Mathematics

Sr No	New Course code	Name of Course	L-T-P-C	Proposed Level (UG/PG)
1	MA 101	Calculus	3-1-0-8	UG
2	MA 102	Linear Algebra	3-1-0-4	UG
3	MA 103	Differential Equations -I	3-1-0-4	UG
4	MA 109	Calculus I	3-1-0-4	UG
5	MA 121	Calculus II	3-1-0-4	UG
6	MA 201	Complex Analysis	3-1-0-4	UG
7	MA 202	Advanced Linear Algebra	2-1-0-6	UG
8	MA 203	Differential Equations – II	3-1-0-4	UG
9	MA 209	Introduction to probability theory	3-1-0-8	UG
10	MA 210	Statistics	2-1-0-6	UG
11	MA 211	Art of Problem Solving Lab	0-0-3-3	UG
12	MA 220	Real Analysis	2-1-0-6	UG
13	MA 221	Group Theory	2-1-0-6	UG
14	MA 222	Introduction to Numerical Analysis	3-1-0-8	UG
15	MA 305	Ordinary Differential Equations	2-1-0-6	UG
16	MA 306	Introduction to Mathematical Finance I	3-0-0-6	UG
17	MA 307	Rings and Modules	2-1-0-6	UG
18	MA 308	Introduction to Complex Analysis	2-1-0-6	UG
19	MA 309	General Topology	2-1-0-6	UG
20	MA 310	Stochastic Models	3-0-0-6	UG
21	MA 311	Numerical Analysis Lab	0-0-3-3	UG
22	MA 320	Introduction to Mathematical Finance 2	3-0-0-6	UG
23	MA 401	Numerical Linear Algebra	3-0-0-6	UG
24	MA 402	Discrete Mathematics: Combinatorics and codes	3-0-0-6	UG
25	MA 403	Introduction to Number theory	3-0-0-6	UG
26	MA 404	Numerical Analysis	2-1-0-6	UG
27	MA 406	Introduction to Numerical Methods	3-1-0-4	UG

28	MA 407	Introduction to Numerical Linear Algebra	3-1-0-4	UG
29	MA 408	Elementary Algebra and number theory	3-0-0-6	UG
30	MA 409	Algebraic codes and Combinatorics	3-0-0-6	UG
31	MA 410	Fourier series and Fourier transforms	3-0-0-6	UG
32	MA 420	Fields and Galois theory	2-1-0-6	UG
33	MA 421	Partial Differential Equations	3-0-0-6	UG
34	MA 422	Commutative Algebra	3-0-0-6	UG
35	MA 423	Introduction to Algebraic Geometry	3-0-0-6	UG
36	MA 424	Differential Geometry	3-0-0-6	UG
37	MA 428	Special Topics in Number Theory	3-0-0-6	UG
38	MA 901	Measure Theory	3-1-0-8	PG
39	MA 902	Perfect graphs and graph algorithms	3-1-0-8	PG
40	MA 903	Algebraic Topology	3-0-0-6	PG
41	MA 904	Advanced Algebra	3-1-0-8	PG
42	MA 906	Advanced Numerical Analysis of Ordinary and Partial Differential Equations	4-0-0-8	PG
43	MA 907	Theory of Perfect Graphs	3-1-0-8	PG
44	MA 908	Seminar	4 credits	PG
45	MA 909	Functional Analysis	3-0-0-6	PG
46	MA 910	Homological Algebra	3-1-0-4	PG
47	MA 920	Introduction to Representation Theory	3-0-0-6	PG
48	MA 921	Differential Topology	3-0-0-6	PG
49	MA 922	Topology	3-1-0-8	PG
50	MA 923	Introduction to Graduate Algebra	3-1-0-8	PG
51	MA 924	Numerical Analysis of Partial Differential Equations	4-0-0-8	PG
52	MA 925	Advanced Commutative Algebra	3-1-0-8	PG
53	MA 926	Algebraic Geometry I	3-1-0-8	PG
54	MA 927	Algebraic Geometry II	3-1-0-8	PG
55	MA 928	Algebra	3-1-0-8	PG
56	MA 929	Random Schrodinger Operators	2-1-0-6	PG
57	MA 930	Advanced Graph Theory	3-1-0-8	PG
58	MA 907	Theory of Perfect Graphs	3-0-0-6	PG
59	MA 932	Linear Integral Equation	3-0-0-6	PG

60	MA 931	Measure Theory	2-1-0-6	PG
61	MA 001	Preparatory Mathematics 1		UG
62	MA 002	Preparatory Mathematics-2		UG
63	MA 932	Linear Integral Equation	3-0-0-6	PG
64	MA 933	Theory of Perfect Graphs	3-0-0-6	PG
65	MA 321	Topics in Graph Theory	1-0-0-2	UG (ALO)
66	MA 701	Topics in Elliptic Partial Differential Equations	3-0-0-6	PG
67	MA 702	Numerical Solution of Linear Integral Equations	3-0-0-6	PG
68	MA 934	Seminar II	0-0-4-4	
69	MA 703	Complex Analysis with Applications to Number Theory	3-0-0-6	PG
70	MA 601	Introduction to Diophantine Approximation	3-0-0-6	PG
71	MA 602	Introduction to Lie Algebras	3-0-0-6	PG
72	MA 603	Irrational and Transcendental Numbers	3-0-0-6	PG
73	MA 604	Algebraic Number Theory	3-0-0-6	PG

1	**Title of the course** (L-T-P-C)	**Calculus** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	-
3	**Course content**	Review of limits, continuity, differentiability. Mean value theorem, Taylors Theorem, Maxima and Minima. Riemann integrals, Fundamental theorem of Calculus, Improper integrals, applications to area, volume. Convergence of sequences and series, power series. Partial Derivatives, gradient and directional derivatives, chain rule, maxima and minima, Lagrange multipliers. Double and Triple integration, Jacobians and change of variables formula. Parametrization of curves and surfaces, vector fields, line and surface integrals. Divergence and curl, Theorems of Green, Gauss, and Stokes.
4	**Texts/References**	1. B.V. Limaye and S. Ghorpade, A Course in Calculus and Real Analysis, Springer UTM (2004) 2. B.V. Limaye and S. Ghorpade, A Course in Multivariable Calculus and Analysis, Springer UTM (2010) 3. James Stewart, Calculus (5th Edition), Thomson (2003). 4. T. M. Apostol, Calculus, Volumes 1 and 2 (2nd Edition), Wiley Eastern (1980). 5. Marsden and Tromba, Vector calculus (First Indian Edition), Springer (2012)

1	**Title of the course** (L-T-P-C)	**Linear Algebra** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Vectors in R^n, notion of linear independence and dependence, linear span of a set of vectors, vector subspaces of R^n, basis of a vector subspace. Systems of linear equations, matrices and Gauss elimination, row space, null space, and column space, rank of a matrix. Determinants and rank of a matrix in terms of determinants. Abstract vector spaces, linear transformations, matrix of a linear transformation, change of basis and similarity, rank-nullity theorem. Inner product spaces, Gram-Schmidt process, orthonormal bases, projections and least squares approximation. Eigenvalues and eigenvectors, characteristic polynomials, eigenvalues of special matrices (orthogonal, unitary, hermitian, symmetric, skew-symmetric, normal). Algebraic and geometric multiplicity, diagonalization by similarity transformations, spectral theorem for real symmetric matrices, application to quadratic forms.
4	**Texts/References**	1. H. Anton, Elementary linear algebra with applications (8th Edition), John Wiley (1995). 2. G. Strang, Linear algebra and its applications (4th Edition), Thomson (2006) 3. S. Kumaresan, Linear algebra - A Geometric approach, Prentice Hall of India (2000) 4. E. Kreyszig, Advanced engineering mathematics (10th Edition), John Wiley (1999)

1	**Title of the course** (L-T-P-C)	**Differential Equations -I** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Exact equations, integrating factors and Bernoulli equations. Orthogonal trajectories. Lipschitz condition, Picard's theorem, examples on non-uniqueness. Linear differential equations generalities. Linear dependence and Wronskians. Dimensionality of space of solutions, Abel-Liouville formula. Linear ODE's with constant coefficients, the characteristic equations. Cauchy-Euler equations. Method of undetermined coefficients. Method of variation of parameters. Laplace transform generalities. Shifting theorems. Convolution theorem.
4	**Texts/References**	1. E. Kreyszig, Advanced engineering mathematics (10th Edition), John Wiley (1999) 2. W. E. Boyce and R. DiPrima, Elementary Differential Equations (8th Edition), John Wiley (2005)

1	**Title of the course** (L-T-P-C)	**Calculus I** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Review of limits, continuity, differentiability. Mean value theorem, Taylor's Theorem, Maxima and Minima. Riemann integrals, Fundamental theorem of Calculus, Improper integrals, applications to area, volume. Convergence of sequences and series, power series.
4	**Texts/References**	1. B. V. Limaye and S. Ghorpade, A Course in Calculus and Real Analysis, Springer International Publishing (2004) 2. James Stewart, Calculus (5th Edition), Thomson Brooks/Cole (2003) 3. T. M. Apostol, Calculus, Volume 1, Wiley Eastern (1980)

1	**Title of the course** (L-T-P-C)	**Calculus II** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Calculus I
3	**Course content**	Partial Derivatives, gradient and directional derivatives, Chain rule, Maxima and Minima, Lagrange multipliers. Double and Triple integration, Jacobians and change of variables formula. Parametrization of Curves and Surfaces, Vector fields, Line and Surface integrals. Divergence and Curl, Theorems of Green, Gauss, and Stokes.
4	**Texts/References**	1. B.V. Limaye and S. Ghorpade, A Course in Multivariable Calculus and Real Analysis, Springer International Publishing (2010) 2. James Stewart, Calculus (5th Edition), Thomson Brooks/Cole (2003) 3. T. M. Apostol, Calculus, Volume 2, Wiley Eastern (1980) 4. Marsden and Tromba, Vector calculus (First Indian Edition), Springer (2012)

1	**Title of the course** (L-T-P-C)	**Complex Analysis** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Exposure to Calculus (MA 101)
3	**Course content**	Definition and properties of analytic functions. Cauchy- Riemann equations, harmonic functions. Power series and their properties. Elementary functions. Cauchy's theorem and its applications. Taylor series and Laurent expansions. Residues and the Cauchy residue formula. Evaluation of improper integrals. Conformal mappings. Inversion of Laplace transforms.
4	**Texts/References**	1. E. Kreyszig, Advanced engineering mathematics (10th Edition), John Wiley (1999) 2. R. V. Churchill and J. W. Brown, Complex variables and applications (7th Edition), McGraw-Hill (2003) 3. Theodore Gamelin, Complex Analysis – Springer Undergraduate texts in Mathematics (2003)

1	**Title of the course** (L-T-P-C)	**Advanced Linear Algebra** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	MA 102 or Instructor's consent
3	**Course content**	Review of Linear algebra from MA 102: Systems of linear equations, matrices, rank, Gaussian elimination, Linear transformations, representation of linear transformations by matrices, rank-nullity theorem, duality and transpose, Determinants, Laplace expansions, cofactors, adjoint, Cramer's Rule. Abstract vector spaces over fields, subspaces, bases and dimension. Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley Hamilton Theorem, triangulation, diagonalization, rational canonical form, Jordan canonical form. Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia, positive definiteness.
4	**Texts/References**	1. H. Anton, Elementary linear algebra and applications, 8th edition, John Wiley, 1995.M. Artin, Algebra, Prentice Hall of India, 1994 2. S. Kumaresan, Linear algebra - A Geometric Approach, Prentice Hall of India, 2000. 3. K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. 4. S. Lang, Linear Algebra, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989. 5. G. Strang, Linear algebra and its applications, 4th edition, Thomson, 2006.

1	**Title of the course** (L-T-P-C)	**Differential Equations – II** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Exposure to Calculus (MA 101) , Differential Equation-I (MA 104)
3	**Course content**	Review of power series and series solutions of ODE's. Legendre's equation and Legendre polynomials. Regular and irregular singular points, method of Fresenius. Bessel's equation and Bessel's functions. Strum- Liouville problems. Fourier series. D'Alembert solution to the Wave equation. Classification of linear second order PDE in two variables. Laplace, Wave, and Heat equations using separation of variables. Vibration of a circular membrane. Heat equation in the half space.
4	**Texts/References**	1. E. Kreyszig, Advanced engineering mathematics (10th Edition), John Wiley (1999) 2. W. E. Boyce and R DiPrima, Elementary Differential Equations (8^{th} Edition), John Wiley (2005)

1	**Title of the course** (L-T-P-C)	**Introduction to probability theory (3-1-0-8)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Combinatorial probability and urn models, Independence of events, Conditional probabilities, Random variables, Distributions, Expectation, Variance and moments, probability generating functions and moment generating functions, Standard discrete distributions (uniform, binomial, Poisson, geometric, hypergeometric), Independence of random variables, Joint and conditional discrete distributions. Univariate densities and distributions, standard univariate densities (normal, exponential, gamma, beta, chi-square, Cauchy). Expectation and moments of continuous random variables. Transformations of univariate random variables. Tchebychev's inequality. Modes of convergence. Law of large numbers. Central limit theorem.
4	**Texts/References**	1. K. L. Chung and F. AitSahlia, Elementary Probability Theory., 4th Edition, Springer Verlag, 2003 2. R. Ash : Basic Probability Theory, Dover publication, 3. W. Feller : Introduction to Probability Theory and its Applications, Volume 1, Wiley-India Edition 4. W. Feller : Introduction to Probability Theory and its Applications, Volume 2, Wiley India Edition

1	**Title of the course** (L-T-P-C)	**Statistics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Probability or Instructor's Consent
3	**Course content**	Introduction to Statistics with examples of its use; Descriptive statistics; Graphical representation of data: Histogram, Stem-leaf diagram, Box-plot; Exploratory statistical analysis with a statistical package; Basic distributions, properties; Model fitting and model checking: Basics of estimation, method of moments, Basics of testing, interval estimation; Distribution theory for transformations of random vectors; Sampling distributions based on normal populations: t, χ 2 and Fx distributions. Bivariate data, covariance, correlation and least squares
4	**Texts/References**	1. Lambert H. Koopmans: An introduction to contemporary statistics. 2. David S Moore, George P McCabe and Bruce Craig: Introduction to the Practice of Statistics 3. Larry Wasserman: All Statistics. A Concise Course in Statistical Inference. 4. John A. Rice: Mathematical Statistics and Data Analysis 5. Robert V. Hogg, J.W. McKean, and Allen T. Craig: Introduction to Mathematical Statistics, Seventh Edition, Pearson Education, Asia. 6. Edward J Dudewicz and Satya N. Mishra: Modern Mathematical Statistics, Wiley.

1	**Title of the course** (L-T-P-C)	**Art of Problem Solving Lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	Calculus and Linear Algebra or Instructor’s consent
3	**Course content**	Riddle like mathematical problems without prerequisites solving hands on, playing physical mathematical games based logical ideas (such as, Catan, Ticket to ride, Chess, Bridge, Go, etc.) and discussing strategies, solving physical mathematical problems such as Rubik's cube and variants, learning to use LaTEX, learning to write proofs (including solutions of the above mentioned riddles and game strategies) in LaTEX, presenting proofs from the book (elegant proofs) using the Latex beamer package, solving problems from the book "Test of Mathematical at the 10+2 level" (published by Indian Statistical Institute as a compilation of previous years entrance examination questions and similar. The questions are relevant for all ISI entrance examinations (from undergraduate to PhD), UGC-NET, CAT, and several other various competitive examinations. The book is designed is such a way that solving it improves the overall problem solving ability and speed of a student
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**Real Analysis** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Calculus and Linear Algebra or Instructor’s consent
3	**Course content**	Review of basic concepts of real numbers: Archimedean property, Completeness. Metric spaces, compactness, connectedness, (with emphasis on Rn). Continuity and uniform continuity. Monotonic functions, Functions of bounded variation; Absolutely continuous functions. Derivatives of functions and Taylor's theorem. Riemann integral and its properties, characterization of Riemann integrable functions. Improper integrals, Gamma functions. Sequences and series of functions, uniform convergence and its relation to continuity, differentiation and integration. Fourier series, pointwise convergence, Fejer's theorem, Weierstrass approximation theorem.
4	**Texts/References**	1. W. Rudin, Principles of Mathematical Analysis, 3rd Edition, McGraw-Hill, 1983. 2. T. Apostol, Mathematical Analysis, 2nd Edition, Narosa, 2002 3. S. Abbott, Understanding Analysis, 2nd Edintion, Springer Verlag New York, 2015. 4. S. R. Ghorpade and B. V. Limaye, A course in Calculus and Real Analysis, 2nd Edition, Springer international publishing, 2018

1	**Title of the course** (L-T-P-C)	**Group Theory** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Symmetries of plane figures, translations, rotations and reflections in the Euclidean plane, composing symmetries, inverse of a symmetry, Cayley tables Definition of group, basic properties, examples, Homomorphisms, Isomorphisms, subgroups, subgroup generated by a set, Cyclic groups, subgroups of cyclic groups, Review of Equivalence relations, Cosets, Lagrange's theorem, Normal subgroup, Quotient Group, Examples, Isomorphism theorems, Automorphisms Group actions, conjugacy classes, orbits and stabilizers, faithful and transitive actions, centralizer, normalizer, Cayley's theorem. Conjugation, Class equation, Cauchy's theorem, Applications to p-groups, Conjugacy in S 5 Sylow theorems, Simplicity of A_n and other applications Direct products, Structure of Finite abelian groups Semi-Direct products, Classification of groups of small order Normal series, Composition series, Solvable groups, Jordan- Holder theorem, Insolvability of S_5 Lower and upper central series, Nilpotent groups, Basic commutator identities, Decomposition theorem of finite nilpotent groups (if time permits) Three dimensional symmetries: platonic solids and their dual, symmetries of a tetrahedron, symmetries of a cube and octahedron, symmetries of icosahedron and dodecahedron, classification of finite subgroups of SO(3) (if time permits)
4	**Texts/References**	1. M. Artin, Algebra, Prentice Hall of India, 1994. 2. D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, John Wiley, 2002. 3. J. A. Gallian, Contemporary Abstract Algebra, 4th Edition, Narosa, 1999. 4. I.N. Herstein, Topics in Algebra, Wiley, 2nd Edition, 1975. 5. K. D. Joshi, Foundations of Discrete Mathematics, Wiley Eastern, 1989. S. 6. Lang, Undergraduate Algebra, 2nd Edition, Springer, 2001. 7. S. Lang, Algebra, 3rd Edition, Springer (India), 2004.

1	**Title of the course** (L-T-P-C)	**Introduction to Numerical Analysis** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Calculus (MA 101), Linear Algebra (MA 102), Differential Equations I (MA 104)
3	**Course content**	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, implementation of Gaussian elimination and Gauss-seidel methods, partial pivoting, row echelon form, LU factorization Cholesky's method, ill-conditioning, norms. 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-Multimethod, multi-step methods, predictor-corrector methods, order of convergence, nite dierence methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations. Eigenvalue problem, power method, QR method, Gershgorin's theorem.
4	**Texts/References**	1. S. D. Conte and Carl de Boor, Elementary Numerical Analysis- An Algorithmic Approach (3rd Edition), McGraw-Hill, (1980) 2. C. E. Froberg, Introduction to Numerical Analysis (2nd Edition), Addison-Wesley (1981) 3. David Kincaid and Ward Cheney, Numerical Analysis: Mathematics of Scientific Computing (2002) 4. E. Kreyszig, Advanced engineering mathematics (8th Edition), John Wiley (1999)

1	**Title of the course** (L-T-P-C)	**Ordinary Differential Equations** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Calculus 1 and 2, Linear Algebra, DE 1 or Instructor’s consent
3	**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. Higher Order Linear Equations and linear Systems: fundamental solutions, Wronskian, variation of constants, matrix exponential solution, behaviour of solutions.Two Dimensional Autonomous Systems and Phase Space Analysis: critical points, proper and improper nodes, spiral points and saddle points.Asymptotic Behavior: stability (linearized stability and Lyapunov methods). Boundary Value Problems for Second Order Equations: Green’s function, Sturm comparison theorems and oscillations, eigenvalue problems.
4	**Texts/References**	1. M. Hirsch, S. Smale and R. Deveney, Differential Equations, Dynamical Systems and Introduction to Chaos, Academic Press, 2004 2. Perko, Differential Equations and Dynamical Systems, Texts in Applied Mathematics, Vol. 7, 2nd Edition, Springer Verlag, New York, 1998. 3. Rama Mohana Rao, Ordinary Differential Equations: Theory and Applications. Affiliated East-West Press Pvt. Ltd., New Delhi, 1980. 4. D. A. Sanchez, Ordinary Differential Equations and Stability Theory: An Introduction, Dover Publ. Inc., New York, 1968.

1	**Title of the course** (L-T-P-C)	**Introduction to Mathematical Finance I (3-0-0-6)**
2	**Pre-requisite courses(s)**	Calculus, Linear Algebra and Probability. An instructor's permission may be sought to enrol for the course otherwise.
3	**Course content**	Introduction to financial market and financial instruments: bonds, annuities, equities, contracts, swaps and options Risky and risk free assets, time value of money, binomial model for risky assets and corresponding properties Portfolio management, Capital Asset Pricing Model Options, futures and derivative, European options, Elementary stochastic calculus and Black Scholes Merton model and its numerical solution
4	**Texts/References**	John Hull, Options, Futures and Derivatives, 10th Edition(Indian), Pearson, US, 2018 Marek Capiński, Tomasz Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, 2nd Edition, Springer Verlag, London, 2011 Paul Wilmott, Paul Wilmott Introduces Quantitative Finance, 2nd Edition, John Wiler & Sons, US, 2013 Mark H. A. Davis, Mathematical Finance: A Very Short Introduction, Oxford University Press, UK, 2019

1	**Title of the course** (L-T-P-C)	**Rings and Modules** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Group Theory
3	**Course content**	Definition of rings, Homomorphisms, basic examples (Polynomial ring, Matrix ring, Group ring), Integral domain, field, Field of fractions of an integral domain Ideals, Prime and Maximal ideals, Quotient Rings, Isomorphism theorems, Chinese Remainder theorem, Applications Principal ideal domains, Irreducible elements, Unique factorization domains, Euclidean domains, examples Polynomial rings, ideals in polynomial rings, Polynomial rings over fields, Gauss' Lemma, Polynomial rings over UFDs, Irreducibility criteria, Hilbert's basis theorem Definition of modules, submodules, The group of homomorphisms, Quotient modules, Isomorphism theorems, Direct sums, Generating set, Noetherian modules, free modules, Simple modules, vector spaces Free modules over a PID, Finitely generated modules over PIDs, Applications to finitely generated abelian groups and Rational and Jordan canonical forms time permits) Closed subsets of affine space, coordinate rings, correspondence between ideals and closed subsets, affine varieties, Hilbert's nullstellensatz
4	**Texts/References**	M. Artin, Algebra, Prentice Hall of India, 1994. M. F. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 1969. D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, John Wiley, 2002. N. Jacobson, Basic Algebra I and II, 2nd Edition, W. H. Freeman, 1985 and 1989. S. Lang, Algebra, 3rd Edition, Springer (India), 2004. O. Zariski and P. Samuel, Commutative Algebra, Vol. I, Springer, 1975.

1	**Title of the course** (L-T-P-C)	**Introduction to Complex Analysis** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Real analysis and calculus OR Instructor’s consent
3	**Course content**	Definition and properties of analytic functions. Cauchy- Riemann equations, harmonic functions. Power series and their properties. Elementary functions. Cauchy's theorem and its applications. Taylor series and Laurent expansions. Evaluation of improper integrals. Conformal mappings. Inversion of Laplace transforms. Isolated singularities and residues.Residues and the Cauchy residue formula. Zeroes and poles, Maximum Modulus Principle, Argument Principle, Rouche's theorem.
4	**Texts/References**	1. E. Kreyszig, Advanced engineering mathematics (10th Edition), John Wiley (1999). 2. R. V. R. V. Churchill and J. W. Brown, Complex variables and applications (7th Edition), McGraw-Hill (2003) 3. Theodore Gamelin, Complex Analysis – Springer Undergraduate texts in Mathematics (2003). 4. J.B Conway, Functions of one complex variable,Springer, 7th printing 1995 edition

1	**Title of the course** (L-T-P-C)	**Stochastic Models** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Probability or Instructor's Consent
3	**Course content**	Definition and classification of general stochastic processes. Markov Chains: definition, transition probability matrices, classification of states, limiting properties. Markov Chains with Discrete State Space: Poisson process, birth and death processes. Renewal Process: renewal equation, mean renewal time, stopping time. Applications to queuing models. Markov Process with Continuous State Space: Introduction to Brownian motion.
4	**Texts/References**	Bhat, U. N. and Miller, G.K., Elements of Applied Stochastic Processes, 3rd edition, John Wiley & Sons, New York, 2002. Kulkarni, V.G., Modeling and Analysis of Stochastic Systems, 3rd Edition, Chapman and Hall/CRC, Boca Raton, 2017. J. Medhi, Stochastic Models in Queuing Theory, Academic Press, 1991. R. Nelson, Probability, Stochastic Processes, and Queuing Theory: The Mathematics of Computer Performance Modelling, SpringerVerlag, New York, 1995 Sheldon M Ross: Stochastic Processes, John Wiley and Sons, 1996. S Karlin and H M Taylor: A First Course in Stochastic Processes, Academic Press, 1975.

1	**Title of the course** (L-T-P-C)	**Numerical Analysis Lab** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	
3	**Course content**	1. To implement 2. Gauss elimination with partial pivoting 3. LU decomposition 4. Classical iterative solvers to solve linear systems of equations 5. To Implement : 6. Power iteration 7. QR decomposition to find eigenvalues and eigenvectors of matrices 8. To implement: interpolation techniques 9. Solving systems of nonlinear equations following Newton Raphson 10. Solving integral equations using quadrature rules 11. Solving ordinary and partial differential equations using finite difference.
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**General Topology** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Calculus, Linear Algebra, Real Analysis and Elements of Metric Space Theory or Instructor's consent
3	**Course content**	Topological Spaces: open sets, closed sets, neighbourhoods, bases, sub bases, limit points, closures, interiors, continuous functions, homeomorphisms. Examples of topological spaces: subspace topology, product topology, metric topology, order topology. Quotient Topology: Construction of cylinder, cone, Moebius band, torus, etc. Connectedness and Compactness: Connected spaces, Connected subspaces of the real line, Components and local connectedness, Compact spaces, Heine-Borel Theorem, Local -compactness. Separation Axioms: Hausdorff spaces, Regularity, Complete Regularity, Normality, Urysohn Lemma, Tychonoff embedding and Urysohn Metrization Theorem, Tietze Extension Theorem. Tychnoff Theorem, One-point Compactification. Complete metric spaces and function spaces, Characterization of compact metric spaces, equicontinuity, Ascoli-Arzela Theorem, Baire Category Theorem. Applications: space filling curve, nowhere differentiable continuous function.
4	**Texts/References**	1. J. R. Munkres, Topology, 2nd Edition, Pearson Education (India), 2001. 2. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963. 3. M. A. Armstrong, Basic Topology, Springer (India), 2004

1	**Title of the course** (L-T-P-C)	**Introduction to Mathematical Finance 2** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Calculus, Linear Algebra, Probability, Statistics, Stochastic Models or Instructor's consent
3	**Course content**	Basics, Risk Assessment and Diversification Single period utility analysis, Mean-variance portfolio analysis, Graphical Analysis of portfolios and efficient portfolio, Efficient portfolios with and without risk-free assets, Single, two and multi-index models Risk management: Concept of VaR, measuring VaR and estimating volatilities via simple moving averages and GARCH, Var in Black-Scholes, Average VaR in Black- Scholes Capital Asset Pricing Model and its extensions, Continuous- time asset pricing, Arbitrage pricing
4	**Texts/References**	1. J. C. Francis and D. Kim, Modern Portfolio Theory: Foundations, Analysis, and New Developments, John Wiley and Sons, 2013 2. M. J. Capinski and E. Kopp, Portfolio Theory and Risk Management, Cambridge University Press, 2014 3. J.Cvitanic and F. Zapatero, Introduction to the Economics and Mathematics of Financial Markets, MIT press, 2004 4. E. J. Elton, M. J. Gruber, S. J. Brown, W. N. Goetzmann, Modern Portfolio Theory and Investment Analysis, 9th Edition, John Wiley and Sons, 2014

tho d	**Title of the course** (L-T-P-C)	**Numerical Linear Algebra** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Calculus, Linear Algebra
3	**Course content**	Vector and Matrix Norms, Gram Schmidt Orthogonalization, Singular Value Decomposition, QR factorization, Householder Triangularization Floating point number system, Condition number and Stability, Stability of Back substitution, Gauss Elimination and Householder methods Numerical techniques for finding eigenvalues, Rayleigh Quotient, QR methods, Divide and Conquer strategies Krylov subspace techniques, GMRES and Conjugate Gradient
4	**Texts/References**	1. Lloyd N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, US, 1997. 2. Gene Golub and Charles Van Loan, Matrix Computations, 4th Edition, John Hopkins 3. University Press, US, 2013 Iterative Methods for Sparse Linear Systems, 4. Yousef Saad, 2 Edition, SIAM, US, 2003

1	**Title of the course** (L-T-P-C)	**Discrete Mathematics: Combinatorics and codes (3-0-0-6)**
2	**Pre-requisite courses(s)**	Linear Algebra, MA 106
3	**Course content**	Designs: t-designs, incidence matrices, Fischer inequality, symmetric designs, examples, Bruck-Ryser Chowla theorem, projective spaces and projective planes Strongly regular graphs: Bose-Mesner algebra, Krein condition, integrality conditions Inclusion-exclusion principle, Mobius function, Mobius inversion formula, applications Permanents: Bounds on permanents, permanents of doubly stochastic matrices Partitions: Partition functions, Ferrers diagrams, Euler identity, Jacobi triple product product identity, young tableaux and hook formula Algebraic codes: Basic bounds, weight enumerator polynomial; Hamming codes, MacWilliams identity, codes and symmetric designs
4	**Texts/References**	1. Van Lint and Wilson: A course in combinatorics, Cambridge University Press, UK, 2001 2. P.J. Cameron and Van Lint, Graphs, Codes and Designs, LMS lecture notes, Cambridge University Press, UK, 2001

1	**Title of the course** (L-T-P-C)	**Introduction to Number theory** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Primes and Factorization; Fundamental theorem of Arithmetic; Congruences, Euclidean Algorithm, Chinese Reminder theorem. Algebraic and transcendental numbers; algebraic integers, Euler’s phi-function; primitive elements; Wilson's theorem; Introduction to public-key encryption systems. Mobius inversion formula; quadratic law of reciprocity. Lagrange's theorem on an integer as a sum of four squares. Norms on the field Q rational numbers; Statement of Ostrowski's theorem on norms on Q;introduction to p-adic numbers
4	**Texts/References**	1. N. Niven, H. S.Zuckermann,and 2. H. L. Montgomery, An introduction to theory of numbers, Sixth edition (Student edition), US, Wiley, 2018. 3. T. M. Apostol, Introduction to Analytic number theory, Springer international student edition, Narosa publishing house, New Delhi, 2013. 4. H. Davenport, The Higher Arithmetic

1	**Title of the course** (L-T-P-C)	**Numerical Analysis** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Calculus 1 and 2, Linear Algebra, DE 1, Ordinary Differential Equations or Instructor's consent
3	**Course content**	Linear Systems of Equation, LU decomposition, Classical iterative techniques and ill conditioned systems Matrix eigenvalue problems, Power iteration, Jacobi and QR methods Approximation theory, interpolation (Lagrange, Hermite and piecewise interpolation) and best approximations in inner product spaces Nonlinear Equations and their iterative solution Numerical Integration, interpolatory quadratures, Gauss quadrature, quadrature of periodic functions and Romberg integration Finite Difference methods, convergence, stability and consistency, Lax equivalence theorem
4	**Texts/References**	1. Rainer Kress, Numerical Analysis, 1st Edition, Springer- Verlag New York, 1998 2. Stoer and R. Bulirsch, Introduction to Numerical Analysis, 3rd Edition, Springer-Verlag New York, 2002 3. Atkinson and Weimin Han, Theoretical Numerical Analysis, A functional Analysis framework, 3rd Edition, Springer-Verlag New York, 2001 4. Deuflhard and A Hohmann, Numerical Analysis in modern scientific computing, An introduction, 2nd Edition, Springer-Verlag New York, 2003

1	**Title of the course** (L-T-P-C)	**Introduction to Numerical Methods (3-1-0-4)**
2	**Pre-requisite courses(s)**	Calculus, MA101 & Linear Algebra, MA 106
3	**Course content**	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 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, Finite difference methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations. Exposure to MATLAB
4	**Texts/References**	S. D. Conte and Carl de Boor, Elementary Numerical Analysis- An Algorithmic Approach (3rd Edition), McGraw-Hill, 1980

1	**Title of the course** (L-T-P-C)	**Introduction to Numerical Linear Algebra (3-1-0-4)**
2	**Pre-requisite courses(s)**	Calculus, MA 101 & Linear Algebra, MA 106
3	**Course content**	Floating point number system, Big O notation Matrix and vector norms, ill conditioned problems Solution of a system of linear equations, Gauss elimination, LU factorization, Cholesky method, Classical iterative methods: Jacobi and Gauss-Seidel Eigenvalue problems, Power method, QR method, Gershgorin theorem. Exposure to MATLAB
4	**Texts/References**	S. D. Conte and Carl de Boor, Elementary Numerical Analysis- An Algorithmic Approach (3rd Edition), McGraw-Hill, 1980

1	**Title of the course** (L-T-P-C)	**Algebraic codes and Combinatorics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Algebraic codes: Definition and motivation, parameters, parity check matrix of an algebraic code, basic inequalities, Macwilliams' identity, Perfect codes, Hamming codes, Golay codes, cyclic codes, relation to factorisation of X^{n}-1; MDS codes Combinatorics: t-designs, Fischers inequality, Finite projective planes, Bruck-Ryser theorem, extensions of Witt designs, ovals in projective planes Eigen value techniques in graph theory, expander graphs, Ramanujan graphs
4	**Texts/References**	1. J.H. Van Lint, Introduction to coding theory, 3rd edition, Graduate texts in Maths, 86, Springer 2. J.H. Van Lint and R.M. Wilson, A course in Combinatorics, Cambridge Univ. Press, 2001 3. P. J. Cameron and J.H. Van Lint, Graphs, Codes and designs (Revised edition og Graph theory, Coding theory and block designs)London Math Society 43, CUP 19890

1	**Title of the course** (L-T-P-C)	**Elementary Algebra and number theory** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Some knowledge of discrete structures, would help but is not essential
3	**Course content**	Groups, subgroups, normal subgroups and quotient groups; homomorphism theorems; Symmetric and alternating groups; Group actions, Sylow theorems and applications. Rings; subrings, ideals, factor rings, polynomial rings, discriminents. Fields, algebraic and transcendental extensions, Separable and normal extensions, Statement of Galois theorem, Finite fields. Congruence relations in integers; Chinese reminder theorem; quadratic reciprocity law, cyclotomic polynomials
4	**Texts/References**	1. D.S. Dummit and R.S. Foote, Abstract Algebra, John Wiley (Asian reprint 2003) 2. M.Artin, Algebra, Prentice Hall (2011), paperback Indian edition is available. 3. N.Jacobson, Basic Algebra vol I, W.H. Freeman and Co (1985) paperback Indian edition is available. 4. J.H.Siverman, A friendly introduction to number theory, Second edition,Prentice (2005) 5. Ireland and M.Rosen, A classical introduction to modern number theory, Second edition, Springer (Indian edition available).

1	**Title of the course** (L-T-P-C)	**Fourier series and Fourier transforms.** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Calculus (MA 101), Linear Algebra (MA 102)
3	**Course content**	Notion of Fourier series: definition and examples, trigonometric polynomials, various notion of convergence. Convolution: Dirichlet kernel and approximation identities, Fejer's summation, Planchered and Parseval's theorems, L^2 convergence, orthonormal basis. Application of Fourier series: isoperimetric inequality and Weyl's equidistribution theorem. Fourier transform: definition and examples, character theory, Schwartz functions, fourier inversion formula, Plancherel theorem, fourier tranform on euclidean spaces, introduction to the theory of distributions, poisson summation formula, zeta and theta functions. Applications of fourier transform: analytic properties of Riemann zeta function, poisson kernel and heat equations, partial differential equations, Heiseinberg's uncertainity principle.equations, partial differential equations, Heiseinberg's uncertainity principle.
4	**Texts/References**	1. Princeton lectures in Analysis-I, Fourier analysis- an introduction by E. M. Stein and R. Shakarchi, Princeton university press, 2003 2. Analysis II Differential and Integral Calculus, Fourier Series, Holomorphic Functions, by Roger Godement, Springer 2005 edition. 3. Fourier Analysis and Its Applications (Pure and Applied Undergraduate Texts), by Gerald B. Folland, American Mathematical Society, 2009.

1	**Title of the course** (L-T-P-C)	**Fields and Galois theory** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Group Theory, Rings and Modules OR Instructor's consent
3	**Course content**	Polynomial rings, Gauss lemma, Irreducibility criteria Definition of a field and basic examples, Characteristic and prime subfields, Field extensions, Algebraic extensions Classical ruler and compass constructions Finite fieldsSplitting fields and normal extensions, algebraic closures. Separable and inseparable extensions, Galois extensions Cyclotomic fields,Galois groups, Fundamental Theorem of Galois Theory Composite extensions, Examples (including cyclotomic extensions and extensions of finite fields), Abelian extensions over Q Galois groups of polynomials, Solvability by radicals, Solvability of polynomialsComputations of Galois groups over QNorm, trace and discriminant, Cyclic extensions, Abelian extensions, Polynomials with Galois groups S_n. Transcendental extensions.
4	**Texts/References**	1. M. Artin, Algebra, Prentice Hall of India, 1994. 2. D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, John Wiley, 2002. 3. D. J. H. Garling, A Course in Galois Theory, Cambridge University Press, 1986. 4. N. Jacobson, Basic Algebra I, 2nd Edition, W. H. Freeman, 1985 and 1989. 5. S. Lang, Algebra, 3rd Edition, Springer (India), 2004. I. Stewart, Galois Theory, 3rd Edition, Chapman & Hall/CRC Press (2004). 6. J. Rotman, Galois Theory, 2nd Edition, Springer (2005). O. Zariski and P. Samuel, Commutative Algebra, Vol. I, Springer, 1975.

1	**Title of the course** (L-T-P-C)	**Partial Differential Equations** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Calculus 1 and 2, Linear Algebra, DE 1, Ordinary Differential Equations or Instructor's consent
3	**Course content**	Examples of partial differential equations, Cauchy Problems for First Order Hyperbolic Equations, Method of characteristics, Mongcone, Classification of Second Order Partial Differential Equations, Normal forms and characteristics. Laplace equation: mean value property, weak and strong maximum principle, Green`s function, Poisson`s formula, Dirichlet`s principle, existence of solution using Perron`s method (with/without proof). Heat equation: initial value problem, fundamental solution, weak and strong maximum principle and uniqueness results. Wave equation: uniqueness, D'Alembert's method, method of spherical means and Duhamel`s principle, methods of separation of variables for heat, Laplace and wave equations.
4	**Texts/References**	1. L.C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, Vol. 19, American Mathematical Society, 1998. 2. F. John, Partial Differential Equations, 4th Edition, Springer-Verlag New York, 1982 3. R. C. McOwen, Partial Differential Equations: Methods and Applications, 2nd edition, Pearson, 2003 4. M. Renardy and R. C. Rogers, Introductin to Partial Differential Equations, 2nd Edition, Springer-Verlag New York, 2004

1	**Title of the course** (L-T-P-C)	**Commutative Algebra** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Group Theory, Rings and Modules, Fields and Galois Theory OR Instructor's consent
3	**Course content**	Dimension theory of affine algebras: Principal ideal theorem, Noether normalization lemma, dimension and transcendence degree, catenary property of affine rings, dimension and degree of the Hilbert polynomial of a graded ring, Nagata's altitude formula, Hilbert's Nullstellensatz, finiteness of integral closure Associated primes of modules, degree of the Hilbert polynomial of a graded module, Hilbert series and dimension, Dimension theorem, Hilbert-Samuel multiplicity, associativity formula for multiplicity Complete local rings: Basics of completions, Artin-Rees lemma, associated graded rings of filtrations, completions of modules, regular local rings Basic Homological algebra: Categories and functors, derived functors, Hom and tensor products, long exact sequence of homology modules, free resolutions, Tor and Ext, Koszul complexes Cohen-Macaulay rings: Regular sequences, quasi- regular sequences, Ext and depth, grade of a module, Ischebeck's theorem, Basic properties of Cohen-Macaulay rings, Macaulay's unmixed theorem, HilbertSamuel multiplicity and Cohen-Macaulay rings, rings of invariants of finite groups. Optional Topics: Face rings of simplicial complexes, shellable simplicial complexes and their face rings. Dedekind Domains and Valuation Theory.
4	**Texts/References**	1. M. F. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 1969. 2. W. Bruns and J. Herzog, CohenMacaulay Rings, Revised edition, Cambridge Studies in Advanced Mathematics No. 39, Cambridge University Press, 1998. 3. D. Eisenbud, Commutative Algebra (with a view toward algebraic geometry), Graduate Texts in Mathematics 150, Springer- Verlag, 2003. 4. H.Matsumura, Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press, 1980.

1	**Title of the course** (L-T-P-C)	**Introduction to Algebraic Geometry (3-0-0-6)**
2	**Pre-requisite courses(s)**	Group Theory, Rings and Modules, Fields and Galois Theory OR Instructor's consent
3	**Course content**	Varieties: Affine and projective varieties, coordinate rings, morphisms and rational maps, local ring of a point, function fields, dimension of a variety. Curves: Singular points and tangent lines, multiplicities and local rings, intersection multiplicities, Bezout's theorem for plane curves, Max Noether's theorem and some of its applications, group law on a nonsingular cubic, rational parametrization, branches and valuations.
4	**Texts/References**	1. S.S. Abhyankar, Algebraic Geometry for Scientists and Engineers, American Mathematical Society, 1990. 2. W. Fulton, Algebraic Curves, Benjamin, 1969. 3. J. Harris, Algebraic Geometry: A First Course, Springer-Verlag, 1992. 4. M. Reid, Undergraduate Algebraic Geometry, Cambridge University Press, Cambridge, 1990. 5. I.R. Shafarevich, Basic Algebraic Geometry, Springer- Verlag, Berlin, 1974. 6. R.J. Walker, Algebraic Curves, SpringerVerlag, Berlin, 1950.

1	**Title of the course** (L-T-P-C)	**Differential Geometry** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Calculus OR Instructor's consent
3	**Course content**	Graphs and level sets of functions on Euclidean spaces, vector fields, integral curves of vector fields, tangent spaces. Surfaces in Euclidean spaces, vector fields on surfaces, orientation, Gauss map. Geodesics, parallel transport, Weingarten map. Curvature of plane curves, arc length and line integrals, Curvature of surfaces. Parametrized surfaces, local equivalence of surfaces. Gauss-Bonnet Theorem, Poincare-Hopf Index Theorem.
4	**Texts/References**	1. M. doCarmo, Differential Geometry of Curves and Surfaces, Prentice Hall, 1976. 2. B. O'Neill, Elementary Differential Geometry, Academic Press, 1966. 3. Pressley, Elementary Differential Geometry, Springer, Indian reprint, 2004 4. J.J. Stoker, Differential Geometry, Wiley Interscience, 1969. 5. J. A. Thorpe, Elementary Topics in Differential Geometry, Springer (India), 2004.

1	**Title of the course** (L-T-P-C)	**Special Topics in Number Theory** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Prime integers, Fundamental Theorem of Arithmetic, some elementary results about prime numbers and their distribution. An explanation of the Riemann Zeta function and the relation of Riemann hypothesis to the distribution of primes. Some standard Arithmetic functions like \phi(n), \mu(n), d(n), \sigma(n), r(n); their generating functions, orders of their magnitudes, perfect integers. Partitions of integers, Euler's recursive formula, partition identities of Ramanujan.Waring's problem. Some applications to cryptography
4	**Texts/References**	1. Apostol T M, Introduction to Analytic number theory, Springer International student edition 2. Niven I, Zuckerman H S, Montgomery H L, “An Introduction to the Theory of Numbers”, Wiley-India Edition, 2008

1	**Title of the course** (L-T-P-C)	**Measure Theory** **(3-1-0-8) (old)**
2	**Pre-requisite courses(s)**	Real analysis
3	**Course content**	Construction of Lebesgue measure on Real line, Introduction to abstract measure theory, Measurable functions, Caratheodory's Extension Theorem, MCT, Fatou's Lemma, DCT, Product space, Product measure, Fubini's Theorem, Definition of signed measures, Positive and negative sets. Hahn-Jordan Decomposition. Absolute continuity of two σ- finite measures. Radon-Nikodyme Theorem and Lebesgue Decomposition.
4	**Texts/References**	1. H. L. Royden; Real analysis. Third edition. Macmillan Publishing Company, New York, 1988. 2. W. Rudin; Real and complex analysis. Third edition. McGraw- Hill Book Co., New York, 1987. 3. S. Athreya and V.S. sunder; Measure & probability. CRC Press, Boca Raton, FL, 2018. 4. K.R. Parthasarathy; Introduction to probability and measure, Hindustan Book Agency, 2005.

1	**Title of the course** (L-T-P-C)	**Perfect graphs and graph algorithms** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Exposure to CS 201,211 Data Structures and Algorithms, Lab,CS 203 Discrete Structures or equivalent.
3	**Course content**	Perfect graphs, The Weak Perfect Graph Theorem, The Strong Perfect Graph Theorem (statement only), Chrodal graphs, Perfect Elemination Order and Scheme, Split graphs, degree sequence, Erdos-Gallai Theorem, Comparability graphs, Permutation graphs, Intersection graphs, Interval graphs and some of its properties, Circular arc graphs
4	**Texts/References**	M. C. Golumbic. *Algorithmic Graph Theory and Perfect Graphs*. Academic Press, New York, 1980.

1	**Title of the course** (L-T-P-C)	**Algebraic Topology** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Topology / Instructor’s consent
3	**Course content**	Paths and homotopy, homotopy equivalence, contractibility, deformation retracts Basic constructions: cones, mapping cones, mapping cylinders, suspension Cell complexes, subcomplexes, CW pairs Fundamental groups. Examples (including the fundamental group of the circle) and applications (including Fundamental Theorem of Algebra, Brouwer Fixed Point Theorem and Borsuk-Ulam Theorem, both in dimension two). Van Kampen's Theorem. Covering spaces, lifting properties, deck transformations, universal coverings Simplicial complexes, barycentric subdivision, stars and links, simplicial approximation. Simplicial Homology. Singular Homology. Mayer-Vietoris sequences. Long exact sequence of pairs and triples. Homotopy invariance and excision Degree, Cellular Homology Applications of homology: Jordan-Brouwer separation theorem, Invariance of dimension, Hopf's Theorem for commutative division algebras with identity, Borsuk-Ulam Theorem, Lefschetz Fixed Point Theorem Optional Topics: Outline of the theory of: cohomology groups, cup products, Kunneth formulas, Poincare duality
4	**Texts/References**	1. M.J. Greenberg and J. R. Harper, Algebraic Topology, Benjamin, 1981. 2. W. Fulton, Algebraic topology: A First Course, Springer-Verlag, New York, 1995. 3. A. Hatcher, Algebraic Topology, Cambridge Univ. Press, Cambridge, 2002. 4. W. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, Berlin, 1991. 5. J. R. Munkres, Elements of Algebraic Topology, Addison-Wesley, Menlo Park, CA, 1984. 6. J. J. Rotman, An Introduction to Algebraic Topology, Springer (India), 2004. 7. H. Seifert and W. Threlfall, A Textbook of Topology, Academic Press, New York-London, 1980.

1	**Title of the course** (L-T-P-C)	**Advanced Algebra** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Introduction to Algebra
3	**Course content**	Semisimple and simple rings: Semisimple modules, Jacobson density theorem, semisimple and simple rings, Wedderburn-Artin structure theorems, Jacobson radical, the effect of a base change on semisimplicity Representations of finite groups: Basic definitions, characters, class functions, orthogonality relations, induced representations and induced characters, Frobenius reciprocity, decomposition of the regular representation, supersolvable groups, representations of symmetric groups Noetherian modules and rings: Primary decomposition, Nakayama's lemma, filtered and graded modules, the Hilbert polynomial, Artinian modules and rings, projective modules, Krull-Schmidt theorem, completely reducible modules
4	**Texts/References**	Dummit, Foote: Abstract algebra, second edition, Wiley student editions, 2005 1. Jacobson: Basic algebra, I, Dover publications, 2009 2. Jacobson: Basic algebra, II, Dover publications, 2009 Lang: Algebra, third edition, Springer-Verlag, GTM 211, 2002

1	**Title of the course** (L-T-P-C)	**Advanced Numerical Analysis of Ordinary and Partial Differential Equations (4-0-0-8)**
2	**Pre-requisite courses(s)**	Real Analysis, Complex Analysis, Linear Algebra
3	**Course content**	**1.** Numerical ODE - Multi Step and Multi Stage methods, A-stability, Stiffness **2.** Numerical solution of linear equations – direct and iterative techniques **3.** Numerical solution of Elliptic Boundary value problems - Consistency, Stability and Convergence **4.** Numerical solution of Parabolic equations **5.** Numerical solution of Hyperbolic problems
4	**Texts/References**	Finite Difference Methods for Ordinary and Partial Differential Equations - Randall Leveque

1	**Title of the course** (L-T-P-C)	**Theory of Perfect Graphs** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Basic Graph Theory
3	**Course content**	Perfect graphs, The Weak Perfect Graph Theorem, The Strong Perfect Graph Theorem (statement only), Chrodal graphs, Perfect Elemination Order and Scheme, Split graphs, degree sequence, Erdos-Gallai Theorem, Comparability graphs, Permutation graphs, Intersection graphs, Interval graphs and some of its properties, Circular arc graphs
4	**Texts/References**	**1.** M. C. Golumbic. *Algorithmic Graph Theory and Perfect Graphs* . Academic Press, New York, 1980. **2.** D. B. West, Introduction to Graph Theory 2nd edition. Prentice Hall.

1	**Title of the course** (L-T-P-C)	**Functional Analysis** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Basic topological concepts, Metric spaces, Measure theory
3	**Course content**	Stone-Weierstrass theorem, L^p spaces, Banach spaces,Bounded linear functionals and dual spaces, Hahn-Banachtheorem. Bounded linear operators, open-mapping theorem, closed graph theorem, uniform boundedness principle. Hilbert spaces, Riesz representation theorem. Bounded operators on aHilbert space. The spectral theorem for compact, self- adjoint, normal (including unbounded) operators.
4	**Texts/References**	1. J. B. Conway: A course in functional analysis, Springer-Verlag, New York, 1990 2. B.V.Limaye: Functional Analysis, New Age International Limited,Publishers, New Delhi, 1996 3. Michael Reed, Barry Simon: Methods of modern mathematical physics. I. Functional analysis. Second edition.Academic Press, Inc, New York, 1980 4. E. Kreyszig: Introductory Functional Analysis withApplications, John Wiley & Sons, New York, 2001.

1	**Title of the course** (L-T-P-C)	**Homological Algebra** **(3-1-0-4)**
2	**Pre-requisite courses(s)**	Basics of Group Theory, Ring Theory and Module Theory, Linear Algebra
3	**Course content**	Categories and functors: definitions and examples. Functors and natural transformations, equivalence of categories,. Products and coproducts, the hom functor, representable functors, universals and adjoints. Direct and inverse limits. Free objects. Homological algebra: Additive and abelian categories, Complexes and homology, long exact sequences, homotopy, resolutions, derived functors, Ext, Tor, cohomology of groups, extensions of groups.
4	**Texts/References**	1. M. Artin, Algebra, 2^{nd} Edition, Prentice Hall of India, 1994. 2. N. Jacobson, Basic Algebra, Vol. 1, 2^{nd} Edition, Hindustan Publishing Corporation, 1985. 3. N. Jacobson, Basic Algebra, Vol. 2, 2^{nd} Edition, Hindustan Publishing Corporation, 1989. 4. S. Lang, Algebra, 3rd Edition, Addison Wesley, 1993. 5. O. Zariski and P. Samuel, Commutative Algebra, Vol.1, Corrected reprinting of the 1958 edition, Springer-Verlag, New York, 1975. 6. O. Zariski and P. Samuel, Commutative Algebra, Vol.1, Reprint of the 1960 edition, Springer-Verlag, 1975.

1	**Title of the course** (L-T-P-C)	**Introduction to Representation Theory (3-0-0-6)**
2	**Pre-requisite courses(s)**	A course in (graduate) algebra
3	**Course content**	Basic notions of representation theory that includes irreducible modules and complete reducibility theorem. Character theory, Schur's orthogonality relations, isotopic components and the canonical decomposition. Group algebra and integrality, and the degree of an irreducible representation. Induced representations, Frobenius reciprocity, and Mackey theory. Various examples: Abelian groups, Dihedral groups, Symmetric groups in 3,4, and 5 letters.
4	**Texts/References**	1. J.-P.Serre, Linear representations of finite groups, Graduate Texts in Mathematics, Vol. 42, Springer- Verlag, New York-Heidelberg 1977 2. W. Fulton and J. Harris, Representation theory, A first course, Graduate Texts in Mathematics, 129. Readings in Mathematics, Springer-Verlag, New York, 1991 3. Benjamin Steinberg, Representation theory of finite groups : introductory approach, Springer-Verlag, New York, 2012.

1	**Title of the course** (L-T-P-C)	**Differential Topology** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Multivariable Calculus, General Topology and Linear Algebra
3	**Course content**	Differentiable manifolds, smooth maps between manifolds, Tangent spaces and cotangent spaces, Vector fields, tangent and cotangent bundles, Vector bundles, Sub manifolds, submersion and immersions, Basic notion of Lie groups, Tensors and differential forms, Integration on manifolds and de Rham theory
4	**Texts/References**	**1.** John M. Lee, Introduction to Smooth Manifolds, Springer Verlag, New York, 2003. **2.** Frank Warner, Foundations of Differentiable Manifolds and Lie Groups, Springer Verlag, New York, 1983 . **3.** Glen Bredon, Topology and Geometry, Springer Verlag, New York, 1993.

1	**Title of the course** (L-T-P-C)	**Topology** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Undergraduate level calculus and some mathematical maturity
3	**Course content**	Topological spaces, open and closed sets, basis, closure, interior and boundary. Subspace topology, Hausdorff spaces. Continuous maps: properties and constructions; Pasting Lemma. Homeomorphisms. Product topology, Quotient topology and examples of Topological Manifolds. Connected, path- connected and locally connected spaces. Lindelof and Compact spaces, Locally compact spaces, one- point compactification and Tychonoff's theorem. Paracompactness and Partitions of unity. Countability and separation axioms. Urysohn's lemma, Tietze extension theorem and applications. Completion of metric spaces. Baire Category Theorem and applications. (If time permits) Urysohn embedding lemma and metrization theorem for second countable spaces. Covering spaces, Path Lifting and Homotopy Lifting Theorems, Fundamental Group.
4	**Texts/References**	**1.** J. R. Munkres, Topology: a first course, Prentice- Hall of India (2000). **2.** K. Janich, Topology, UTM, Springer (Indian reprint 2006). **3.** M. A. Armstrong, Basic Topology, Springer (Indian reprint 2004). **4.** G. F. Simmons, Introduction to Topology and Modern Analysis, TataMcGraw- Hill (1963). **5.** J. L. Kelley, General Topology, Springer (Indian reprint 2005). **6.** I. M. Singer and J. A. Thorpe, Lecture Notes on Elementary Topology and Geometry, UTM, Springer (Indian reprint 2004). **7.** J. Dugundji, Topology, UBS (1999).

1	**Title of the course** (L-T-P-C)	**Introduction to Graduate Algebra (3-1-0-8)**
2	**Pre-requisite courses(s)**	Basics of Group Theory, Ring Theory and Module Theory, Linear Algebra, Field Theory and Galois Theory
3	**Course content**	Review of Group theory: Sylow's theorem and Group Actions, Ring theory: Euclidean Domains, PID and UFD's, Module theory: structure theorem of modules over PID Review of field and Galois theory, Infinite Galois extensions, Fundamental Theorem of Galois theory for infinite extensions, Transcendental extensions, Luroth`s theorem Review of integral ring extensions, prime ideals in integral ring extensions, Dedekind domains, discrete valuations rings, Categories and functors, Basic Homological algebra: Complexes and homology, long exact sequences, homotopy, resolutions, derived functors, Ext, Tor, cohomology of groups
4	**Texts/References**	**1.** Artin, Algebra, 2^{nd} Edition, Prentice Hall of India, Delhi, 1994. **2.** Jacobson, Basic Algebra, Vol. 1, 2^{nd} Edition, Hindustan Publishing Corporation, Delhi, 1985. **3.** Jacobson, Basic Algebra, Vol. 2, 2^{nd} Edition, Hindustan Publishing Corporation, Delhi, 1989. **4.** Lang, Algebra, 3rd Edition, Addison Wesley, Boston, 1993. **5.** Zariski and P. Samuel, Commutative Algebra, Vol.1, Corrected reprinting of the 1958 edition, Springer-Verlag, New York, 1975 **6.** Zariski and P. Samuel, Commutative Algebra, Vol.2, Reprint of the 1960 edition, Springer-Verlag, New York, 1975.

1	**Title of the course** (L-T-P-C)	**Numerical Analysis of Partial Differential Equations (4-0-0-8)**
2	**Pre-requisite courses(s)**	Analysis, ODE, PDE and Numerical Analysis
3	**Course content**	Numerical ODE - Multi Step and Multi Stage methods, A-stability, Stiffness Numerical solution of Elliptic Boundary value problems - Consistency, Stability and Convergence, Solution of Poisson's Equation in 2D, Numerical solution of Elliptic Eigenvalue problems Numerical solution of Conservation Laws – Local and Global Errors, Conservative Methods, Godunov Methods and High Resolution Methods, WENO scheme
4	**Texts/References**	**1.** Arieh Iserles, A first course in the numerical analysis of differential equations, 2^{nd} Edition, Cambridge University Press, UK, 2008 **2.** K. W. Morton & D. F. Mayers, Numerical solution of partial differential equations: An Introduction, 2^{nd} Edition, Cambridge University Press, UK, 2005 **3.** Randall J. LeVeque, Finite volume methods for Hyperbolic Problems, 2^{nd} Edition, Cambridge University Press, UK, 2002 **4.** Stig Larsson & Vidar Thomee, Partial Differential Equations with numerical methods, Text in Applied Mathematics, Springer-Verlag Berlin Heidelberg, 2003

1	**Title of the course** (L-T-P-C)	**Advanced Commutative Algebra** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Introduction to Algebra
3	**Course content**	Homological Algebra: Flat and faithfully flat modules, Complexes, homology and cohomology, the Tor modules, Injective resolutions and the Ext modules, Projective dimension, Global dimension Dimension Theory: Noether's Normalization Lemma, Graded rings and modules, Hilbert functions and series, Hilbert's Theorem, Hilbert-Samuel functions, Dimension Theorem Regular local rings: Homological characterisation of regular local rings, The Jacobian criterion for geometric regularity Cohen-Macaulay rings: Koszul complexes, Properties of CM modules. Complete local rings: Derivations and the module of Kähler differentials, Formal smoothness, Cohen's Structure Theorem for complete local rings Gorenstein rings: Basic properties of Gorenstein rings, Matlis duality
4	**Texts/References**	**1.** S. Bosch, Algebraic geometry and commutative algebra, Univers ,itext, Springer, (2013). **2.** W. Bruns, and J. Herzog, Cohen-Macaulay rings, Cambridge Studies in Advanced Mathematics 39, revised ed., Cambridge University Press, (1998). **3.** H. Matsumura, H, Commutative ring theory, Cambridge University Press, 1986. **4.** M. P. Murthy, Commutative Algebra, Course-notes, University of Chicago, 1972 / 73. **5.** P. Serre, Local Algebra, Springer-Verlag (2000). **6.** Singh, Basic Commutative Algebra, World Scientific Publications, (2011).

1	**Title of the course** (L-T-P-C)	**Algebraic Geometry I** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Introduction to Algebra
3	**Course content**	Affine, projective varieties, Hilbert's nullstellensatz, morphisms, rational maps, blowing up of a variety at a point, non-singular varieties, non-singular curves, intersection multiplicity Bézout's theorem
4	**Texts/References**	1. S. S. Abhyankar, Algebraic Geometry for Scientists and Engineers, American Mathematical Society, Providence, RI, 1990. 2. D. Eisenbud and J. Harris, The Geometry of Schemes, Springer-Verlag, 2000. 3. W. Fulton, Algebraic Curves, Benjamin, 1969. 4. J. Harris, Algebraic Geometry: A First Course, Springer-Verlag, 1992. 5. R. Hartshorne, Algebraic Geometry, Springer- Verlag, 1977. 6. I. R. Shafarevich, Basic Algebraic Geometry, Vol. 1 and 2, Second edition, Springer-Verlag, 1994.

1	**Title of the course** (L-T-P-C)	**Algebraic Geometry II** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Introduction to Algebra
3	**Course content**	Schemes: Sheaves, schemes, morphisms, separated and proper morphisms, sheaves of modules, divisors, Projective morphisms, differentials, formal scheme Cohomology: cohomology of sheaves, cohomology of a Noetherian affine scheme, Cech cohomology, the cohomology of projective space, the Serre duality theorem, flat morphism, smooth morphisms
4	**Texts/References**	1. R. Hartshorne, Algebraic Geometry, Springer- Verlag, 1977. 2. D. Mumford. The red book of varieties and schemes expanded ed., Lecture Notes in Mathematics 1358, Springer, 1999. 3. I. R. Shafarevich, Basic Algebraic Geometry, Vol. 1 and 2, Second edition, Springer-Verlag, 1994.

1	**Title of the course** (L-T-P-C)	**Algebra** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Basics of Group Theory, Ring Theory and Module Theory, Linear Algebra, Field Theory and Galois Theory
3	**Course content**	Categories and functors: definitions and examples. Functors and natural transformations, equivalence of categories, Products and coproducts, the hom functor, representable functors, universals and adjoints. Direct and inverse limits. Free objects. Homological algebra: Additive and abelian categories, Complexes and homology, long exact sequences, homotopy, resolutions, derived functors, Ext, Tor, cohomology of groups, extensions of groups, Review of field and Galois theory, Infinite Galois extensions, Fundamental Theorem of Galois theory for infinite extensions, Transcendental extensions, Luroth`s theorem, Review of integral ring extensions, prime ideals in integral ring extensions, Dedekind domains, discrete valuations rings.
4	**Texts/References**	1. M. Artin, Algebra, Prentice Hall of India, 1994. 2. N. Jacobson, Basic Algebra, Vol. 1 and 2, Hindustan Publishing Corporation. 3. S. Lang, Algebra, 3rd Ed., Addison Wesley, 1993. 4. O. Zariski and P. Samuel, Commutative Algebra, Vol.1 and 2, Springer-Verlag, 1975.

1	**Title of the course** (L-T-P-C)	**Random Schrodinger Operators (2-1-0-6)**
2	**Pre-requisite courses(s)**	Real analysis, Measure theory, Functional analysis and Probability Theory
3	**Course content**	Review of spectral theorem and functional calculus of self-adjoint operator on Hilbert space, Borel (or Stieltjes) transform of measure, The Anderson Model: Discrete Schrodinger operators, random potentials, Ergodic operators, Wegner estimate, integrated density of states (proof of existence), Lifshitz tail, The spectrum, Anderson localization in large disorder, fractional moments of Green's function, Multiscale analysis.
4	**Texts/References**	1. Aizenman M, Warzel S: Random Operators: Disorder Effects on Quantum Spectra and Dynamics, Graduate Studies in Mathematics, vol. 168 , Amer. Math. Soc. 2015. 2. Carmona C, Lacroix J: Spectral Theory of Random Schrodinger Operators, Birkhauser, Boston, 1990. 3. Kirsch W: An Invitation to Random Schrodinger Operators, (With an appendix by Frederic Klopp) Panor. Syntheses, 25, Random Schrodinger operators, 1, Soc. Math. France, Paris, 1−119, 2008. 4. Demuth M, Krishna M: Determining Spectra in Quantum Theory, Progress in Mathematical Physics, Vol. 44 (Birkhauser, Boston, 2005). 5. Simon B: Trace Ideals and Their Applications Mathematical Surveys and Monographs, vol.20.American Mathematical Society, Providence (2005)

1	**Title of the course** (L-T-P-C)	**Theory of Perfect Graphs** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	CS 201/113 Data Structures and Algorithms or equivalent CS 203/207 Discrete Structures or equivalent
3	**Course content**	Perfect graphs, The historical definition of perfect graphs, The Weak Perfect Graph Theorem, It's proof by Lovasz, The Strong Perfect Graph Theorem (statement only), Chrodal graphs, Perfect Elimination Order and Scheme, Proof of the correctness of Perfect Elimination Algorithm, The subtree intersection representation of chordal graphs, Split graphs, Degree sequence, Erdos-Gallai Theorem, Intersection graphs, Interval graphs, Adjacency and incidence Matrix Characterization, Properties
4	**Texts/References**	1. Golumbic M. C. *Algorithmic Graph Theory and Perfect Graphs*, Academic Press, New York, 1980 2. West D. B., Introduction to Graph Theory, 2nd Edition, Prentice Hall, Uper Saddle River, NY, 2001

1	**Title of the course** (L-T-P-C)	**Linear Integral Equation** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Real Analysis
3	**Course content**	Different types of integral equations and their applications. Basic solution strategies like successive approximation Review of normed spaces bounded and compact operator on normed spaces. linear integral operator with continuous and weakly singular kernel, compact linear integral operators Riesz theory and Fredholm theory and application to linear integral equations Boundary integral equations corresponding to interior and exterior problems of Laplace equations Cauchy Integral Operator, Singular integral equations with Cauchy Kernel Integral equations in the context of heat equations (If time permits)
4	**Texts/References**	1. Kress R., Linear Integral Equations, 3rd Edition, Springer New York, NY (2013) 2. Kanwal Ram P., Linear Integral Equations: Theory and Technique, 2nd Edition, Springer New York (2012) 3. Hackbusch W., Integral Equations, Theory and Numerical Treatment, 1st Edition, Birkhäuser Basel (1995).

1	**Title of the course** (L-T-P-C)	**Preparatory Mathematics 1**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Complex numbers as ordered pairs. Argand's diagram. Triangle inequality. De Moivre's Theorem. Algebra: Quadratic equations and expressions. Permutations and combinations. Binomial theorem for a positive integral index. Coordinate Geometry: Locus, Straight lines. Equations of circle, parabola, ellipse and hyperbola in standard forms. Parametric representation. Vectors: Addition of vectors. Multiplication by a scalar. Scalar product, cross product and scalar triple product with geometrical applications. Matrices and Determinants: Algebra of matrices. Determinants and their properties. Inverse of a matrix. Cramer's rule.
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**Advanced Graph Theory** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Real analysis, Measure theory, Functional analysis and Probability Theory
3	**Course content**	Fundamental concepts of graph theory, Trees and distances, Planar graphs, Graphs on surfaces, Coloring and chromatic numbers, Edge coloring and chromatic index, Total coloring and total chromatic number, List coloring and choosability, Graph minors, Directed and Oriented graphs, Graph homomorphisms, Graph homomorphisms and colorings, Graph homomorphisms and minors, Extremal graph theory, Random graphs.
4	**Texts/References**	1. B. West, Introduction to Graph Theory 2nd edition. Prentice Hall. 2. Harary. Graph Theory. Reading, MA: Perseus Books, 1999. 3. R. Diestel, Graph Theory, 5th edition. Springer.

1	**Title of the course** (L-T-P-C)	**Preparatory Mathematics-2**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Function, Inverse function, Elementary functions and their graphs, Limit, Continuity, Derivative and its geometrical significance. Differentiability. Derivatives of sum, difference, product and quotient of functions. Derivatives of polynomial, rational, trigonometric, logarithmic, exponential, hyperbolic, inverse trigonometric and inverse hyperbolic functions. Differentiation of composite and implicit functions. Tangent and Normals, Increasing and decreasing functions. Maxima and Minima. Integrations as the inverse process of differentiation, Integration by parts and by substitution. Definite integrals and its application to the determination of areas.
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**Measure Theory** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Real Analysis
3	**Course content**	Construction of Lebesgue measure on Real line, Introduction to abstract measure theory, Measurable functions, Caratheodory's Extension Theorem, MCT, Fatou's Lemma, DCT, Product space, Product measure, Fubini's Theorem, Definition of signed measures, Positive and negative sets. Hahn-Jordan Decomposition. Absolute continuity of two σ-finite measures. Radon-Nikodyme Theorem and Lebesgue Decomposition.
4	**Texts/References**	**1.** H. L. Royden; Real analysis. Third edition. Macmillan Publishing Company, New York, 1988. **2.** W. Rudin; Real and complex analysis. Third edition. McGraw-Hill Book Co., New York, 1987. **3.** S. Athreya and V.S. sunder; Measure & probability. CRC Press, Boca Raton, FL, 2018. 4. K.R. Parthasarathy; Introduction to probability and measure, Hindustan Book Agency, 2005.

1	**Title of the course** (L-T-P-C)	**Linear Integral Equations** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Real Analysis
3	**Course content**	Different types of integral equations and their applications. Basic solution strategies like successive approximation Review of normed spaces bounded and compact operator on normed spaces. linear integral operator with continuous and weakly singular kernel, compact linear integral operators Riesz theory and Fredholm theory and application to linear integral equations Boundary integral equations corresponding to interior and exterior problems of Laplace equations Cauchy Integral Operator, Singular integral equations with Cauchy Kernel Integral equations in the context of heat equations (If time permits)
4	**Texts/References**	Kress R., Linear Integral Equations, 3rd Edition, Springer New York (2013) Kanwal Ram P., Linear Integral Equations: Theory and Technique, 2nd Edition, Springer New York (2012). Hack Busch W., Integral Equations, Theory and Numerical Treatment, 1st Edition, Burkhouse Basel (1995).

1	**Title of the course** (L-T-P-C)	**Theory of Perfect Graphs** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	CS 201/113 Data Structures and Algorithms or equivalent CS 203/207 Discrete Structures or equivalent
3	**Course content**	Perfect graphs, The historical definition of perfect graphs, The Weak Perfect Graph Theorem, It's proof by Lovasz, The Strong Perfect Graph Theorem (statement only), Chrodal graphs, Perfect Elimination Order and Scheme, Proof of the correctness of Perfect Elimination Algorithm, The subtree intersection representation of chordal graphs, Split graphs, Degree sequence, Erdos-Gallai Theorem, Intersection graphs, Interval graphs, Adjacency and incidence Matrix Characterization, Properties
4	**Texts/References**	1. Golumbic M. C. *Algorithmic Graph Theory and Perfect Graphs*, Academic Press, New York, 1980 2. West D. B., Introduction to Graph Theory, 2nd Edition, Prentice Hall, Uper Saddle River, NY, 2001

1	**Title of the course** (L-T-P-C)	**Topics in Graph Theory** **(1-0-0-2)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Solving elementary combinatorial problems, learning mathematical writing, reading a combinatorial research paper or a book and presenting it, literature review (if applicable)
4	**Texts/References**	1. West D. B., Introduction to Graph Theory, 2nd edition. First Indian Reprint, Pearson Education (2002) 2. Harary F., Graph Theory. 1st Edition, Reading, MA: Perseus Books (1999) 3. Diestel R., Graph Theory, 5th edition. Springer Berlin, Heidelberg (2017) 4. Stunk W., Jr. and White E. B., The elements of Style, 4th Edition, Allyn & Bacon, US (1999)

1	**Title of the course** (L-T-P-C)	**Topics in Elliptic Partial Differential Equations** (3-0-0-6)
2	**Pre-requisite courses(s)**	Measure Theory, Metric spaces & Introductory Functional Analysis
3	**Course content**	Convolutions, mollifiers, cut-off functions & partitions of unity Elliptic and Uniformly Elliptic Operators, Maximum principles, Hopf's lemma, Uniqueness of boundary value problems of elliptic PDEs, Weak derivatives and their properties, Definition of Sobolev spaces, Global and local approximation of functions in $W^{k,p}$ by smooth functions, Trace theorem, Sobolev inequalities, imbedding results Idea of weak solution of elliptic PDEs, Lax-Milgram theorem and existence and uniqueness of weak solutions of linear Elliptic pdes, Interior and boundary regularity of weak solutions
4	**Texts/References**	1. Evans L., Partial Differential Equations, 2nd Edition, GSM, Vol 19, AMS, Providence, Rhode Island (2010) 2. Han Q. and Lin F., Elliptic Partial Differential Equations, 2nd Edition, Vol 3. CIMS and AMS, Providence, Rhode Island (2011) 4. Renardy M. & Rogers R. C., An Introduction to Partial Differential Equations, 2nd Edition, Springer NY (2006) 5. Gilberg D. & Trudinger N. S., Elliptic Partial DIfferential Equations of second order, 2nd ed. Springer-Verlag, Berlin (1983)

1	**Title of the course** (L-T-P-C)	**Numerical Solution of Linear Integral Equations (3-0-0-6)**
2	**Pre-requisite courses(s)**	Metric spaces & Introductory Functional Analysis
3	**Course content**	Operator approximations, approximations based on norm and pointwise convergence Method of degenerate kernels, degenerate kernels via Taylor expansion, orthogonal expansion and expansion by interpolation Theory of projection methods, Collocation and Galerkin techniques, their examples Nystrom technique for continuous and weakly continuous kernels Boundary integral equations of Laplace equation in 2 Dimension and 3 Dimension in domains with smooth boundary Multivariable integral equations and their numerical solutions
4	**Texts/References**	1. Kress R., Linear Integral Equations, 3rd Edition, Springer New York (2013) 2. Atkinson K., The Numerical Solution of Integral Equations of the Second Kind, 1st Edition, Cambridge University Press, (1997) 3. Hackbusch W., Integral Equations, Theory and Numerical Treatment, 1st 4. Edition, Birkhäuser Basel (1995)

1	**Title of the course** (L-T-P-C)	**Complex Analysis with Applications to Number Theory (3-0-0-6)**
2	**Pre-requisite courses(s)**	Real Analysis, Basic Complex Analysis
3	**Course content**	Introduction to holomorphic functions, Complex integration, Cauchy's Theorem, and its applications, Entire and Meromorphic functions, functions of finite order, Argument principle, Maximum modulus principle, Jensen's formula. Estimate for the number of zeros of an exponential polynomial inside a disc, zero density estimates (Use of three circle method, effect of small derivatives) to estimate growth of a function in terms of zero and derivatives, Hermite Interpolation formula. Weierstrass infinite product, Hadamard's factorization theorem, Gamma and Riemann Zeta functions, Euler product, Functional equation and Analytic continuation An introduction to Elliptic functions, Introduction of Jacobi theta functions, Hermite Pade-Approximation, Transcendental function, algebraically independent functions, Entire functions with rational values
4	**Texts/References**	1. Lang S., Complex Analysis, 4th Edition, Springer-Verlag, New York (1999). 2. Stein E. M. and Shakarchi R., Complex Analysis, Vol. 2, 1st Edition Princeton Lectures in Analysis, Princeton University Press, Princeton, NJ (2003). 3. Shorey T. N., Complex Analysis with Applications to Number Theory, 1st Edition, Springer, Singapore (2020). 4. Ahlfors L., Complex Analysis, 3rd Edition, McGraw-Hill Book Co., New York (1978)

1	**Title of the course** (L-T-P-C)	**Introduction to Diophantine Approximation (3-0-0-6)**
2	**Pre-requisite courses(s)**	Linear algebra, prior knowledge of Field and Galois theory over Q is helpful, but not necessary as the course is self-contained
3	**Course content**	b-ary expansion, Continued fraction expansion, Legendre theorem, Dirichlet approximation theorem, Simultaneous approximation theorem, Minkowski's convex body theorem Linear independence criteria (including Siegel and Nesterenko's criterion), Liouville theorem, Transcendence of e and π, Roth's theorem on the approximation of algebraic numbers by rationals, Brief introduction to Schmidt Subspace theorem(higher dimensional generalization of Roth's Theorem) and some of its application, b-ary(or base b-expansion) expansion of algebraic numbers Finite Automata, Automatic Sequences and Transcendence
4	**Texts/References**	1. Allouche J. P. and Shallit J.. Automatic sequences: Theory, Applications, Generalizations, 1st Edition, Cambridge University Press (2003). 2. Bugeaud Y., Approximation by algebraic numbers, 1st Edition, Cambridge University Press (2004). 3. Ram Murty M. and Rath P., Transcendental numbers, 1st Edition, Springer, New York (2014). 4. Natarajan S. and Thangadurai R., Pillars of Transcendental number theory, 1st Edition, Springer Verlag (2020) 5. Niven I., Irrational numbers, Sixth printing, The Mathematical Association of America (2006). 6. Schmidt W. M., Diophantine Approximation, 1st Edition, Springer Verlag, Lecture Notes in Mathematics 785 (1980). 7. Waldschmidt M., Criteria for irrationality, linear independence, transcendence, and algebraic independence, Lecture Notes at CMI and IMSc, http://people.math.jussieu.fr/~miw/enseignements.htMl

1	**Title of the course** (L-T-P-C)	**Introduction to Lie Algebras** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Linear algebra. Familiarity with the basics of rings and modules is preferable but not mandatory.
3	**Course content**	Definition and examples of Lie algebras, namely, classical Lie algebras: general linear, special linear, symplectic, even-odd orthogonal Lie algebras. Elementary properties of Lie algebras: solvable and nilpotent. Theorems of Lie, Cartan, and Engel. Structure and classification of semisimple Lie algebras over the field of complex numbers. Root systems and their construction, Dynkyn diagrams. Representation theory of semisimple Lie algebras (if time allows): highest weight modules, Borel subalgebras and Verma modules. Course will have the rank two simple algebra (namely all two by two traceless matrices) as a running example.
4	**Texts/References**	1. Humphreys J. E., Introduction to Lie Algebras and Representation Theory, 1st Edition, Springer-Verlag, 3rd printing (1980) 2. Carter R., Lie Algebras of Finite and Affine Type, 1st Edition, Cambridge Studies in Advanced Mathematics, Cambridge University Press (2005) 3. Harris J. and Fulton W., Representation Theory: A First Course, 1st Edition, GTM, Vol. 129, Springer Verlag NY (2004) 4. Erdman K. and Wildon, M. J., Introduction to Lie Algebras, 1st Edition, Springer Undergraduate Mathematics Series, Springer London (2006)

1	**Title of the course** (L-T-P-C)	**Irrational and Transcendental Numbers** (3-0-0-6)
2	**Pre-requisite courses(s)**	Linear Algebra, Complex Analysis, and prior knowledge of Field andGalois theory over Q is helpful
3	**Course content**	Hermite Pade-Approximation, Transcendence of e and pi, Lindemann Weierstrass Theorem, Gelfond-Schneider Theorem, Six-Exponential Theorem, Schneider-Lang Theorem and its applications, Baker's theory oflinear form in logarithm of algebraic numbers. Criterion for linear independence – Siegel and Nesterenko's methods, Irrationality of Reimann Zeta function at odd positive integers: Apery's irrationality proof of zeta(3) and Beukers's proof, Ball-Rivoal theorem, recent results about infinitely many odd zeta values are irrational due to Fischler-Zudilin-Sprang
4	**Texts/References**	1. Baker A., Transcendental Number Theory, Cambridge University Press,1975. 2. Burger E. B. and Tubbs R., Making Transcendence Transparent: An intuitive approach to classical transcendental number theory, Springer NewYork, 2004. 3. Ram Murty M. and Rath P., Transcendental numbers, 1st Edition, Springer, New York (2014). 4. Natarajan S. and Thangadurai R., Pillars of Transcendental number theory,1st Edition, Springer Verlag (2020). 5. Ball, K. and Tanguy R., Irrationality of infinitely many values of the zetafunction at odd integers, Invent. Math. (2001). 6. Fischler S., Johannes S. and Zudilin W., Many odd zeta values areirrational, Compos. Math. (2019)

1	**Title of the course** (L-T-P-C)	**Engineering Mathematics for Advanced Studies** **(4-0-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module-1:** Linear Algebra: Vector Spaces, Matrices, Linear algebraic equations, Eigenvalues and Eigenvectors of matrices, Singular-value decomposition **Module-2:** Tensor Algebra: Index Notation and Summation Convection, Tensor Algebra **Module-3:** Vector Calculus: Dot and Cross Product, Curves. Arc Length. Curvature. Torsion, Divergence and Curl of a Vector Field, Line Integrals, Green's Theorem, Stokes's Theorem, use of Vector Calculus in various engineering streams **Module-4:** Ordinary Differential Equations: Initial Value Problem, Method to solve first order ODE, Homogeneous, linear, 2nd order ODE, Nonhomogeneous, linear, 2nd order ODE, System of 1st order ODE **Module-5:** Laplace and Fourier transformation: First and Second Shifting Theorems, Transforms of Derivatives and Integrals, Fourier Cosine and Sine Transforms, Discrete and Fast Fourier Transforms **Module-6:** Partial Differential Equations: Basic Concepts of PDEs, Modeling: Wave Equation, Heat Equation, Solution by Separating Variables, Solution by Fourier Series, Solution by Fourier Integrals and Transforms **Module-7:** Numerical Methods: Methods for Linear Systems, Least Squares, Householder's Tridiagonalization and QR-Factorization, Methods for Elliptic, Parabolic, Hyperbolic PDEs **Module-8:** Complex Analysis and Potential Theory: The Cauchy-Riemann Equations, Use of Conformal Mapping, Electrostatic Fields, Heat and Fluid Flow Problems, Poisson's Integral Formula for Potentials **Module-9:** Optimization and Linear Programming: Method of Steepest Descent, Linear Programming, , Fundamental theorem of linear inequalities, Cones, polyhedra. and polytopes, Farkas' lemma, LPduality, max-flow min-cut, Simplex Method, primaldual, Fourier-Motzkin elimination, relaxation methods **Module-10:** Probability Theory and Statistics: Experiments, Outcomes, Events, Permutations and Combinations, Probability Distributions, Binomial, Poisson, and Normal Distributions, Distributions of Several Random Variables, Testing Hypotheses, Goodness of Fit, $\chi 2$-Test **Module-11:** Abstract Algebra: Groups, Sub-groups, Cosets and Lagrange's theorem, Group actions, direct and semi-direct products.
4	**Texts/References**	**1.** E. Kreyszig. Advanced Engineering Mathematics, John Wiley & Sons, 2011. **2.** P.V. O'Neil. Advanced Engineering Mathematics, CENGAGE Learning, 2011. **3.** D.G. Zill. Advanced Engineering Mathematics, Jones & Bartlett Learning 2016. **4.** B. Dasgupta. Applied Mathematical Methods, Pearson Education, 2006. **5.** A. Schrijver, Theory of Linear and Integer Programming, 1998. **6.** D.S. Dummit, R.M. Foote, Abstract Algebra, 2004.

1	**Title of the course** (L-T-P-C)	**Algebraic Number Theory** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Group Theory, Elementary Number Theory. We will also need some conceptsabout rings, modules, and Galois theory throughout the course.
3	**Course content**	Algebraic numbers and Algebraic integers, Number Fields and Number rings, Traces and Norms, Discriminant, Dedekind domains,Ideal class group, Unique factorization and prime decomposition in Number rings, Galois theory of Number Fields. Finiteness of ideal class group, Lattices, Minkowski Theory, Dirichlet unit theorem, p-adic numbers, Absolute values, Valuationsand completions of number fields.
4	**Texts/References**	**1.** Lang S., Algebraic Number Theory, Graduate Texts in Mathematics 110, Springer-Verlag, 1994. **2.** Murty Ram M., and Esmonde J., Problems in Algebraic Number Theory, Graduate Texts in Mathematics, Springer-Verlag, New York,2001. **3.** Neukirch J., Algebraic Number Theory, Springer-Verlag, 1999. **4.** Samuel P., Algebraic Theory of Numbers, Houghton Mifflin Co.,Boston, MA, 1970. 109 pp. **5.** Janusz G. J., Algebraic Number Fields, Graduate Studies inMathematics 7, American Mathematical Society, 1996. Milne J.S., Algebraic Number Theory, Available at https://www.jmilne.org/math/CourseNotes/ANT.pdf, 2020.