions, Mappings by elementary functions, Sequences and series, Uniform convergence, Radius of convergence of power series, power series as an analytic function. Elementary conformal mappings, Linear fractional transformations, Cross ratio, Inverse Points, Mappings of disks and half-planes, Symmetric Principle. Complex integration, Arcs and closed curves, Line integral, Analytic functions in regions, Length and area, Cauchy's theorem, Index of a point with respect to a closed curve, Cauchy's integral formula, Morera's theorem, Weierstrass's theorem. Classification of singularities, Taylor's and Laurent's series and theorems, Casorati-Weierstrass theorm, Cauchy's residue theorem, Evaluation of definite integrals. Zeros of analytic functions, Lioville's theorem, Fundamental theorem of algebra, Uniqueness theorem, Maximum modulus principle / theorem, Schwarz lemma. Argument principle, Rouche's theorem, Hurwitz's theorem, Open mapping theorem, Inverse function theorem.
Suggested Books	1. L. V. Ahlfors, *Complex Analysis*, McGraw-Hill International Editions, Third Edition, New Delhi, 1979. 2. J. B. Conway, *Functions of One Complex Variable*, Springer International Student Edition, Narosa Publishing House, New Delhi, 1973. 3. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, Second Edition, New Delhi, 2005. 4. T. W. Gamelin, *Complex Analysis*, Undergraduate Texts in Mathematics, Springer, NY, 2001. 5. S. Ponnusamy and H. Silverman, *Complex Variables with Applications*, Birkhaeuser, Boston, 2006. 6. B. P. Palka, *An Introduction to Complex Function Theory*, Springer-Verlag, 1991.

Course Code	**MA 610N**
Title of the Course	**Complex Analysis**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics of real analysis and metric spaces
Scope of the course (Objectives)	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in differentiability and analyticity of complex functions, conformal mappings, complex integration, classification of singularities and residue theory.
Course Outcomes	This course equips the students with a deep understanding of fundamental concepts like differentiability and analyticity of complex functions, complex integration and their applications.
Course Content	Complex functions, limit and continuity, topology of the complex plane, the complex exponential, the complex logarithm and trigonometric functions, and Möbius transformations. Differentiability, Cauchy-Riemann equations, analytic functions, convergence of series of complex numbers, power series, absolute and uniform convergence of a power series, harmonic functions, harmonic conjugates, branches of the logarithm. The complex integral, Cauchy's theorem, Cauchy integral formula, Morera's theorem, Liouville's theorem, maximum modulus principle, Schwarz lemma, open mapping theorem, Taylor's series, Laurent's series, singularities, Cauchy's residue theorem, Casorati–Weierstrass theorem, evaluation of real integrals, argument principle, Rouche's theorem.
Suggested Books	**Text Books:** 1. L. Ahlfors, Complex Analysis, 2nd ed., McGraw-Hill, New York, 1966. ISBN: 9780070006577 2. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, Second Edition, New Delhi, 2005. ISBN: 9788173196294 **Reference Books:** 1. S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser, Boston, 2006. ISBN: 9780817644574 2. J. B. Conway, Functions of One Complex Variable, Springer International Student Edition, Narosa Publishing House, New Delhi, 1973. ISBN: 9788185015378

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	3. T. W. Gamelin, Complex Analysis, Undergraduate Texts in Mathematics, Springer, NY, 2001. ISBN: 9780387950693 4. B. P. Palka, An Introduction to Complex Function Theory, Springer-Verlag, 1991. ISBN: 9780387974279

Course Code	**MA 611**
Title of the Course	**Analysis-I**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Analysis in metric space, Differentiability, Riemann-Stieltjes integral, and convergence criteria in sequences and series of functions.
Course Syllabus	Review of real number system, Dedekind's cut (without proof), Infimum and supremum, countability. Review on convergence of sequences and series of real numbers, Continuity and differentiability. Metric spaces: Open and closed sets, continuity, connectedness, compactness, Heine-Borel theorem, Bolzano Weierstrass theorem, Cantor Intersection theorem, finite intersection property, uniform continuity, totally boundedness, completeness, completion, Contraction mapping theorem, Baire category theorem. Functions of bounded variations and Riemann-Stieltjes integral. Sequences and series of functions, pointwise and uniform convergence, Interchanging limits, Dini's theorem, equicontinuity, Arzela-Ascoli's theorem, Stone-Weierstrass theorem.
Suggested Books	1. T. M. Apostol, *Mathematical Analysis*, 2nd ed., Narosa Publishers, 2002. 2. K. Ross, *Elementary Analysis: The Theory of Calculus*, Springer Int. Edition, 2004. 3. W. Rudin, *Principles of Mathematical Analysis*, 3rd ed., McGrawHill, 1983. 4. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, John Wiley & Sons, International Ed., 1982. 5. R. R. Goldberg, *Methods of Real Analysis*, 2nd ed., John Wiley & Sons, 1976. 6. S. Ponnusamy, *Foundations of Mathematical Analysis*, Birkhäuser, 2012. 7. N. L. Carothers, *Real Analysis,* 1st ed., Cambridge University Press, Indian Edition, 2009.

Course Code	**MA 611N**
Title of the Course	**Analysis-I**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	None
Scope of the course (Objectives)	At the end of the course, students will learn fundamental knowledge and problem solving skills in analysis.
Course Outcomes	The student will understand the idea of different kinds of distance functions and analysis of their different properties.
Course Content	Review of real number system, Infimum and supremum, countability, convergence of sequences and series of real numbers, Continuity and differentiability and Riemann Integration. Metric spaces: Open and closed sets, continuity, connectedness, compactness, Heine-Borel theorem, Bolzano Weierstrass theorem, Cantor Intersection theorem, finite intersection property, uniform continuity, totally boundedness, completeness, completion, Contraction mapping theorem, Baire category theorem. Sequences and series of functions, pointwise and uniform convergence, Interchanging limits, Dini's theorem, equicontinuity, Statement of Arzela-Ascoli's theorem and Stone-Weierstrass theorem.
Suggested Books	**Text Books:** 1. W. Rudin, Principles of Mathematical Analysis (3rd edition), McGraw-Hill, 1983. ISBN: 9789355325969 2. S. Kumaresan, Topology of metric space, Alpha Science International Ltd., 2005. ISBN: 9781842652503 **Reference Books** 3. A. Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press Taylor & Francis Group, 2014. ISBN: 9781482216370 4. T. M. Apostol, Mathematical Analysis (2nd edition), Narosa Publishers, 2002. ISBN: 9788185015668 5. N. L. Carothers, Real Analysis, Cambridge University Press, 2009. ISBN: 9780521497565

	6. K. Ross, Elementary Analysis: The Theory of Calculus (2nd edition), Springer International Edition, 2013. ISBN: 9781461462705

Course Code	**MA 612**
Title of the Course	**Analysis-II**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Analysis-I
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Multivariable calculus, Inverse function and Implicit function theorem. Lebesgue measure and integration.
Course Syllabus	Differential Calculus: Functions of several variables, Limits and continuity, Directional derivatives, Partial derivatives, Total derivative, Derivatives of vector fields, Jacobian matrix, Chain rules, Mean value Theorem, Higher order derivatives, Taylor's theorem. Applications of Differential Calculus: Maxima, Minima, Lagrange's multipliers, **Inverse function theorem***, **Implicit function theorem***. Lebesgue Integration: Lebesgue Measure; Lebesgue Outer Measure; Lebesgue Measurable Sets. Sigm algebra, Measure space, Measurable Functions, simple functions, Integration. Fatou's lemma, Lebesgue's Monotone Convergence Theorem, Dominated Convergence Theorem, **Lp - Spaces. Differentiation and Fundamental theorem for Lebesgue integration***. Product measure, Fubini's theorem.
Suggested Books	1. T. Apostol, *Mathematical Analysis*, 2nd ed., Narosa Publishers, 2002. 2. W. Rudin, *Principles of Mathematical Analysis*, 3rd ed., McGrawHill, 1983. 3. N. L. Carothers, *Real Analysis,* 1st ed., Cambridge University Press, 2009 Indian Edition. 4. R. R. Goldberg, *Methods of Real Analysis,* 2nd ed., John Wiley & Sons, 1976. 5. G. de Barra, *Measure Theory and Integration,* 2nd ed. New Age International Publishers, 2013. 6. H. L. Royden and P. M. Fitzpatrick, *Real Analysis,* 4th ed., Pearson Prentice Hall (Indian reprint), 2012.

Course Code	**MA 613**
Title of the Course	**Algebra-I**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	None
Scope of the course (Objectives)	This course provides basic knowledge of group theory and ring theory.
Course Outcomes	At the end of the course, students should be exposed to fundamental concepts of group theory and ring theory.
Course Content	**Group Theory:** Binary operation, and its properties, Definition of a group, Examples and basic properties. Subgroup, Coset of a subgroup, Lagrange's theorem. Cyclic group, Order of a group, Normal subgroup, Quotient group, Homomorphisms, Kernel and Image of a homomorphism, Isomorphism theorems, Permutation group, Cayley's theorem, Direct product of groups, Group action on a set, Sylow theorems, Structure of finite Abelian groups. **Ring Theory:** Definition of a ring, Examples and basic properties, Zero divisors, Integral domains, Fields, Characteristic of a ring, Quotient field of an integral domain, Subrings, Ideals, Quotient rings, Isomorphism theorems, Polynomials rings, Prime, Irreducible elements and their properties, UFD, PID and Euclidean domains, Prime ideal, Maximal ideal, Chinese remainder theorem.
Suggested Books	**Text Books:** 1. I. N. Herstein, Topics in Algebra (2nd edition), John Wiley & Sons, 2006. ISBN: 9788126510184 2. D. S. Dummit and R. M. Foote, Abstract Algebra (3rd edition), John Wiley & Sons, 2003. ISBN: 978047136857 **Reference Books** 3. M. Artin, Algebra (2nd edition), Pearson Education India, 2014. ISBN: 9789332549838 4. N. Jacobson, Basic Algebra (Vol 1), Hindustan Publishing Corporation, 2009. ISBN: 9780486471891 5. S. Lang, Algebra (3rd edition), Springer, 2004. ISBN: 9780387953854

Course Code	**MA 414/614**
Title of the Course	**Time Series Analysis**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Probability and Statistics
Objective of the Course	To introduce various techniques for modelling and forecasting the time series data.
Course Outcomes	• Understand the concepts of time series models and their applications in various fields, • Apply these models and techniques to real-life problems such as finance and stock analysis, sales and demand forecasting, weather forecasting etc.
Course Syllabus	• Components of time series, tests for randomness, trend and seasonality, estimation/elimination of trend and seasonality, mathematical formulation of time series, weak stationary, stationary up to order m. • Auto-covariance and auto-correlation functions of stationary time series and its properties, linear stationary processes and their time-domain properties-AR, MA, ARMA, seasonal, non-seasonal and mixed models, ARIMA models, invertibility of linear stationary processes. • Parameter estimation of AR, MA, and ARMA models-least square approach, estimation based on Yule-Walker for AR, ML approach for AR, MA and ARMA models, asymptotic distribution of MLE, best linear predictor and partial auto-correlation function (PACF), model-identification with ACF and PACF, model order estimation techniques-AIC, AICC, BIC, etc.
Suggested Books	Text Books: 1. P. J. Brockwell and R. A. Davis, ***Introduction to Time Series and Forecasting***, Springer, 2002, ISBN: 9781493970865. 2. C. Chatfield and H. Xing, ***The Analysis of Time Series -An Introduction with R***, Chapman and Hall/CRC Press, 2019, ISBN: 9781138066137. Reference Books:

	3. R. H. Shumway, D. S. Stoffer, ***Time Series Analysis and Its Applications with R Examples***, Springer, 2016, ISBN: 9783319524511. 4. G. E. P. Box, G. Jenkins, and G. Reinsel, ***Time Series Analysis-Forecasting and Control***, Prentice-Hall International, Inc., 1994, ISBN: 0130607746.

Course Code	MA 615
Title of the Course	Partial Differential Equations
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics of ordinary differential equations
Scope of the course (Objectives)	At the end of the course, students will manifest the fundamental knowledge and problem-solving skills in second order partial differential equations, one-dimensional diffusion equations, and the Laplace equation.
Course Outcomes	This course equips the students with the ability to understand the concept of PDEs, classify them, apply various solution techniques, check their validity, and interpret their applications in different scientific and mathematical contexts.
Course Content	Physical models leading to partial differential equations. First order partial differential equations: Linear, quasi-linear and fully nonlinear equations-Lagrange and Charpit methods. Cauchy-Kowalewski's Theorem. Second order partial differential equations: Classification and Canonical forms of equations in two independent variables, One dimensional wave equation- D'Alembert's solution. Solution of three-dimensional wave equation. Method of descent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions. One dimensional diffusion equation: Maximum Minimum principle for the diffusion equation, Diffusion equation on the whole line, Diffusion on the half-line, inhomogeneous equation on the whole line, Heat equation, Uniqueness of solutions via energy method. The Laplace equation: Maximum-Minimum principle, Existence theorem by Perron's method, Harnack's theorems. Fourier method for heat equation, wave equation and Laplace equation.

Suggested Books	**Text Books:** 1. Y. Pinchover and J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press, 2005. ISBN: 978-0521613231 2. E. DiBenedetto, Partial Differential Equations, Birkhauser, Boston, 1995. ISBN: 9780817645526. **Reference Books** 1. T. Myint-U and L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th Edition, Birkhauser, 2007. ISBN: 9780817643935 2. W. L. Strauss, Partial Differential Equations, John Wiley & Sons, Ltd, 2007. ISBN: 9780470054567. 3. M. Renardy and R. C. Rogers, An Introduction to Partial Differential Equations, Springer New York, NY, 2006. ISBN: 9780387216874.

Course Code	**MA 416/616**
Title of the Course	**Integral Equations**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge in calculus and differential equations
Objective of the Course	The course introduces the classification of integral equations, fundamental mathematical ideas and techniques that lie at the core of the integral equation approach of problem solving.
Course Outcomes	• understand the concepts of Volterra and Fredholm integral equations • apply appropriate integral equation to solve initial and boundary value problems
Course Syllabus	• Basic concepts, Volterra integral equations, relationship between linear differential equations and Volterra equations, resolvent kernel, method of successive approximations, convolution type equations, Volterra equation of the first kind, Abel's integral equation. • Fredholm integral equations, Fredholm equations of the second kind, the method of Fredholm determinants, iterated kernels, integral equations with degenerate kernels, eigenvalues and eigen functions of a Fredholm alternative, construction of Green's function for BVP. • Weakly singular integral equations, Cauchy singular integral equations, hypersingular integral equations. • Bernstein polynomials, properties and its use in solving integral equations.
Suggested Books	Text Books: 1. F. G. Tricomi, *Integral Equations*, Dover Publications Inc, 1985, ISBN: 9780486648286. 2. N. I. Muskhelishvili, *Singular Integral Equations: Boundary Problems of Functions Theory and Their Applications to Mathematical Physics*, Springer, 2011, ISBN: 9789400999961. Reference Books: 3. D. Porter and D. S. G. Stirling, *Integral Equations: A Practical Treatment, from Spectral Theory to Applications*, Cambridge University Press, 2012, ISBN: 9781139172028. 4. R. P. Kanwal, *Linear Integral Equations: Theory & Technique*, Birkhäuser, 2013, ISBN: 9781461460121.

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Course Code	**MA 617**
Title of the Course	**Functional Analysis**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics of analysis and linear algebra
Scope of the course (Objectives)	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Normed linear spaces, Banach spaces, bounded operators, Hahn-Banach theorem and inner product spaces.
Course Outcomes	This course equips the students with a deep understanding of fundamental concepts like normed spaces, operators, dual spaces and their key properties, enabling them to apply these concepts to solve mathematical problems within various areas of analysis, particularly in areas like PDEs and optimization.
Course Content	Normed linear space; Banach spaces and basic properties: Heine-Borel theorem, Riesz lemma and best approximation property: Inner product space and projection theorem; Orthonormal bases; Bessel inequality and Parseval's formula; Riesz-Fischer theorem. Bounded operators and basic properties; Space of bounded operators and dual space; Riesz representation theorem; Adjoint of operators on a Hilbert space; Examples of unbounded operators; Convergence of sequence of operators. Hahn-Banach Extension theorem; Uniform boundedness principle; Closed graph theorem and open mapping theorem, and their applications.
Suggested Books	**Text Books:** 1. G. F. Simmons, Introduction to Topology and Modern Analysis, Mc- Graw Hill, 2004. ISBN: 9780070856950 2. M.T. Nair, Functional Analysis, A First Course, Prentice Hall of India, 2002. ISBN: 9789390544004 **Reference Books** 1. S. Kesavan, Functional Analysis, Springer Singapore, 2023. ISBN: 97881951961352

	2. J.B. Conway, A Course in Functional Analysis, 2nd ed., Springer, Berlin, 1990. ISBN: 9780387972459 3. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1978. ISBN: 9788126511914 4. B.V. Limaye, Functional Analysis, 2nd ed., New Age International, New Delhi, 1996. ISBN: 9780852265208 5. Haim Brezis, Functional Analysis, Sobolev Spaces and Partial Differential Equations, Springer New York, NY, 1st Edition, 2010. ISBN: 9780387709130

Course Code	MA 618
Title of the Course	Point Set Topology
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics of real analysis
Scope of the course (Objectives)	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in point set topology, countability, connected space, and metrization theorem.
Course Outcomes	This course equips the students with a deep understanding of fundamental concepts like countability, connected space, compact space, and metrization theorem.
Course Content	Topological spaces, Basis for a topology, The order topology, Subspace topology, Closed sets. Countability axioms, Limit points, Continuous functions, product topology, Metric topology, Quotient topology. Connected spaces, components and path components, compact spaces, compactness in metric spaces, local compactness, one-point compactification. Separation axioms, Uryshon's lemma, Uryshon's metrization theorem. Tietz extension theorem, The Tychonoff theorem.
Suggested Books	**Text Books:** 1. J. Munkres, Topology (2nd Edition), Prentice Hall, 2000. ISBN: 9788120320468 2. G. F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw-Hill 2004. ISBN: 9788176711357 **Reference Books:** 1. C. Adams, R. Franzosa, Introduction to Topology Pure and Applied, Pearson Prentice Hall, 2008. ISBN: 9788131726921 2. J. Dugundji, Topology, Allyn and Bacon, Inc., 1966. ISBN: 9780205002719 3. K. Janich., Topology, Springer, 1984. ISBN: 9781461270188

	4. M. A. Armstrong, Basic Topology, Springer, 1983. ISBN: 9781441928191 5. J. L. Kelley, General Topology, Springer, 1975. ISBN: 9780387901251

Course Code	**MA 619**
Title of the Course	Probability and Statistics
Course Category	Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Nil
Scope of the course (Objectives)	The objectives of this course are to understand both theoretical concepts and practical applications of probability, statistical methods, and data analysis techniques.
Course Outcomes	Upon successful completion of the course, students will be able to: ● Learn a solid foundation of probability and statistics, empowering them to analyse data and draw meaningful conclusions. ● Identify and apply the properties of discrete and continuous random variables and statistical methods to estimate population parameters.
Course Content	● Axiomatic definition of probability, conditional probability, and Bayes rule. Random variables, cumulative distribution function, and its properties. Discrete random variables, probability mass function, continuous random variables, probability density function, functions of random variables. Probability integral transform. ● Expectation and moment of a random variable, moment generating function, characteristic function. Some special discrete and continuous probability distributions. ● Bivariate and multivariate random variables, joint probability distributions, marginal and conditional distributions, independence of random variables, covariance, and correlation. ● Markov's inequality, Chebyshev's inequality, Jensen's inequality, convergence in probability and convergence in distribution, weak law of large numbers, strong law of large numbers, central limit theorem. ● Estimation Theory: Problems of point estimation, unbiased estimation, method of moments, and maximum likelihood estimation, non-parametric estimation.

	• Hypothesis Testing: Null and Alternative Hypothesis, Type I and Type II errors, Confidence intervals: confidence intervals for the mean (large samples and small samples) and for population proportions, p-value, z-test, t-test, F-test, etc., Analysis of Variance • LAB based on the topics covered in this course.
Suggested Books	**Text Books:** 1. V. K. Rohatgi, and A. K. Md. E. Saleh, An Introduction to Probability and Statistics, Wiley India, 2008. ISBN: 9788126519262 2. J. A. Rice, Mathematical Statistics and Data Analysis, Cengage Learning India, 2007. ISBN: 9788131519547. **Reference Books:** 3. Stanley Chan, Introduction to Probability for Data Science, Michigan Publishing Services, USA, 2021. ISBN: 9781607857464 4. Robert V. Hogg, J. Mckean, A. T. Craig, Introduction to Mathematical Statistics, Pearson Education, 2021. ISBN: 9789353946760 5. S. M. Ross, Introductory Statistics, Academic Press, USA, 2017. ISBN: 9780128043172 6. Jared P. Lander, R for Everyone: Advanced Analytics and Graphics, Pearson Education, 2018. ISBN: 9789386873521

Course Code	**MA 620**
Title of the Course	**Partial Differential Equations**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre–requisite, if any (for the students)	Ordinary Differential Equation
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Second order partial differential equations, One dimensional diffusion equation, and The Laplace equation.
Course Syllabus	Mathematical models leading equations. First order partial differential equations: Linear, quasi-linear and fully nonlinear equations-Lagrange and Charpit methods. Cauchy-Kowalewski's Theorem. Second order partial differential equations: Classification and Canonical forms of equations in two independent variables, One dimensional wave equation-D'Alembert's solution. Solution of three-dimensional wave equation. Method of decent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions. One dimensional diffusion equation: Maximum Minimum principle for the diffusion equation, Diffusion equation on the whole line, Diffusion on the half-line, inhomogeneous equation on the whole line, Heat equation, Uniqueness of solutions via energy method. The Laplace equation: Maximum-Minimum principle, Existence theorem by Perron's method, Harnack's theorems. Fourier method for heat equation, wave equation and Laplace equation.
Suggested Books	1. I. N. Sneddon, *Elements of Partial Differential equations*, McGraw-Hill, New York, 1986. 2. E. T. Copson, *Partial Differential Equations*, Cambridge university press, London, 1975. 3. W. E. Williams, *Partial Differential Equations*, Clarendon Press, Oxford, 1980. 4. Y. Pinchover and J. Rubinstein, *An Introduction to Partial Differential Equations,* Cambridge University press. 5. E. DiBenedetto, *Partail Differential Equations*, Birkhauser, Boston, 1995.

Course Code	**MA 621 (Till AY 2024-25)**
Title of the Course	**Ordinary Differential Equations**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre–requisite, if any (for the students)	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Power series methods of solution of ODE, Existence and Uniqueness theory of Initial Value Problems, Solution of system of differential equations, and boundary value problems.
Course Syllabus	Review of solution methods for first order as well as second order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. Existence and Uniqueness of Initial Value Problems: Picard's and Peano's Theorems, Gronwall's inequality, Continuation of solutions and maximal interval of existence, Continuous dependence. Systems of Differential Equations: Algebraic properties of solutions of linear systems, the eigenvalue-eigenvector method of finding solutions, Complex eigenvalues, Equal eigenvalues, Fundamental matrix solutions, Matrix exponential, Nonhomogeneous equations, Variation of parameters. Boundary Value Problems for Second Order Equations: Green's function, Sturm comparison theorems and oscillations, Eigenvalue problems.
Suggested Books	1. G. F. Simmons, *Differential Equations with Applications and Historical Notes,* Second edition, Tata Book House, 1991. 2. G. Birkhoff and G. C. Rota, *Ordinary Differential Equations*, Wiley & Sons, 4th Ed., 1989. 3. E. A. Coddington, *Ordinary Differential Equations*, Prentice Hall of India, 1974. 4. M. Hirsch, S. Smale and R. Deveney, *Differential Equations, Dynamical Systems and Introduction to Chaos*, Academic Press, 2004. 5. D. A. Sanchez, *Ordinary Differential Equations and Stability Theory: An Introduction*, Dover Publ. Inc., New York, 1968. 6. L. Perko, *Differential Equations and Dynamical Systems, Texts in Applied Mathematics*, Vol. 7, 2nd ed., Springer Verlag, New York, 1998.

Course Code	**MA 621 (From AY 2025-26 onwards)**
Title of the Course	**Ordinary Differential Equations**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics of real analysis and linear algebra
Scope of the course (Objectives)	At the end of the course, students will manifest the fundamental knowledge and problem-solving skills in power series methods of solution of ODE, existence and uniqueness theory of initial value problems, solution of systems of differential equations, and boundary value problems.
Course Outcomes	This course equips the students with the ability to understand the concept of ODEs, various solution techniques and basic qualitative theory
Course Content	Review of solution methods for first order as well as second order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. Existence and Uniqueness of Initial Value Problems: Picard's and Peano's Theorems, Gronwall's inequality, Continuation of solutions and maximal interval of existence, Continuous dependence. Systems of Differential Equations: Algebraic properties of solutions of linear systems, The eigenvalue-eigenvector method of finding solutions, Complex eigenvalues, Equal eigenvalues, Fundamental matrix solutions, Matrix exponential, Nonhomogeneous equations, Variation of parameters. Boundary Value Problems for Second Order Equations: Green's function, Sturm comparison theorems and oscillations, Eigenvalue problems
Suggested Books	**Text Books:** 1. L. Perko, Differential Equations and Dynamical Systems, Texts in Applied Mathematics, Vol. 7, 3rd ed., Springer Verlag, New York, 2001. ISBN: 9780387951164 2. M. Hirsch, S. Smale and R. Deveney, Differential Equations, Dynamical Systems and Introduction to Chaos (3rd edition), Academic Press, 2012. ISBN: 9780123820105 **Reference Books**

	1. E. A. Coddington, Ordinary Differential Equations, Prentice Hall of India, 1974. ISBN: 9780486659428 2. G. F. Simmons, Differential Equations with Applications and Historical Notes (2nd edition), Tata Book House, 1991. ISBN: 9780070530713

Course Code	**MA 422 / MA 622**
Title of the Course	**Hyperbolic Geometry**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Knowledge of Complex Analysis and Topology
Scope of the course (Objectives)	This course provides basic information about hyperbolic geometry from two dimensions to higher dimensions in order to start research on hyperbolic geometry.
Course Outcomes	At the end of the course, students should have some fundamental knowledge about hyperbolic geometry through Complex Analysis and topology of non-Euclidean metric geometry.
Course Content	**Mobius transformations:** Stereographic projections. Review of Mobius transformations in the complex plane, Mobius Transformations in higher dimensions. **Schwarz lemma and the hyperbolic metric:** Schwarz lemma, Characterization of conformal maps of the unit disk, Schwarz-pick lemma, Hyperbolic metric of the unit disk and the upper half plane, Schwarz-pick theorems (non-Euclidean), hyperbolic geodesics, Hyperbolic metric in higher dimensions, Topology of the metric balls. **Mapping theorems and the hyperbolic metric:** Riemann mapping theorem (without proof), hyperbolic metric in a simply connected domain, covering spaces, uniformization theorem, hyperbolic metric in hyperbolic regions, Topology of metric balls. **Generalizations of the hyperbolic metric in higher dimensions:** The quasi-hyperbolic metric, Mobius invariant metrics, geodesics, comparison of metrics and their applications, geometry and topology of metric balls.

Suggested Books	**Text Books:** 1. L. Keen and N. Lakic, Hyperbolic Geometry from a Local Viewpoint, Cambridge University Press, 2007. ISBN: 9780521682244 2. A.F. Beardon, The Geometry of Discrete Groups, Springer, 1983. ISBN: 9780387907888 **Reference Books** 3. J.W. Anderson, Hyperbolic Geometry, Springer, 2005. ISBN: 9781852339340 4. M. Vuorinen, Conformal Geometry and Quasiregular Mappings, Springer-Verlag, 1988. ISBN: 9783540193425 5. P. Hariri, R. Klen and M. Vuorinen, Conformally Invariant Metrics and Quasiconformal Mappings, Springer, 2020. ISBN: 9783030320676 6. L.V. Ahlfors, Complex Analysis, McGraw Hill Education, 2013. ISBN: 9781259064821

Course Code	**MA 623**
Title of the Course	**Measure Theory**
Course Category	Elective Course (suitable for 3rd Semester M.Sc and 4th year B.Tech)
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of Mathematical Analysis
Scope of the course (Objectives)	• Fundamental framework for modern integration, particularly the Lebesgue integral • Applications in probability theory, functional analysis and signal processing.
Course Outcomes	• Understanding of concepts of outer and Lebesgue measure, measurable functions, and the Lebesgue integral. • Learning applications in the areas like probability theory and partial differential equations. • Applications of various convergence theorems and familiarity with L^p spaces, equipping them to handle complex integration and measuring problems.
Course Content	• Lebesgue Integration: Lebesgue Measure; Lebesgue Outer Measure; Lebesgue Measurable Sets. Sigma algebra, Measure space, Measurable Functions, simple functions, Integration. • Fatou's lemma, Lebesgue's Monotone Convergence Theorem, Dominated Convergence Theorem, Modes of Convergence, Product measure and Fubini-Tonelli Theorem. • Signed Measures and Differentiation: Signed Measures, the Lebesgue-Radon-Nikodym Theorem, Differentiation on Euclidean Space, Functions of Bounded Variation. • L^p spaces: Definition and basic properties, the Dual of L^p, Interpolation of L^p spaces, Convolutions and smoothening.

Suggested Books (Text Books , Reference Books) *in order of,* *Name of Author(s) :* *Book Title : Publisher :* *Place of Publication :* *Year of publication :* *ISBN*	**Text Books:** 1. H. L. Royden and P. M. Fitzpatrick, Real Analysis, 4th ed., Pearson Prentice Hall, 2015. **ISBN:** 978-9332551589. 2. G.B. Folland, Real Analysis, Modern Techniques and their Applications, 2nd Edition. John Wiley and Sons, Inc. 1999, ISBN 0-471-31716-0. 3. G. de Barra, Measure Theory and Integration, 3rd Edition, New Age International Publishers, 2022. **ISBN:** 978-9393159915 **Reference Books** 4. W. Rudin, Real and Complex Analysis, 3rd Edition., McGrawHill, 1987. ISBN 0-07-100276-6. 5. I. K. Rana, An Introduction to Measure and Integration, 2nd Edition, Narosa, 2007. **ISBN:** 978-8173194306. .

Course code	**MA 424/624**
Title of the course	**Algebraic Number Theory**
Course Category	**Elective**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Basic knowledge of number theory and algebra.
Objective of the course	The primary aim of this course is to introduce the key concepts of algebraic number theory and provide an overview of its various applications like solving Diophantine equations.
Course Outcomes	At the end of the course, students will have basic understanding of algebraic number theory and its applications to solve different types of problems in number theory.
Course Syllabus	Motivation via Fermat's Last Theorem, Algebraic Numbers and Integers, Number Fields, Real and Complex Embeddings, Norms, Traces, Discriminant, Ramification, Norms of Ideals. Ring of Integers, Integral Basis, Dedekind Domain, Fractional Ideals, Ideal Class Group, Class Number, Computation of Class Group of Number Fields, Finiteness of Class Group. Dirichlet Unit Theorem and its Applications, Fundamental Units, Units in Quadratic Fields, Cyclotomic Fields, Dedekind Zeta Function, Applications to Diophantine Equations.
Suggested Books	**Text Books:** 1. J. Esmonde and M. R. Murty, Problems in Algebraic Number Theory, Springer, New York, 2004, ISBN: 9780387221823 2. R. A. Mollin, Algebraic Number Theory, CRC Press, 1999. ISBN: 9781138627857 **Reference Book:** 3. J. Neukirch, Algebraic Number Theory, Springer Berlin, Heidelberg, 1999. ISBN: 3540653996

Course Code	**MA 625**
Title of the Course	Multivariable Calculus
Course Category	Flexi Core
Credit Structure	L-T- P-Credits 2-1-0-1.5 (half semester)
Name of the Department	Mathematics
Pre-requisite, if any	Basics of calculus
Objectives of the course	• Provide the students with fundamental concepts and techniques of calculus in the presence of more than one variable. • Develop their skills for handling applications in other areas, including partial differential equations and optimisation.
Course Outcomes	• Exposure to the fundamental concepts in multivariable calculus, the inverse and Implicit function theorem and optimisation problems with Lagrange multipliers. • Knowledge of multiple integrals and the applications of Stokes theorem to calculate the same.
Course Content	**Module1:** Differential Calculus for functions of several variables: directional derivatives, total derivative, Jacobian matrix, chain rules, Mean-value theorems, higher-order derivatives, and Taylor's theorem. **Module 2:** Applications of Differential Calculus: Maxima, Minima, Lagrange's multipliers, Inverse function theorem, Implicit function theorem, Rank theorem. **Module 3:** Integral Calculus: Multiple integrals, differential forms, the general Stokes formula.
Suggested Books (Text Books , Reference Books)	**Text Books:** 1. C.C. Pugh, Real Mathematical Analysis, Springer, 2010. ISBN 978-3-319-17770-0. 2. T. Apostol, Mathematical Analysis, Narosa Publishers, 2002. **ISBN-13 :** 978-8185015668. **Reference Books:** 3. M. Spivak, Calculus on Manifolds, A Modern Approach to Classical Theorems of Advanced Calculus. Taylor and Francis, 1971. **ISBN-13 :** 978-1138329393.

Course code	**MA 426/626**
Title of the course	**Theory of Modular Forms**
Course Category	**Elective**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Basic knowledge of Complex analysis, Group theory, and Linear Algebra.
Objective of the course	The theory of modular forms is developed as a tool to use in number theory, but it accommodates itself in many branches of mathematics as well as in physics.
Course Outcomes	At the end of this course, students will have a brief idea of the basic techniques and applications of modular forms and their relationship with the theory of elliptic curves.
Course Syllabus	Full Modular Group and its Subgroups, Hecke Subgroups, Action of $\mathbf{SL_2(Z)}$ on the Upper-half Plane**,** Fundamental Domain. Modular Functions, Modular Forms, Cusp Forms, Fourier Expansions, Space of Modular Forms, The Valence Formula and the Dimension Formula, Examples of Modular Forms: Eisenstein series and Ramanujan's Delta function, Ramanujan Tau Function. The Hecke Operators T_n, Multiplicative Property of the Hecke Operators, Eigenfunctions of Hecke Operators. Dirichlet Series, ***L***-functions attached to Modular Forms, Analytic Continuation and Functional Equation. Atkin-Lenner Theory, Newforms, Relation between Modular Forms and Elliptic Curves.
Suggested Books	**Text Books:** 1. J. P. Serre, A Course in Arithmetic, Springer, 1978, ISBN: 9780387900407. 2. M. R. Murty, M. Dewar, H. Graves, Problems in the Theory of Modular Forms, Springer, 2015, ISBN: 9789380250724. **Reference Books:** 3. T. M. Apostol, Modular Functions and Dirichlet Series in Number Theory, Springer, 2012, ISBN:9781468499100.

	4. F. Diamond, J. Shurman, A First Course in Modular Forms, Springer, 2005, ISBN: 9780387272269.

Course Code	**MA 627**
Title of the Course	**Fractal Geometry**
Course Category	Flexicore
Credit Structure	L-T- P-Credits 2-1-0-1.5 (Half Semester)
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basics of real and complex analysis
Scope of the course (Objectives)	● Connecting real and complex analysis concepts to several geometrical structures. ● Course content is well connected with real-world problems such as image compression, image encoding and decoding, financial markets, biological modeling and structure in medicine, etc.
Course Outcomes	● Students will learn about many geometrical structures through mathematical analysis. ● Students can also visualize how living structures in nature can be generated by mathematical algorithms.
Course Content	**Module 1:** Cantor set, Sierpinski triangle, Von Koch curve, Hilbert and Peano curves, Weierstrass function. **Module 2:** Self-similarity, Scaling, Similarity dimension, Box-counting dimension, Information dimension, Capacity dimension, Hausdorff measures and dimension. **Module 3:** Foundations of iterated function systems (IFS), Classical fractals generated by IFS, Contractions mapping principle, Collage theorem. **Module 4**: Some applications of Fractals in image compression, image encoding and decoding, financial markets, etc.
Suggested Books (Text Books , Reference Books)	**Text Books:** 1. Kenneth Falconer, Fractal Geometry: Mathematical Foundations and Applications, Wiley, 2014. ISBN: 9781119942399, 111994239X 2. Michael F. Barnsley, Fractals Everywhere, Academic Press Professional, 2014. ISBN: 9781483257693, 148325769X **Reference Books** 3. Michael Frame, Amelia Urry, Fractal Worlds: Grown, Built, and Imagined. Yale University Press, 2016. ISBN: 9780300197877, 030019787X

Course Code	**MA 628**
Title of the Course	**Basics of Data Structures and Algorithms**
Course Category	Core
Credit Structure	L-T- P-Credits 1-0-2-2
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic knowledge of computer programming
Scope of the course (Objectives)	This course introduces and explores some data structures and their importance in efficient programming through algorithms.
Course Outcomes	Students will learn various data structures and will implement them using algorithms.
Course Content	**Introduction:** Basic concepts of data structures and algorithms, concept of complexity analysis and asymptotic notations. **Data structures:** ● Array: types of array, representation, operations and applications. ● Linked lists: types of linked lists, representations, operations and use of linked lists for problem solving. ● Stack: representation, operations and applications such as infix to postfix, postfix evaluation. ● Queues: types of queue, representations and applications. **Algorithms:** • Sorting: bubble sort, insertion sort, merge sort and quick sort. • Searching: linear search and binary search. • Hashing: concept of hash functions and collision resolution techniques LAB: Based on the topics covered in this course using mathematical tools.
Suggested Books	Text Books: 1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, Introduction to Algorithms, MIT Press, 2022. ISBN: 9780262046305 2. D. Samanta, Classic Data Structures, PHI Learning Private Limited, 2009, ISBN: 978812033731 Reference Books: 1. Chung. A. V. Aho, J. D. Ullman, and J. E. Hopcroft, Data Structures and Algorithms, Pearson Publication, 1983. ISBN: 9780201000238

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	2. S. Sahni, Data structures, algorithms, and applications in C++, McGraw-Hill, 1998. ISBN: 9780929306322 3. M.T. Goodrich, R. Tamassia, and D. Mount, Data Structures and Algorithms in C++, Wiley, 2011. ISBN: 9780470383278.

Course Code	**MA 630**
Title of the Course	**Basic Algebraic Topology**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Department	Mathematics
Pre-requisite, if any	Basic knowledge in algebra and topology
Objectives of the course	• This course provides basic tools and techniques for studying topological spaces using algebraic methods. • Build and apply homotopy theory to prove key results including the Fundamental Theorem of Algebra, the Brouwer Fixed Point Theorem, and the Borsuk-Ulam Theorem.
Course Outcomes	• Compute fundamental groups and homology groups of standard topological spaces and use them to distinguish non-homeomorphic spaces. • Construct rigorous mathematical proofs and connect algebraic invariants with geometric and topological intuition.
Course Content	**Module 1:** Paths and homotopy, homotopy equivalence, contractibility, deformation retracts, multiplication of paths. **Module 2:** Fundamental groups, its computation for topological spaces such as circles, spheres and torus. Applications to the Fundamental Theorem of Algebra, Brouwer Fixed Point Theorem in dimension two, and Borsuk-Ulam Theorem in dimension two. **Module 3:** Van Kampen's Theorem, Covering spaces, lifting properties, deck transformations. universal coverings and existence theorem. **Module 4:** Singular Homology. Mayer-Vietoris Sequences. Long exact sequence of pairs and triples.

Suggested Books (Text Books , Reference Books)	**Text Books:** 1. J. R. Munkres, S. G. Krantz & H. R. Parks, *Elements of Algebraic Topology*, 2nd ed., Chapman & Hall / CRC Press, 2025. ISBN-9781032765549 2. A. Hatcher, Algebraic Topology, Cambridge Univ. Press, 2002. ISBN-9780521795401. **Reference Books** 3. W. Fulton, Algebraic topology: A First Course, Springer Science & Business Media, 2013. ISBN- 9781461241805 4. W. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, 1991. ISBN- 9780387974309 5. E. L. Lima, Fundamental Groups and Covering Spaces, Taylor & Francis, 2003. ISBN- 9781568811314.

Course Code	**MA 631**
Title of the Course	**Functional Analysis**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Department	Mathematics
Pre–requisite, if any (for the students)	Analysis-I, Analysis-II, Linear Algebra
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Normed linear spaces, Banach spaces, spaced of bounded operators, Hahn-Banach theorem and inner product spaces.
Course Syllabus	Normed linear space; Banach spaces and basic properties: Heine-Borel theorem, Riesz lemma and best approximation property: Inner product space and projection theorem; Orthonormal bases; Bessel inequality and Parseval's formula; Riesz-Fischer theorem. Bounded operators and basic properties; Space of bounded operators and dual space; Riesz representation theorem; Adjoint of operators on a Hilbert space; Examples of unbounded operators; Convergence of sequence of operators. Hahn-Banach Extension theorem; Uniform boundedness principle; Closed graph theorem and open mapping theorem and their applications. Invertibility of operators; Spectrum of an operator.
Suggested Books	1. J.B. Conway, *A Course in Functional Analysis*, 2nd ed., Springer, Berlin, 1990. 2. E. Kreyzig, *Introduction to Functional Analysis with Applications*, John Wiley & Sons, New York, 1978. 3. B.V. Limaye, *Functional Analysis*, 2nd ed., New Age International, New Delhi, 1996. 4. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Mc-Graw Hill, 2004. 5. M.T. Nair, *Functional Analysis, A First Course*, Prentice Hall of India, 2002.

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Course Code	**MA 432/ MA 632**
Title of the Course	**Introduction to Commutative Algebra**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Department	Mathematics
Pre-requisite, if any	Basic knowledge in algebra
Objectives of the course	• Develop a thorough understanding of the structure of commutative rings and modules. • Build the foundational tools for algebraic geometry and algebraic number theory.
Course Outcomes	• Apply core concepts of commutative rings and ideals to solve algebraic problems and prove basic structural results. • Work effectively with modules over commutative rings, including homomorphisms, exact sequences, and tensor products.
Course Content	**Module 1:** Commutative rings, ideals, prime and maximal ideals. Noetherian and Artinian rings. **Module 2:** Primary decomposition over Noetherian rings, Modules over commutative rings, Nakayama's lemma, Extension and Contraction. **Module 3:** Exact sequences, Exactness properties of the Tensor product, rings and modules of fractions, Integral dependence. **Module 4:** Valuations and Dedekind domains, Local properties, Going-Up and Going-Down Theorem.

Suggested Books (Text Books , Reference Books)	**Text Books:** 1. M. F. Atiyah and I. G. MacDonald, Introduction to Commutative Algebra, CRC Press, 2019. ISBN-978113832960 2. H. Matsumura, Commutative Ring Theory, Cambridge University Press, 1989. ISBN- 9780521367646 **Reference Books** 3. D. Eisenbud, Commutative Algebra with a View Toward Algebraic Geometry, Graduate Texts in Mathematics, Springer Science & Business Media, 1995. ISBN- 9780387942698 4. R. Y. Sharp, Steps in Commutative Algebra, Issue 51 of London Mathematical Society Student Texts, Cambridge University Press, 2000. ISBN- 9780521646239

Course Code	**MA 434 / MA 634**
Title of the Course	**Introduction to Modal Logic**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	A working knowledge of elementary set theory, relations, and orderings.
Objectives of the course	• To provide a rigorous introduction to the syntax, semantics, and proof theory of modal logic, with particular emphasis on Kripke frames, models, and the principal normal systems **K**, **T**, **S4**, and **S5**. • To analyze the expressive power of modal languages and explore their applications in computer science, and artificial intelligence.
Course Outcomes	Upon completing the course, students will be able to: • Comprehend and apply the syntax, semantics, and axiomatic systems of modal logic. • Analyze various modal logics, including epistemic and temporal logics. • Develop reasoning techniques for applications such as knowledge representation and distributed reasoning.
Course Content	**Introduction to Modal Logic** • Syntax and semantics of modal logic • Kripke models and accessibility relations • Basic modal axioms and their properties • The minimal modal system K and extensions (T, S4, S5) **Proof Theory and Expressiveness** • Hilbert-style axiomatic systems • Soundness and completeness theorems • Expressive power of modal languages. **Applications** • Epistemic logic and reasoning about knowledge and belief, multi-agent reasoning • Temporal logic for reasoning about time

Suggested Books (Text Books , Reference Books)	**Text Books:** 1. Patrick Blackburn, Maarten de Rijke, and Yde Venema, Modal Logic, Cambridge University Press, ISBN: 9781316101957 2. Ronald Fagin, Joseph Y. Halpern, Yoram Moses, and Moshe Y. Vardi, Reasoning About Knowledge, MIT Press. ISBN: 9780262562003. **Reference Books:** 3. Brian F. Chellas, Modal Logic: An Introduction, Cambridge University Press. ISBN: 9780521295154 4. Robert Goldblatt, Logics of Time and Computation, CSLI Publications. ISBN: 9780937073993 5. Alexandru Baltag, and Sonja Smets, The Logic of Knowledge, Belief, and Certainty, Cambridge University Press. ISBN: 9781107036639

Course Code	**MA 640**
Title of the Course	**Algebra-I**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Group and Ring theories.
Course Syllabus	Binary operation, and its properties, Definition of a group, Examples and basic properties. Subgroups, Coset of a subgroup, Lagrange's theorem. Cyclic groups, Order of a group. Normal subgroups, Quotient group. Homomorphisms, Kernel and Image of a homomorphism, Isomorphism theorems. Permutation groups, Cayley's theorems. Direct product of groups. Group action on a set. Sylow' theorems. Structure of finite Abelian groups. Rings: definition, examples and basic properties. Zero divisors, Integral domains, Fields, Characteristic of a ring, Quotient field of an integral domain. Subrings, Ideals, Quotient rings, Isomorphism theorems. Ring of polynomlals. Prime, Irreducible elements and their properties, UFD, PID and Euclidean domains. Prime ideal, Maximal ideals, Prime avoidance theorem, Chinese remainder theorem.
Suggested Books	1. I. N. Herstein, *Topics in Algebra* (2nd Edition), John Wiley & Sons, 2005. 2. T. W. Hungerford, *Algebra*, Springer, 2008. 3. M. Artin, *Algebra*, Prentice Hall of India, 1999. 4. D. S. Dummit and R. M. Foote, *Abstract Algebra* (2nd Edition), John Wiley and Sons, 2003. 5. S. Lang, *Algebra* (3rd Edition), Springer, 2004. 6. N. Jacobson, *Basic Algebra vol 1*, Hindustan Publishing Corporation, 1993.

	7. P. M. Cohn, *Basic Algebra*, Springer, 2005.

Course Code	**MA 641**
Title of the Course	**Linear Algebra**
Credit Structure	L-T- P-Credits 3-1-0-4
Name of the Concerned Department	Mathematics
Pre–requisite, if any (for the students)	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem-solving skills in Vector space, Linear transformations, rank, Eigenvalues and eigenvectors, Inner product spaces, and Bilinear forms.
Course Syllabus	Vector spaces, subspaces, bases and dimension. Systems of linear equations, matrices, rank. Linear transformations, the matrix of linear map, rank-nullity theorem, duality and transpose. Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonal-lization, Invariant subspace, Rational canonical form, Jordan canonical form. Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, Operators on real vector spaces, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators. Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic forms, Sylvester's law of inertia.
Suggested Books	1. S. Axler, *Linear Algebra,* Done Right, Springer, 1997. 2. M. Artin, *Algebra*, Prentice Hall of India, 1994. 3. K. Hoffman and R. Kunze, *Linear Algebra*, Pearson Education (India), 2003. Prentice-Hall of India, 1991. 4. S. Lang, *Linear Algebra*, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989. 5. G. Strang, *Linear Algebra and Its Applications*, Brooks/Cole, 2006. 6. P. Lax, *Linear Algebra*, John Wiley & Sons, New York,. Indian Ed. 1997. 7. H. E. Rose, *Linear Algebra*, Birkhauser, 2002.

Course Code	**MA 641N**
Title of the Course	**Linear Algebra**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	None
Scope of the course (Objectives)	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Vector space, Linear transformations, rank, Eigenvalues and eigenvectors, Inner product spaces, and Bilinear forms.
Course Outcomes	The student will understand the ideas on solving problems related to Linear Algebra arising in different courses.
Course Content	Vector spaces, subspaces, bases and dimension. Systems of linear equations, matrices, rank. Linear transformations, the matrix of linear map, rank-nullity theorem, duality and transpose. Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonalization, Invariant subspace, Rational canonical form, Jordan canonical form. Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, Operators on real vector spaces, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators.

Suggested Books	**Text Books:** 1. S. Axler, Linear Algebra, Done Right (3rd edition), Springer, 1997. ISBN: 9783319110790 2. G. Strang, Linear Algebra and Its Applications (4th edition), Brooks/Cole, 2006. ISBN: 9788131501726 **Reference Books** 3. M. Artin, Algebra (2nd edition), Pearson Education, 2024. ISBN: 9789353432751 4. K. Hoffman and R. Kunze, Linear Algebra (2nd edition), Prentice Hall India Learning Private Limited, 2015. ISBN: 9789332550070 5. S. Lang, Linear Algebra, Undergraduate Texts in Mathematics (3rd edition), Springer-Verlag, New York, 2004. ISBN: 9780387964126 6. P. Lax, Linear Algebra, John Wiley & Sons, New York, Indian Ed. 1997. ISBN: 9780471111115 7. H. E. Rose, Linear Algebra, Birkhauser, 2002. ISBN: 9783764367923

Course Code	**MA 643 (Till AY 2024-25)**
Title of the Course	**Algebra-II**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Linear Algebra (MA 641), Algebra-I (MA 640)
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Field and Galois theories.
Course Syllabus	Fields: definition and examples. Ring of polynomials over a field. Field extensions. Algebraic and transcendental elements. Algebraic extensions. Splitting field of a polynomial. Algebraic closure of a field. Normal, separable, purely inseparable extensions. Primitive elements of a field extension – simple extensions. Fundamental theorem of Galois. Geometric constructions. Cyclotomic extensions. Solvability by radicals, Solutions of cubic and quartic polynomials, Insolvability of quintic and higher degree polynomials.
Suggested Books	1. J. Rotman, *Galois Theory* (2nd Edition), Springer, 1998. 2. E. Artin, *Galois Theory*, Dover Publications, 1998. 3. D. A. Cox, *Galois Theory* (2nd Edition), John Wiley & Sons, 2012. 4. F. Borceux and G. Janelidze, *Galois Theories*, Cambridge University Press, 2001. 5. S. Lang, *Algebra* (3rd Edition), Springer, 2004.

Course Code	**MA 643 (From AY 2025-26 onwards)**
Title of the Course	**Algebra-II**
Course Category	Departmental Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisites, if any	Basics of linear algebra and algebra
Scope of the course (Objectives)	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in Field theory and Galois theory.
Course Outcomes	This course will enhance problem-solving skills for further study in algebra and related areas such as cryptography and algebraic coding theory.
Course Content	• Fields: definition and examples. Ring of polynomials over a field. • Field extensions. Algebraic and transcendental elements. Algebraic extensions. Splitting field of a polynomial. Algebraic closure of a field. Normal, separable, purely inseparable extensions. Primitive elements of a field extension – simple extensions. • Fundamental theorem of Galois. Geometric constructions. Cyclotomic extensions. Solvability by radicals, Solutions of cubic and quartic polynomials, Insolvability of quintic and higher degree polynomials.
Suggested Books	**Text Books:** 1. D. A. Cox, Galois Theory (2nd Edition), John Wiley & Sons, 2012, ISBN: 978111807205 2. J. Rotman, Galois Theory (2nd Edition), Springer, 1998, ISBN: 9780387985411 **Reference Books:** 1. F. Borceux and G. Janelidze, Galois Theories, Cambridge University Press, 2001, ISBN: 9780521803090 2. S. Lang, Algebra (3rd Edition), Springer, 2004, ISBN: 9780387953854

Course Code	**MA 651 (Till AY 2024-25)**
Title of the Course	**Numerical Analysis**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre–requisite, if any (for the students)	Analysis-I, Linear Algebra, ODE
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in interpolation theory, Numerical integration, numerical solution of system of linear equations, Numerical solution of ordinary differential equations, and finite difference methods.
Course Syllabus	Introduction, finite floating point arithmetic, catastrophic cancellation, chopping and rounding errors. Interpolation by polynomials, divided differences, error of the interpolating polynomial, piecewise linear and cubic spline interpolation. Numerical integration, composite rules, error formulae. Solution of a system of linear equations. Solution of a nonlinear equation, bisection and secant methods. Newton's method, rate of convergence, solution of a system of nonlinear equations. Numerical solution of ordinary differential equations, Euler and Runge-Kutta methods, multi-step methods, predictor-corrector methods, order of convergence, global errors, algebraic and shooting methods for boundary value problems. Finite difference methods, numerical solutions of elliptic, parabolic and hyperbolic partial differential equations. Eigen-value problem, power method, QR method, Gershgorin's theorem. Exposure to software packages like MATLAB.
Suggested Books	1. G. W. Stewarts, *Afternotes on Numerical Analysis*, SIAM, 1996. 2. S. D. Conte and C. de Boor, *Elementary Numerical Analysis- An Algorithmic Approach* (3rd Edition), McGraw- Hill, 1980. 3. G. Dahlquist and Å. Björck, *Numerical methods in Scientific Computing*, Vol-1, SIAM-2008. 4. C. E. Forberg, *Introduction to Numerical Analysis* (2nd Edition), Addison-Wesley, 1981. 5. D. Watkinson, *Fundamentals of Matrix Computations*, Wiley-Interscience (2nd edition), 2002. 6. M. L. Overton, *Numerical Computing with IEEE floating point Arithmetic*, SIAM 2001.

Course Code	**MA 651N (From AY 2025-26 onwards)**
Title of the Course	**Numerical Analysis**
Course Category	Core
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic Analysis, Linear Algebra, and Differential Equations
Scope of the course (Objectives)	Understanding different approximation methods with optimal errors to solve systems of equations, determine integrations, and computationally solving differential equations.
Course Outcomes	• Determining approximate roots of nonlinear equations. • Generating polynomials corresponding to non algebraic functions through interpolation techniques. • Applications of finite difference schemes to solve differential equations.
Course Content	Introduction, finite floating point arithmetic, catastrophic cancellation, chopping and rounding errors. Interpolation by polynomials, divided differences, error of the interpolating polynomial, piecewise linear and cubic spline interpolation. Numerical integration, composite rules, error formulae. Solution of system of linear equations, solution of nonlinear equations, bisection and secant methods. Newton's method, solution of systems of nonlinear equations. Convergence of the methods. Numerical solution of ordinary differential equations, Euler's and Runge-Kutta methods, multi-step methods, predictor-corrector methods, stability and order of convergence, global errors, algebraic and shooting methods for boundary value problems. Finite difference approximations of partial derivatives. LAB: Based on the topics covered in this course using mathematical tools.

Suggested Books	**Text Books:** 1. B. Bradie, A Friendly Introduction to Numerical Analysis, Pearson, 2017. ISBN: 9780130130549 2. David Kincaid, Ward Cheney. Numerical Analysis: Mathematics of Scientific Computing, American Mathematical Soc., 2009. ISBN: 9780821852071 **Reference Books** 1. Kendall Atkinson, Weimin Han, David Stewart, Numerical Solution of Ordinary Differential Equations, John Wiley & Sons, 2009. ISBN:9780470042946 2. Richard L. Burden, J. Douglas Faires, Numerical Analysis, 9th Edition, Cengage India Private Limited, 2012. ISBN:9788131516546

Course code	**MA 652/ MA 452**
Title of the course	**Theory of Transforms**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Calculus, Complex Variable, Differential Equations
Scope of the course	This course provides a working knowledge of analytical methods required in pure and applied mathematics, physics and engineering. It also gives a systematic exposition of the basic properties of various integral transforms and their applications to the solution of initial and boundary value problems in mathematical physics, engineering, and applied mathematics.
Course Syllabus	Fourier Series, Riemann-Lebesgue Lemma, Gibbs Phenomenon, Fourier Sine and Cosine Series, Fourier Transform, Fourier Integral Theorem, Convolution and Parseval_s Theorem, Applications to Partial Differential Equations. Laplace Transform: definition and properties, Complex Inversion, Convolution Theorem, Heaviside's Expansion Theorem, Bromwich Contour Integral, Applications to Initial and Boundary Value Problems. Fundamental Theorem of the Discrete Fourier Transform, Cyclical Convolution, and Parseval's Theorem. Z Transform: definition and examples, Basic Operational Properties of Z Transforms, Inverse Z Transform and Examples, Applications of Z Transforms to Finite Difference Equations and Summation of Infinite Series.
Suggested Books	1. L. Debnath, D. Bhatta, ***Integral transforms and their applications,*** Chapman & Hall/CRC, New York, 2006, 1584885750

	2. R. J. Beerends, H. G. ter Morsche, J. C. van den Berg, E. M. van de Vrie, ***Fourier and Laplace Transforms,*** Cambridge University Press, New York, 2003, 0521534410 3. A. Pinkus, S. Zafrany, ***Fourier Series and Integral Transforms,*** Cambridge University Press, New York, 1997, 0521597714 4. U. Graf, ***Applied Laplace Transforms and Z-Transforms for Scientists and Engineers***, Birkhauser Verlag, Basel, Switzerland, 2004 : 3034895933

Course code	**MA 653**
Title of the course	**Ramanujan's Mathematics**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic Knowledge of Real and Complex Analysis
Scope of the course	Srinivasa Ramanujan discovered around 4000 formulas in his short life of 32 years. In this course, we shall study various areas of Mathematics in which Ramanujan made startling contributions. At the end of the course, students will have a brief idea of recent research activities developed from Ramanujan's work.
Course Syllabus	Magic square, History of magic Square, Some open problems on Magic square, Ramanujan 's taxi-cab number, Generalization of Ramanujan's taxi-cab number, Hypergeometric series, Rapidly convergent series for 1 by pi, Gamma function, Riemann zeta function, Euler's formula for even zeta values, Ramanujan's formula for odd zeta values, Meaning to some divergent series, for example 1+2+3+---= -1/12, Partition function, Congruence of partition function, Asymptotic of the partition function, Ramanujan's tau function, Some important properties of Ramanujan's tau function.
Suggested Books	1. S. Ramanujan, ***Notebooks of Srinivasa Ramanujan, Vol 1 and 2***, TIFR, Mumbai, 2012. 2. B. C. Berndt, ***Ramanujan's Notebooks Vol I, II, III, IV and, V***, Springer. 3. S. Ramanujan, ***The Lost Notebook and other unpublished works of Srinivasa Ramanujan,*** Narosa Publishing House, 2008. ISBN: 978-81-7319-947-9 4. B. C. Berndt, ***Number theory in the spirit of Ramanujan***, American Mathematical Society, 2006: ISBN-13: 978-0-8218-4178-5

Course code	MA 654/ MA 454
Title of the course	**Mathematical Modeling and Simulations**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre-requisite, if any	Differential Equations, Linear Algebra
Scope of the course	The Mathematical model plays a significant role providing a quantitative framework for understanding and solving many real-life problems under certain conditions. Most of the mathematical models have been like individual works of art that reflected the personal characteristics and scientific views of the modeler. At the end of the course, students should be exposed to fundamental knowledge of implementing the models in real-world situations. They will get the bright idea about constructing or selecting the appropriate model, identify the problem, Analytically or numerically computing the solution and test the validity of models. This course provides an introduction to modeling through in-depth discussion of a series of real examples.
Course Syllabus	**Introduction to Mathematical Modeling:** Characteristics, Classifications, Tools, Techniques, Deterministic and stochastic models, Modeling approaches, Compartmental models, Introduction to Discrete Models and Continuous Models, Dynamical systems and its mathematical models. **Models from systems of natural sciences:** Population models for a single species (discrete and continuous-time models), Modeling of population dynamics of two interacting species, Analytical Tool: Kolmogorov Theorem, Linear Stability Analysis, Lotka-Volterra Model, Variation of the Classical LV Model, Leslie-Gower Model, Prey-Predator Model, Arms Race Model, Holling-Tanner Model, Modified HT Model, Applications of Lyapunov functions. **Modeling of Atmospheric, Mining and Engineering systems:** Spatial Models Using Partial Differential Equations, Modeling with Stochastic Differential Equations, Models of Heating and Cooling, Models for traffic flow, Model for detecting land mines, Models in Mechanical Systems, Models in Electronic systems, Models for vehicle dynamics, Kicked Harmonic oscillator, Modeling the ventilation system of a mine. MATLAB/MATHEMATICA programs to study the dynamics of the developed model systems.
Suggested Books	1. B. Barnes, G. R. Fulford, ***Mathematical Modeling with Case Studies,*** CRC PRESS, Taylor & Francis, London, New York, 2009, 13, 978-1-4200-8348-4 2. Edward A. Bender, ***An Introduction to Mathematical Modeling***: John Wiley & Sons, United States of America, 1978, 0-471-02951-3 3. R. K. Upadhyay, S. R. K. Iyengar, ***Introduction to Mathematical Modeling and Chaotic Dynamics,*** CRC Press Taylor & Francis, London, New York, 2014, 13: 978-1-4398-9887-1 4. S. Banerjee, ***Mathematical Modeling,*** Models, Analysis and Applications, CRC Press, Taylor & Francis, London, New York, 2014, 13: 978-1-4822-2916-5

Course Code	**MA 456 / MA 656**
Title of the Course	**Stochastic Approximation**
Course Category	Elective
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Theoretical knowledge of probability
Scope of the course (Objectives)	This course provides basic tools and techniques for studying Stochastic Algorithms and their convergence analysis
Course Outcomes	The student is able to use iterative method to find the approximate zeros of class of function whose numerical value is not directly available. The student will expose to theoretical convergence analysis of recursive stochastic algorithms.
Course Content	• Introduction to stochastic approximation. • Conditional Expectation, Independence, Filtration, Martingales, Doob's Maximal inequality, Martingale convergence theorem, Burkholder-Davis-Gundy Inequality. • Robbin-Monro method, Kiefer-Wolfowitz method, Robbins-Siegmund Lemma, stochastic gradient method, the ordinary differential equation method, rate of convergence, asynchronous schemes
Suggested Books	**Text Books:** 1. R. L. Karandikar, B.V. Rao, Introduction to Stochastic Calculus, Springer Nature Singapore, 2018. ISBN: 978981108318 2. H. J. Kushner, G.G. Yin, Stochastic Approximation and Recursive Algorithms and Applications, Springer, New York NY, 2011. ISBN: 9780387891194 3. Vivek S. Borkar, Stochastic Approximation: A dynamical systems viewpoint, Springer, Singapore, 2023. ISBN: 9789819982769 **Reference Book** 4. Gilles Pages, Numerical Probability: An introduction with applications to finance, Springer Nature, Switzerland, 2018. ISBN: 9783319902746 5. M.T. Wasan, Stochastic Approximation, Cambridge University Press, New York NY, 2004. ISBN: 9780521604857

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

Course Code	**MA 673**
Title of the Course	**Fundamentals of Discrete Mathematics**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem solving skills in basic graph theory, basic mathematical logics, boolean algebras, basic combinatorics, and advanced set theory.
Course Syllabus	**Graphs:** Graphs and Graph Models, Graph Terminology and Special Types of Graphs, Representing Graphs and Graph Isomorphism, Connectivity, Euler and Hamilton Paths, Shortest-Path Problems, Planar Graphs, Graph Coloring. **Logic:** Propositional Logic, Propositional Equivalences, Predicates and Quantifiers, Nested Quantifiers, Rules of Inference. **Boolean Algebras:** Lattices, Distributive and Complemented lattices, Boolean Algebras, Uniqueness of Finite Boolean Algebras, Boolean Functions, Switching Circuits. **Combinatorics:** Numbers and Counting, Partitions and Permutations, Principle of Inclusion and Exclusion, Pigeon Hole Principle, Recurrence Relations, Generating Functions. **Set Theory:** Axiom of Choice, Zorn's Lemma, Cardinality, Schroder-Bernstein Theorem, Countability and Uncountability, Cantor's Theorem, Cardinal Arithmatic.
Suggested Books	1. K. H. Rosen, *Discrete Mathematics and Its Applications*, McGraw-Hill Education, 4th Edition, 1999. 2. C. L. Liu and D. P. Mohapatra, *Elements of Discrete Mathematics*, Tata McGraw-Hill, 3rd Edition. 3. D. J. Hunter, *Essentials of Mathematics*, Jones & Bartlett Publishers, 2010. 4. P. R. Halmos, *Naive Set Theory*, Springer-Verlag, New York, 1974. 5. P. J. Cameron, *Combinatorics: Topics, Techniques, Algorithms*, Cambridge University Press, 1994.

Course Code	**MA 675 / ME 675**
Title of the Course	**Probability and Statistical Methods**
Credit Structure	L-T- P-Credits 2-0-2-3
Name of the Concerned Disciplines	Mathematics and Mechanical Engineering
Pre–requisite, if any	None
Scope of the Course	The primary goal is to develop ability as well as awareness of reasoning and decision-making utilizing statistical data. The quality of decision making is decided by the way data and information is handled/interpreted by a researcher.
Course Syllabus	**Introduction to statistics**: definitions and terminology; data classification; data collection techniques, various scales for measurement and their relevance **Descriptive statistics:** frequency distributions; measures of central tendency, Variation **Probability:** basic concepts; multiplication and addition rules, Bayes rule, Discrete probability distributions: basic concepts; Binomial, Poisson, and other discrete distributions, Continuous probability distributions: Exponential, Normal, Weibull, and other continuous distribution. **Normal probability distributions**: introductory concepts; the standard normal Distribution; central limit theorem, applications of normal distributions, approximations to discrete probability distributions **Correlation and Regression analysis:** overview of correlation; linear regression, **Hypothesis Testing:** Null and Alternative Hypothesis, Type I and Type II errors, Confidence intervals: confidence intervals for the mean (large samples and small samples) and for population proportions, p-value, z-test, t-test, F-test, etc. Analysis of Variance **Taguchi Method and Design of Experiments, Non-parametric tests, Case studies and applications to managerial decision making**
Suggested Books	1. P.L. Meyer, **Introductory Probability and Statistical Applications**, Oxford and IBH Publishers, ISBN: 0-201-04710-1. 2. I.R. Miller, J.E. Freund, R. Johnson, **Probability and Statistics for Engineers**, Prentice-Hall (I) Ltd, ISBN: 9788177581843. 3. R.E. Walpole and R.H. Myers, **Probability & Statistics for Engineers and Scientists**, Macmillan, ISBN: 9788131715529. 4. S.M. Ross, **Introduction to Probability and Statistics for Engineers and Scientists**, Academic Press, ISBN: 9780123704832.
Lab	It will mainly involve use of computer software (Minitb, Statistica, etc.) to solve complex engineering problems/ case studies as well as manually solving some of the basic tutorials and interpreting the results for decision making. Following points will be mainly covered: a. General, data representation, Mean, expectations, pdf, cdf

	b. Chebyshevs' inequality, probability distributions: Poisson, Binomial, Normal, Weibull, etc. c. MGF, d. Sampling with and without replacement e. Type I , II and Hypothesis testing, Hypothesis testing f. Chi-square test, g. Regression h. RBD, CRD, Factorial, Taguchi

Course Code	**MA 680**
Title of the Course	**Computational Techniques**
Credit Structure	L-T- P-Credits 3-0-2-4
Name of the Concerned Department	Mathematics
Pre–requisite, if any (for the students)	Basic knowledge in matrix algebra, differential equations, calculus, and statistics.
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge in data structures, algorithms, programming languages, and computations using MATLAB, Mathematica, and R-Software.
Course Syllabus	**Programming in C:** Background, Variables, Constants, Data types, Operators and Expressions, Conditional statements: if, if-else, Loops: for, while, do-while, Array, Function, Pointers, Dynamic memory allocation, Files. **Data Structure and Algorithm:** Stack, Applications of stack: arithmetic expression evaluation, recursion, Queue, Circular queue, Linked list: Single linked list, Circular linked list, Doubly linked list, Tree Data Structure: Binary tree, Tree traversal techniques, AVL Tree, B-tree, B+-tree, Graph: representation of graph using adjacency matrix and linked list, Applications of graph structures: Minimum spanning trees, Connectivity in graph, DFS, BFS, Hashing: Hash function, Collision resolution in hashing, Complexity Analysis of Algorithms: Asymptotic notations, Searching and Sorting: Linear search, binary search, Bubble sort, Selection sort, Insertion sort, Quick sort, Heap sort, merge sort. **MATLAB:** IEEE Arithmetic, Mathematical Functions, Matrix and Array operations, Matrix manipulation, Script and functions, working with mfiles and the matlab path, two-dimensional graphics (Basic plots), Three dimesional Graphics, LU, QR, Systems of Linear Equation, Basic numerical Methods for solving simple ODE, Data fitting, Optimization, non linear equation. **Mathematica:** User interface, Mathematica language and syntax, Introduction to computation, polynomial operations, solving equations, functions and simplification, 2D and 3D plotting, plotting data, creating dynamic and interactive graphics, solving simple ordinary differential equations. **The R Software:** Introduction to R; Importing and exporting data from - Excel, SPSS, SAS, Stat, CSV, txt file; Data Types (like vector, matrix, dataframe, list, numeric, factors, characters,etc); Viewing Data, Date Values, Access to DBM.S.; Sorting Data , Merging Data, Appending Data, Reshaping Data, Subsetting Data; Data Type Conversion, Merging, RMySQL (joins); R-packages, Built-in-Functions, write functions, call functions; Local & global variables and functions; Control Structures- if, ifelse, for, while, switch, stop , break, which function; Descriptive Statistics; Frequency & Crosstab; Visualization, Graph and plots (Histogram, time series, box plot).

Suggested Books	1. A. V. Aho, J. D. Ullman, and J. E. Hopcroft, *Data Structures and Algorithms*, Addison-Wesley, 1983. 2. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, McGraw-Hill, 2001. 3. Y. Kanetkar, *Let Us C*, BPB Publications, ISBN-13: 9788183331630, 2012. 4. E. Balaguruswamy, *Programming in ANSI C*, Tata McGraw-Hill, ISBN-13: 9781259004612, 2012. 5. B. W. Kernighan and D. M. Ritchie, *The C Programming Language*, Prentice Hall of India, ISBN-13: 9788120305960, 2009. 6. B. Gottfried, *Schaum's Outline of Programming with C*, Tata McGraw-Hill, ISBN-13: 9780070240353. 7. D. Samanta, *Classic Data Structures*, PHI, Second Edition, 2009. 8. S. Lipschutz, *Data Structure with C*, Schaum's OuTlines, TMH, 2011. 9. Y. Langsam, M. J. Augenstein, and A. M. Tenenbaum, *Data Structure using C and C++*, Prentice Hall, Second Edition, 2009. 10. D. J. Higham and N. J. Higham, *MATLAB Guide*, 2nd Edition, SIAM, 2005. 11. A. Gilat, *MATLAB: An Introduction with Applications*, John Wiley & Sons Inc. 5th Edition, 2014. 12. S. Wolfram, *Mathematica: Standard Add-on Packages*, Cambridge University Press, 1996. 13. P. R. Wellin, R. J. Gaylord, and S. N. Kamin, *An Introduction to Programming with Mathematica*, 3rd Edition, Cambridge University Press, 2005. 14. H. Ruskeepaa, *Mathematica Navigator: Mathematics, Statistics, and Graphics*, 3rd Edition, Academic Press Inc., 2009. 15. W. N. Venables and D. M. Smith, *An Introduction to R*, Network Theory Limited, Second Edition, 2009. 16. P. Teetor, *R Cookbook*, O'Reilly Media, First Edition, 2011.
Lab	Laboratory components include Programming using C++ language, computations using MATLAB, Mathematica and the R Software. All these will be taught in computer lab using computers.

Course Code	**MA 701**
Title of the Course	**Experimental Designs and Data Analysis**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Nil
Scope of the course	
Course Syllabus	Review of standard discrete and continuous statistical distributions. Sampling distributions such as chi-square, Student's t and, F- distribution. Estimation and Tests of Hypotheses. Regression and Correlation Analysis. Test for independence and goodness of fit. Non-parametric tests. Analysis of Variance (ANOVA): One way and Two-way classification. Analysis of Covariance (ANCOVA). Experimental Designs: CRD, RBD, LSD, BIBD. Split plot and missing plot technique. Orthogonal Arrays: Application to Taguchi Method. Introduction to Response Surface Methodology (RSM).
Suggested Books	1. R.E. Walpole, **Probability and Statistics for Engineers and Scientists**, Prentice-Hall-Gale, 1998. (ISBN:0138402086.) 2. D.C. Montgomery, **Design and Analysis of Experiments** (5th edition), John Wiley & Sons (Asia) Pte. Ltd. Singapore, 2004. (ISBN: 0471316490). 3. R. Y. Myers, et al., **Response Surface Methodology: Process and Product Optimization using Designed Experiments** (3rd edition), Wiley, 2009. 4. M.S. Phadke, **Quality Engineering Using Robust Design**, Prentice Hall, Englewood Cliff, New Jersey, 1989.

Course Code	**MA 702**
Title of the Course	**Conformal Mappings**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Complex Analysis
Scope of the course	
Course Syllabus	**Preliminaries:** Analytic functions, Basic theorems, The Riemann sphere, Möbius transformations, Cross ratio, Inverse points, Characterization of maps between special domains. **Conformal Mappings:** Definition of conformal maps, Disk automorphism, Schwarz's lemma, Schwarz-Pick's lemma, The hyperbolic metric in the unit disk, The upper half plane model. **The Riemann Mapping Theorem:** Normal families, The Riemann mapping theorem, the hyperbolic metric in simply connected domains, The Schwarz reflection principle, The Schwarz-Christoffel mappings. **Quasiconformal Mappings:** Conformal and quasiconformal maps, Introduction to Grötzsch problem, Complex dilatation, Definition of quasiconformal maps, Solution to Grötzsch problem, Composition maps, Extremal length, Geometric definition of quasiconformal maps, Mori's theorem.
Suggested Books	1. Lars V. Ahlfors, Complex Analysis, McGraw Hill, 1996. 2. T.W. Gamelin, Complex Analysis, Springer (Corrected edition), 2001. 3. S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser, 2006. 4. Zeev Nehari, Conformal Mapping, Dover Publications, 1982. 5. L. Keen and N. Lakic, Hyperbolic Geometry from a Local Viewpoint (London Mathematical Society Student Texts), Cambridge University Press, 2007. 6. Lars V. Ahlfors, Lectures on Quasiconformal Mappings, American Mathematical Society (Second Edition with additional chapters by C.J. Earle and I. Kra, M. Shishikura, J.H. Hubbard), 2006. (Originally published by D. Van Nostrand Company, Inc. 1966) 7. O. Lehto and K.I. Virtanen, Quasiconformal mappings in the plane, Springer, 1973. 8. O. Lehto, Book Title: Univalent functions and Teichmüller spaces, Springer, 1986. 9. K. Asthala, T. Iwaniec, and G. Martin, Elliptic Partial Differential Equations and Quasi-conformal Mappings in the Plane, Princeton University Press, 2008.

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Course Code	**MA 703**
Title of the Course	**Topics in Analysis**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline/Discipline	Mathematics
Pre–requisite, if any	Real Analysis, Complex Analysis, Functional Analysis, Fourier Series
Scope of the course	
Course Syllabus	Functions of bounded variations, Riemann-Stieltjes Integration, Riemann Mapping Theorem, Univalent Functions, Bieberbach's Theorem, Hadamard's three circle theorem, Riemann's Zeta Function, Continuous but nowhere differentiable functions (example), Weierstrass approximation theorem (Stone-Weierstrass Theorem), Hahn Banach Theorem, Fourier series, Dirichlet's Theorem, Fejer's Theorem.
Suggested Books	1. H.M. Edwards, Riemann's Zeta Function, Dover Publications; Dover 2. Ed edition, 2001, ISBN: 9780486417400. 3. E.C. Titchmarsh, The theory of the Riemann Zeta-Function, Oxford 4. University Press, USA; 2 edition, 1987, ISBN: 9780198533696. 5. Walter Rudin, Principles of mathematical analysis (3rd. ed.), McGraw-Hill, 1976, ISBN: 978-0070542358. 6. Walter Rudin, Functional analysis, McGraw-Hill, 1973, ISBN: 7. 9780070542365. 8. Peter L. Duren, Univalent Functions, Springer-Verlag Berlin and 9. Heidelberg GmbH & Co. K, 1983, ISBN: 9783540907954. 10. Georgi P. Tolstov, Fourier Series, Dover Publications, 1976, ISBN: 978-0486633176. 11. G.H. Hardy and W.W. Rogosinski, Fourier Series, Dover Publications 1999, 978-0486406817.

Course Code	**MA 704**
Title of the Course	**Probability Theory**
Credit Structure	L-T-P-Credits 2-1- 0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Measure Theory
Scope of the course	
Course Syllabus	Probability Space, Random Variables, Kolmogorov Consistency Theorem, Independence and Dependence, Weak and Strong law of large numbers, Central Limit Theorem, Characteristic Function, Levy's Inversion Formula, Levy's Continuity Theorem, Conditional Expectation, Martingales, Markov Chains, Wiener Process, Stationary Process, Entropy and its Applications, Large Deviations.
Suggested Books	1. Daniel W. Stroock, Probability Theory, an Analytic View, Cambridge University Press; Revised edition (January, 2000), ISBN-10: 0521663490, ISBN-13: 978-0521663496. 2. Krishna B. Athreya and Soumendra Lahiri, Probability Theory, Hindusthan Book Agency, 2006, ISBN: 978-81-85931-70-8. 3. A.N. Kolmogorov, Foundations of the Theory of Probability, Chelsea Pub Co, 2nd edition,1960 (ISBN: 9780828400237) 4. K.R. Parthasarathy, Introduction to Probability and Measure (Texts & Readings in Mathematic), Hindustan Book Agency, New Delhi, 2005. (ISBN: 9788185931555) 5. W. Feller, An Introduction to Probability Theory and Its Applications, Wiley, 3 edition,1968. (ISBN: 9780471257080)

Course Code	**MA 705**

Title of the Course	**Applied Operator Theory**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Real Analysis, Complex Analysis and Linear Algebra.
Scope of the course	Familiarize the basic concepts of functional analysis and their application in solving various operator equations
Course Syllabus	Normed Linear Space, Linear Transformations, Zorn's Lemma, Hamel Basis and Hahn-Banach Theorem, The Baire Theorem and Uniform Boundedness Theorem, The interior mapping and closed mapping Theorems, Weak convergence, Reflexive Space. Hilbert Spaces, Orthogonality and Bases, Linear functonals and operators, Spectral Theory, Strum-Liouville Theory. Calculus in Banch spaces, The Frechet Derivative, The chain Rule and Mean value Theorems. Basic Approximate methods of Analysis, The method of iteration, Regularization method, Projection methods, The Galerkin method, The Rayleigh-Ritz method, Conjucate Direction methods, Methods Based on Homotopy and continuation.
Suggested Books	1. W. Cheney, *Analysis for Applied Mathematics,* Springer, 2001. ISBN: 978-0-387-95279-6 2. E. Zeidler, *Applied Functional Analysis: Applications to Mathematical Physics,* Springer 1995. ISBN: 978-0387944425 3. L.P. Lebedev, I.I. Vorovich and G.M.L. Gladwell, *Functional Analysis: Applications in Mechanics and Inverse Problems,* Kluwer Academic Publishers, 2002. ISBN: 978-1402006678 4. L. Collatz, *Functional Analysis and Numerical Mathematics*, Springer-Verlag New York ,1966. 5. J.T. Oden and L.F. Demkowicz, *Applied Functional Analysis* CRC- Press, 1996. ISBN: 978-0849325519

Course Code	**MA 706**
Title of the Course	**Numerical Linear Algebra**
Credit Structure	2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Knowledge of basic linear algebra.
Scope of the course	Problems in Numerical Linear Algebra arise in a wide variety of scientific and engineering applications including the control theory, the analysis of electrical networks, and the modeling of chemical processes. This course will cover the analysis and implementation of algorithms used to solve linear algebra problems. We will study algorithms for linear systems solution, linear least-square problems, and eigenvalue and singular value problems. Further, we study the sensitivity and stability analysis of the above algorithms to improve efficiency of problems by using various structures of matrices.
Course Syllabus	Floating point error, Round off error, Gram-Schmidt orthonormal process, Modified Gram-Schmidt orthonormal process, **Solution of linear system:** Triangular systems and Inverse of a triangle matrix, Gauss elimination and LU Factorization method, QR factorization, QR Algorithm. Rank deficient least square problems, SVD, Moore Penrose inverse, Linear iterative methods – Convergence results for Jacobi & Gauss -Seidel and relaxation method. Stationary & non stationary iterative methods Convergence analysis of the Richardson method, the gradient method, the Conjugate gradient method. Method based on Krylov subspace Arnoldi method, the GMRES, The Lanczos method. Approximation of Eigen value: Power method, Inverse iteration, Sensitivity analysis of Eigen values and Eigen vectors, canonical forms of matrices, Reduction to Hessenberg and tridiagonal form, conditioning of numerical algorithms. Applications to control, H_∞ control, Distance problems. Analysis of electric network. Finite Difference analysis of ordinary differential equation- Beam bending problem. Finite difference analysis of partial differential equation-Heat equation. Applications to Internet search engine-Google Matrix.
Suggested Books	1. G. H. Golub and V. Van Loan, Matrix Computations, third edition, John Hopkins U. Press, Baltimore, 1996. 2. C. Pozrikidis, Numerical Computation in Science and Engineering, Oxford University Press, 1998. 3. A. Quarteroni, R. Sacco, and S. Fausto, Numerical Mathematics, second edition Springer-Berlin Heidelberg, 2007. 4. K. Bryan and T. Leise, The $ 25,000,000,000 eigenvector: The Linear Algebra Behind Google, SIAM Review, 48, 569-581. 5. David S. Watkins, Fundamentals of Matrix Computations, Wiley 3rd edition. 6. James W. Demmel, Applied Numerical Linear Algebra, 1st edition, SIAM 1997. 7. B. N. Datta, Numerical Linear Algebra and Application 2nd edition SIAM 8. B. N. Datta, Numerical Methods for Control Systems Design and Analysis, Elsevier Academic Press, 2003.

Course Code	**MA 707**
Title of the Course	**Special Functions**
Credit Structure	2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Basic complex analysis and differential equations
Scope of the course	
Course Syllabus	**Preliminaries:** Infinite product; Gamma function; Beta function **Hypergeometric Functions:** Integral form; The contiguous function relation; Hypergeometric differential equation; Logarithmic solution; Relation between functions of z and 1-z **Bessel's Functions:** Definition; Bessel's differential equation; Recurrence relation; A generating function; Bessel's integral; Modified Bessel's function **Generating Functions:** Functions of the form G(2xt-t^2); Functions of the form exp(t) ψ(xt); Functions of the form A(t) exp(-xt/(1-t)) **Orthogonal Polynomials:** Legendre polynomial; Hermite polynomial; Laguerre polynomial; Jacobi polynomial
Suggested Books	1. Earl D. Rainville, *Special Functions*, Chelsea Pub. Co. NY, 1971. ISBN: 978-0828402583 2. G.E. Andrews, R. Askey, and R. Roy, *Special Functions*, Cambidge University Press, 1999. ISBN: 978-0521623216 3. R. Beals and R. Wong, *Special Functions: A Graduate Text*, Cambidge University Press, 2010. ISBN: 978-0521197977 4. N.M. Temme, *Special Functions, An Introduction to the Classical Functions of Mathematical Physics*, Wiley-Interscience, 1996. ISBN:978-0471113133 5. A.M. Mathai and H.J. Haubold, *Special Functions for Applied Scientists*, Springer, 2008. ISBN: 978-0387758930 6. W.W. Bell, *Special Functions for Scientists and Engineers*, Dover Publication, 2004. ISBN: 978-0486435213

Course Code	**MA 708**
Title of the Course	**Ergodic Theory**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Measure Theory
Scope of the course	
Course Syllabus	Measure Preserving and Continuous Transformation, Poincare's recurrence Lemma, Ergodic Theorems, Ergodicity, Mixing and weak mixing and their Spectral Characterizations, isomorphism invariants, Discrete Spectrum Theorem, Entropy and Kolmogorov, Sinai Theorem, Stacking method of constructing transformations, Ambrose theorem on representation of flows. Van der Waerden's theorem on arithmetical Progressions.
Suggested Books	1. I.P. Cornfeld, S.V. Fomin, and Ya G. Sinai, Ergodic Theory, Springer-Verlag Berlin and Heidelberg GmbH Co. K (December 31,1982), ISBN-10: 3540905804, ISBN-13: 978-3540905806. 2. P. Walters, An Introduction to Ergodic Theory (Graduate Texts in Mathematics), Springer, 2000. (ISBN: 9780387951522) 3. M.G. Nadkarni, Basic Ergodic Theory, Hindusthan Book Agency, 1995.

Course Code	**MA 709**
Title of the Course	**Advance Numerical Methods for Linear Control Systems**
Credit Structure	2-1-0-3
Name of the Concerned Discipline/Discipline	Mathematics
Pre–requisite, if any	Basic Linear Algebra and Numerical Linear Algebra Techniques
Scope of the course	Modern Numerical linear techniques for mathematical problems arising in the design and analysis of linear control systems both for the first-order and second-order models. In this course we impose systematic descriptions and implementations of numerical algorithms based on well-established, efficient, and stable manner so that it will be help full to solve the various problems on design and analysis of linear control systems.
Course Syllabus	Review of Basic Concepts and Results from Theoretical Linear Algebra; Fundamental Tools and Concepts from Numerical Linear Algebra; Canonical Forms Obtained via Orthogonal Transformations; Linear State Space Models and Solutions of the State Equations; Controllability, Observability and Distance to Uncontrollability; Stability, Inertia and Robust Stability; Numerical Solutions and Conditioning of Lyapunov and Sylvester Equations; Numerical Methods and Conditioning of the Eigenvalue Assignment Problems; State Estimation; Numerical Solutions and Conditioning of Algebraic Riccati Equations;
Suggested Books	1. B. N. Dutta, *Numerical Methods for Linear Control System,* Elsevier Academic Press, 2003 2. G. H. Golub and V. Van Loan, *Matrix Computations,* 3rd edition, John Hopkins U. Press, Baltimore, 1996. 3. B. N. Dutta, *Numerical Linear Algebra and Application,* 2nd edition, SIAM.

Course Code	**MA 710**
Title of the Course	**Fractional Differential Equations**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Real Analysis
Scope of the course	Answering the following questions: 1. Why do we need fractional calculus / fractional differential equation? 2. How to solve the fractional differential equations explicitly? 3. When does the fractional differential equations have unique solutions?
Course Syllabus	Introduction to Fractional calculus, Grunwald-Letnikov Fractional Derivatives, Riemann-Liouville Fractional Derivatives, Caputo's Fractional Derivative. Introduction to Fractional Differential Equation, Explicit solution of fractional differential equation via Integral Transform Methods. Existence and Uniqueness Theorem for initial value problem, boundary value problem. Fractional delay differential equation.
Suggested Books	1. A.A. Kilbas, H.M. Srivastava and J.J. Trujillo, *Theory and Applications of fractional differential equations*, Elsevier, USA, 2006. ISBN: 978-0-444-51832-3. 2. I. Podlubny, *Fractional Differential Equations*, Academic Press, USA, 1999. ISBN: 978-0-12-558840-2. 3. K. Diethelm, *The analysis of fractional differential Equations*, Springer, New York, 2010. ISBN: 978-3-642-14573-5. 4. R. Hilfer, *Applications of fractional calculus in physics*, World Scientific, Singapore, 2000. ISBN: 978-9810234577

Course Code	**MA 711**
Title of the Course	**Analysis**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Elementary Analysis, Functional Analysis, Multivariable Calculus, Elementary Topology and Measure Theory
Objectives of the course	It is one of the basic fundamental courses for research scholars in Discipline of Mathematics. This course will enable them to understand topics from various branches in Mathematics.
Course Syllabus	Metric spaces, Open and closed sets, Compactness and connectedness, Completeness, Continuous functions (several variables and on metric spaces), uniform continuity, C(X) for a compact metric space X, Uniform convergence, Compactness criterion, Weierstrass approximation theorem (Stone-Weierstrass Theorem), Differentiation, Inverse and Implicit fuction theorems, Riemann Integration, Lebesgue Integration, L^p-spaces, Banach Spaces and Hilbert Spaces.
Suggested Books	1. G.F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill International, New York, 1963. 2. H.L. Royden, *Real Analysis*, Macmillan Publishing Company, New York, 1968. 3. B.V. Limaye, *Functional Analysis with Applications*, New Age International, 2008. 4. W. Rudin, *Principles of Mathematical Analysis*, McGraw-Hill International, 1976. 5. Tom. M. Apostol, *Mathematical Analysis*, Addison-Wesley, 1974. 6. I.J. Maddox, *Elements of Functional Analysis*, Cambridge University Press, 1988.

Course Code	**MA 712**
Title of the Course	**Advanced Analysis**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/Discipline	Mathematics
Pre–requisite, if any	Basic functional analysis
Scope of the course	It is the fundamental course for research scholars in the Discipline of Mathematics. This course will enable them to understand various branches in Mathematics.
Course Syllabus	Review of general measure and integral; Positive Borel measures; Riesz representation theorem; Luzin's theorem; Vitali Caratheodory theorem. Lp-spaces and their dense subspaces, Elementary Hilbert space theory, Examples of Banch space Techniques, Complex measures; Absolute continuity; Radon-Nykodym theorem, Product measures; Fubini's theorem; Convolutions.
Suggested Books	1. W. Rudin, *Real and Complex Analysis*, Third edition, McGraw-Hill, International Editions, 1986. ISBN: 978-0070542341 2. H.L. Royden, Real *Analysis* (3rd ed.), Prentice Hall, 1988, ISBN: 978-0024041517 3. I.K. Rana, *An Introduction to Measure and Integration*, Alpha Science International Limited, 2004. ISBN: 978-1842651049 4. P.R. Halmos, *Measure Theory*, Springer-Verlag, 1974. ISBN: 978-0387900889

Course Code	**MA 714**
Title of the Course	**Advanced Complex Analysis**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Complex Analysis
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem-solving skills in Harmonic functions, Meromorphic and entire functions, Analytic continuation, Riemann Mapping and Uniformization Theorems.
Course Syllabus	**Harmonic Functions:** Definition and basic properties, The Mean-value property, Poisson's formula, Harnack's principle, The Dirichlet problem. **Meromorphic and Entire Functions:** Infinite sums and meromorphic functions, Infinite products, The gamma function, The zeta function, Jensen's formula, The order and the genus of entire functions, Hadamard's factorization theorem, Weierstrass's product theorem, Mittag-Leffler's theorem. **Analytic Continuation:** Schwarz's Reflection principle, Direct Analytic Continuation, Analytic continuation along arcs, Monodromy Theorem. **Range of Analytic Functions:** Univalent functions, The Schwarz-Pick lemma, Normal families, The Riemann mapping theorem, Bloch's theorem, The little Picard theorem, Schottky's theorem, The great Picard theorem. **Riemann Surfaces:** Topological spaces, Neighborhood systems, Germs and sheaves, Analytic manifolds, Covering spaces, The uniformization theorem.
Suggested Books	1. L. V. Ahlfors, *Complex Analysis*, McGraw-Hill International Editions, Third Edition, New Delhi, 1979. 2. J. B. Conway, *Functions of One Complex Variable*, Springer International Student Edition, Narosa Publishing House, New Delhi, 1973. 3. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, Second Edition, New Delhi, 2005. 4. T. W. Gamelin, *Complex Analysis*, Undergraduate Texts in Mathematics, Springer, NY, 2001. 5. S. Ponnusamy and H. Silverman, *Complex Variables with Applications*, Birkhaeuser, Boston, 2006.

Course code	**MA 715**
Title of the course	**Analytic Number Theory**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Mathematics
Pre-requisite, if any	Basic Knowledge of Real and Complex Analysis
Scope of the course	Number Theory is one of the oldest branches of mathematics. The primary goal of this course is to understand various important concepts in number theory and to solve problems in number theory using the techniques of real and complex analysis.
Course Syllabus	Prime numbers, Euclid's theorem (Infinitude of primes), Fermat numbers, Some well-known open problems, Arithmetic functions, Mobius function, Euler's totient function, Multiplicative function, Dirichlet multiplication of arithmetic functions, Big Oh notation, Euler's summation formula, average order of some arithmetical functions, Chebyshev's function, Divisor function, Dirichlet divisor problem, Prime number theorem, Dirichlet character, Gauss sums, Dirichlet's theorem on primes in arithmetic progressions, Gamma function, Introduction to the theory of the Riemann zeta function, Functional equation, Analytic continuation, Zero-free regions, Riemann hypothesis (Million dollars open problem).
Suggested Books	1. T. M. Apostol, ***Introduction to Analytic Number Theory***, Springer, 1998. ISBN 978-1-4757-5579-4 2. K. Chandrasekharan, ***Introduction to Analytic Number Theory***, Springer, 1968. ISBN 978-3-642-46124-8 3. M. Ram Murty, ***Problems in Analytic Number Theory***, Springer, 2001. ISBN 978-0-387-72350-1 4. G. H. Hardy and E. M. Wright, ***An introduction to the Theory of Numbers***, Oxford University Press, Sixth Edition, 2008. ISBN: 9780199219865 5. J. Stopple, ***A Primer of Analytic Number Theory: From Pythagoras to Riemann***, Cambridge University Press, 2003. ISBN: 9780521813099

Course Code	**MA 720**
Title of the Course	**Differential Equations**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Elementary Ordinary and Partial Differential Equations
Objectives of the course	It is one of the basic fundamental courses for research scholars in Discipline of Mathematics. This course will enable them to understand topics from various branches in Mathematics.
Course Syllabus	Preliminaries, Picard's Method of Successive Approximations, Existence Theorems, Continuous Dependence on Initial Conditions, Linear equations, general theory, Solutions of linear equations with constant coefficients, Equations with periodic coefficients, Green's Functions, Sturm-Liouville Problems, Lyapunov theory of stability. First order quasi-linear equations, Nonlinear equations, Cauchy-Kowalewski's theorem, Classification of second order equations, One dimensional wave equation and De'Alembert's method, Solution of wave equation, Solutions of equations in bounded domains and uniqueness of solutions, BVPs for Laplace's and Poisson's equations, Maximum principle and applications, Green's functions and properties, Existence theorem by Perron's method, Heat equation, Maximum principle, Uniqueness of solutions via energy method, Uniqueness of solutions of IVPs for heat conduction equation, Green's function for heat equation.
Suggested Books	1. E.A. Coddington, *Introduction to Ordinary Differential Equations*, Prentice Hall, 1961. 2. E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, Tata McGraw-Hill, 1955. 3. P. Prasad and R. Ravindran, *Partial Differential Equations*, New Age International, 1985. 4. S.G. Deo and V. Raghavendra, *Ordinary differential equations and stability theory*, Tata McGraw-Hill, 1980. 5. F. John, *Partial Differential Equations*, Springer, 1981. 6. I.N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill, 1972. 7. I.N. Sneddon, *Elements of Partial Differential Equations*, Dover Publications, 2006. 8. G.B. Folland, *Introduction to Partial Differential Equations*, Princeton University Press, 1995.

Course Code	**MA 734**
Title of the Course	Fourier Analysis on Euclidean Spaces
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Functional Analysis
Objectives of the course	At the end of course, students should have the basic understanding of Fourier series, Fourier transform, Maximal function and Hilbert Transform.
Course Syllabus	Fourier series, Summability methods, Convergence in norm. Fourier transform, the Schwartz space, Fourier Inversion and Plancherel theorem, The Poission summation formula. Interpolation of operators, The Hardy-Littlewood Maximal function, Lebesgue Differentiation theorem, Hilbert Transform, Boundedness of Singular integral operators.
Suggested Books	1. E. M. Stein and R. Shakarchi, *Fourier Analysis: An Introduction*, Princeton University Press, 2003. 2. E. M. Stein and G. Weiss, *Introduction to Fourier analysis on Euclidean Spaces*, Princeton University Press, 1975. 3. J. Duoandikoetxea, *Fourier Analysis*, GSM-29 American Mathematical Society, 2001. 4. H. Dym and H. McKean, *Fourier Series and Integrals*, Academic Press, 1985. 5. Y. Katznelson, *An Introduction to Harmonic Analysis* (3rd Edition), Cambridge University Press, 2004. 6. L. Grafakos, *Classical Fourier Analysis* (2nd Edition), Springer , 2011. 7. A. Torchinsky, *Real-Variable Methods in Harmonic Analysis*, Dover Publications, 2004.

Course Code	**MA 736**
Title of the Course	**Wavelet Analysis**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Functional Analysis
Objectives of the course	At the end of course, students should have the basic understanding in Fourier Analysis, Wavelet transforms, Time-frequency Analysis and Multi-resolution Analysis.
Course Syllabus	**ELEMENTS OF FOURIER ANALYSIS:** Fourier series, Fourier transforms Inversion formula, Parseval Identity and Plancherel Theorem, Continuous-time convolution and the delta function, Poisson's summable formula, Shanon sampling theorem. **WAVELET TRANSFORM.S. AND TIME- FREQUENCY ANALYSIS:** The Balian-Low theorem, The Gabor transform, Windowed Fourier transform, uncertainty principle, Integral wavelet transform, Dyadic wavelets, Frames, Wavelet series. **MULTI-RESOLUTION ANALYSIS:** Multiresolution Analysis, Scaling functions, Wavelets and their duals, linear phase filtering, compactly supported wavelets, orthogonal wavelets.
Suggested Books	1. C. K. Chui, *An Introduction to Wavelets*, Academic Press, 1992. 2. M. W. Frazier, *An Introduction to Wavelets Through Linear Algebra*, Springer, 2001. 3. G. Bachmann, L. Narici and Edward Beckenstein, *Fourier and wavelet analysis*, Springer, 1999. 4. E. Hernandez and G. Weiss, *A first course on wavelets*, CRC Press, 1996. 5. L. Debnath, *Wavelet transforms and their applications*, Birkhäuser Boston, 2001. 6. I. Daubechies, *Ten lectures on wavelets*, SIAM, 1992. 7. P. Wojtaszczyk, *Introduction to Wavelets*, Cambridge University Press, 1997. 8. D. F. Walnut, *An Introduction to Wavelet Analysis*, Birkhäuser Boston, 2001. 9. M. Pinsky, *Introduction to Fourier analysis and wavelets*, China Machine Press, 2002.

Course Code	**MA 741**
Title of the Course	**Algebra**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline	Mathematics
Pre–requisite, if any	Elementary Abstract Algebra and Linear Algebra
Objectives of the course	It is one of the basic fundamental courses for research scholars in Discipline of Mathematics. This course will enable them to understand topics from various branches in Mathematics.
Course Syllabus	Groups, Basic properties, Isomorphism theorems, Permutation groups, Cauchy's Theorem, Sylow's Theorems, Structure theorem for finite abelian groups. Rings, Integral domains, Fields, division rings, Ideals, Maximal ideals, Euclidean rings, Polynomial ring over a ring, Maximal & Prime ideals over a commutative ring with unity, Prime avoidance theorem, Chinese Remainder theorem, Field Extension, Algebraic elements and extensions, Finite fields. Vector spaces, Linear transformations, Characteristic and minimal polynomial, diagonalization, Inner product spaces.
Suggested Books	1. I. N. Herstein, *Topics in Algebra* (2nd Edition), John Wiley & Sons, 1975. ISBN: 978-0471010906 2. Thomas W. Hungerford, *Algebra*, Springer, 1980. ISBN: 978-0387905181 3. Michael Artin, *Algebra*, Prentice Hall of India, 1991. ISBN: 978-0130047632 4. David S. Dummit and Richard M. Foote, *Abstract Algebra* (3rd Edition), John Wiley and Sons, 2003. ISBN: 978-0471433347 5. Serge Lang, *Algebra* (3rd Edition), Springer, 2002. ISBN: 978-0387953854 6. P.B. Bhattacharya, S.K. Jain, and S.R. Nagpaul, *Basic Abstract Algebra*, Cambridge University Press, 2nd Edition, 1994. ISBN: 978-0521466295

Course Code	**MA 742**
Title of the Course	**Commutative Algebra**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	Algebra-I, Algebra-II
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge and problem-solving skills in Commutative Algebra.
Course Syllabus	Commutative rings, ideals, prime and maximal ideals, Noetherian Artinian rings, Primary decomposition and Noetherian rings, Modules over commutative rings, Exact sequences, tensor product of modules, rings and modules of fractions, integral dependence, valuations and dedekind domains. Completions, filtrations, graded rings and modules, associated graded ring. Hilbert functions, dimension theory, regular local rings.
Suggested Books	1. M. F. Atiyah and I. G. MacDonald, *Introduction to Commutative Algebra* (1st Edition), Levant Books, Kolkata, 2007. 2. H. Matsumura, *Commutative Ring Thoery*, Cambridge University Press, 2005. 3. D. Eisenbud, *Commutative Algebra with a View Toward Algebraic Geometry*, Springer, 2003. 4. R. Y. Sharp, *Steps in Commutative Algebra*, London Mathematical Society, 1990. 5. G. Kemper, *A Course in Commutative Algebra*, Springer, 2011.

Course Code	**MA 780**
Title of the Course	**Mathematical Logic**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge in Mathematical Logic.
Course Syllabus	**First Order Logic:** Syntax of FOL, Semantics, Consequences, Calculations, Prenex Form, Skolemization, Herbrand Interpretation, Skolem-Lowenheim Theorem. **Proof Theory:** Resolution in PL, Propositional Calculus (PC), Completeness and Compactness of PC, Analytic Tableaux for PL, Analytic Tableaux for FL, Completeness of Analytic Tableaux, Compactness of PL and FL, Issue of Decidability.
Suggested Books	1. A. Singh, *Logics for Computer Science*, PHI Learning, New Delhi, 2003. 2. A. Margaris, *Mathematical Logic*, Dover Publications, Inc., New York, 1990. 3. R. E. Hodel, *An Introduction to Mathematical Logic*, PWS Publishing Company, Boston, 1995.

Course Code	**MA 782**
Title of the Course	**Theory Of Computation**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Discipline/School	Mathematics
Pre–requisite, if any (for the students)	None
Objectives of the course	At the end of the course, students should be exposed to fundamental knowledge in the theory of computations.
Course Syllabus	Some Fundamental Proof Techniques. Finite Automata: Finite Automata and Regular Languages, Languages that are and are not Regular, Algorithm Aspects of Finite Automata. Context-free Grammars: Push-down Automata, Languages that are and are not context-free, Algorithms for Context-free Grammars. Basic Turing Machine Model and Turing Computability: Variants of Turing Machines. Grammars and Turing Machines: Primitive Recursive Functions, μ-recursive Functions and Turing Computability. Church-Turing Thesis and Universal Turing Machines: Halting Problem, Some Undecidable Problems. Time-bounded Turing Machines: Classes *P* and *NP*, *NP*-completeness, Examples of *NP*-complete Problems.
Suggested Books	1. H. R. Lewis and C. H. Papadimitriou, *Elements of Theory of Computation*, Prentice-Hall, 2nd Edition, Englewood, New Jersey, 1997. 2. J. Hopcroft, R. Motwani, and J. Ullman, *Introduction to Automata Theory, Language, and Computation*, Pearson Education, 2nd Edition, 2001. 3. M. Sipser, *Introduction to the Theory of Computation*, Wadsworth Publishing Co Inc., 3rd Edition, 2012.

Course Code	**MA 797 (Autumn Semester)** **MA 798 (Srping Semester)**
Title of the Course	Ph.D. Seminar Course
Credit Structure	L-T-P-Credits 0-2-0-2
Name of the Concerned Discipline	Mathematics
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