Department of Mathematical Sciences

Course Structure and Syllabus of M.Sc. in Mathematics
(for 2019 entry batch onwards)

Minimum credit requirement: 80
Minimum duration: 2 years (4 semesters)
Maximum duration: 4 years (8 semesters)

COURSE STRUCTURE

Semester I

Course Code	Course Name	L-T-P	CH	CR	Remark
MS 401	Abstract Algebra	3-1-0	4	4	CORE
MS 403	Linear Algebra	3-1-0	4	4	CORE
MS 405	Real Analysis	3-1-0	4	4	CORE
MS 411	Computer Programming+	3-1-0	4	4	CORE
MS 425	Lebesgue Measure and Integration	3-1-0	4	4	CORE
MS 421	Computer Lab	0-0-1	2	1	CORE
Total credits				**21**	

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remark
MS 406	Complex Analysis	3-1-0	4	4	CORE
MS 414	Theory of Ordinary Differential Equations	3-1-0	4	4	CORE
MS 408	Topology	3-1-0	4	4	CORE
MS 416	Numerical Analysis+	3-1-0	4	4	CORE
MS 424	Computer Lab	0-0-1	2	1	CORE
	Open Elective-I[#]	2-1-0	3	3	Open Elective
Total credits				**20**	

List to be notified by the CoE from time to time

+ *Course for which there is a separate practical unit assigned as Computer Laboratory*

L: Lectures T: Tutorials P: Practical CH: Contact Hours (all per week) CR: Credit

Semester III

Course Code	Course Name	L-T-P	CH	CR	Remark
MS 507	Partial Differential Equations	3-1-0	4	4	CORE
MS 510	Functional Analysis	3-1-0	4	4	CORE
	DSE-I*	3-1-0	4	4	DSE
	Open Elective II#	2-1-0	3	3	Open Elective
MS 517	Project	0-2-2	6	4	CORE
Total credits				**19**	

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remark
MS 599	Probability Theory	3-1-0	4	4	CORE
MS 508	Mathematical Methods	3-1-0	4	4	CORE
MS 501	Classical Mechanics	3-1-0	4	4	CORE
	DSE-II*	3-1-0	4	4	DSE
	DSE-III*	3-1-0	4	4	DSE
Total credits				**20**	

DSE-I, II, III* are to be chosen from the following courses:

Course Code	Course Name	L-T-P	CH	CR
MS 538	Theory of Partial Differential Equation	3-1-0	4	4
MS 539	Advanced Numerical Analysis	3-1-0	4	4
MS 541	Fluid Mechanics	3-1-0	4	4
MS 543	Relativity	3-1-0	4	4
MS 544	Operations Research	3-1-0	4	4
MS 545	Elliptic Curves	3-1-0	4	4
MS 546	Algebraic Number Theory	3-1-0	4	4
MS 547	Numerical Linear Algebra	3-1-0	4	4
MS 549	Graph Theory	3-1-0	4	4
MS 551	Introduction to Category Theory	3-1-0	4	4
MS 552	Operator Theory-I	3-1-0	4	4
MS 554	Commutative Algebra	3-1-0	4	4
MS 558	General Theory of Relativity	3-1-0	4	4
MS 561	Stochastic processes-I	3-1-0	4	4
MS 565	Fuzzy Sets and Applications-I	3-1-0	4	4
MS 566	Fourier Analysis	3-1-0	4	4

MS 567	Continuum Mechanics	3-1-0	4	4
MS 568	Theory of Distribution and Sobolev Spaces	3-1-0	4	4
MS 569	Coding Theory-I	3-1-0	4	4
MS 570	Coding Theory-II	3-1-0	4	4
MS 572	Operator Theory –II	3-1-0	4	4
MS 573	Analytic Number Theory	3-1-0	4	4
MS 574	Galois Theory	3-1-0	4	4
MS 581	Stochastic Processes –II	3-1-0	4	4
MS 585	Fuzzy Sets and Applications-II	3-1-0	4	4
MS 587	Finite Element Method	3-1-0	4	4
MS 588	Applied Matrix Theory	3-1-0	4	4
MS 591	Computational Fluid Dynamics	3-1-0	4	4
MS 594	Advanced Topology-I	3-1-0	4	4
MS 595	Numerical Solutions of ODE	3-1-0	4	4
MS 596	Advanced Topology-II	3-1-0	4	4
MS 597	Numerical Solutions of PDE	3-1-0	4	4
MS 598	Algebraic Geometry	3-1-0	4	4

Detailed syllabus:

MS 401: Abstract Algebra (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

External direct product of groups, properties of external direct products, internal direct products, fundamental theorem of finite abelian groups and applications.

Unit-2

Group action, properties of group action, class equation of finite groups, Sylow's theorems, applications of Sylow's theorems.

Unit-3

Subnornmal, normal series, derived group, solvable groups, composition series, nilpotent groups, Jordan-Holder theorem.

Unit-4

Word, reduced word, free group, rank of a free group, fundamental theorem of free groups, presentation of groups.

Unit-5

Polynomial rings, rings of formal power series, embedding theorems, field of fractions.

Unit-6

Factorization theory in integral domains, PID, UFD and Euclidean domains.

Unit-7

Field extensions, algebraic and transcendental elements, geometrical constructions, splitting field, finite fields, structure of finite fields, normal, separable and inseparable extension of fields.

Textbook(s):

1. Gallian, J. A., *Contemporary Abstract Algebra*, 4th edition (Narosa Publishing house, New Delhi, 2009).
2. Dummit, D. S. & Foote, R. M., *Abstract Algebra*, 3rd edition (John Wiley & Sons, Indian reprint, New Delhi, 2011).
3. Herstein, I. N., *Topics in Algebra*, 2nd edition (John Wiley & Sons, Indian reprint, New Delhi, 2006).

Reference book(s):

1. Fraleigh, J. B. *A First Course in Abstract Algebra*, 7th edition (Pearson Education India, New Delhi, 2008).
2. Lang, S. *Algebra*, 3rd edition (Springer India, New Delhi, 2006).

MS 403: Linear Algebra (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Matrix representation of a linear transformation, Annihilating polynomial of a linear transformation; Elementary Canonical forms: diagonalization and triangulation of linear operators. Gerschgorin's disk theorem.

Unit-2

Primary Decomposition theorem; rational and Jordan forms.

Unit-3

Inner product spaces: inner product, Cauchy-Schwarz inequality, Gram-Schmidt orthogonalization process

Unit-4

Linear functionals and adjoints; self adjoint, positive definite, normal and unitary operators; orthogonal projections; spectral theorem for normal operators on a finite dimensional vector space, Singular value decomposition.

Unit- 6

Bilinear forms, Matrices of bilinear forms, Symmetric bilinear forms, Diagonalization of symmetric matrices, positive and quadratic forms, Sylvester's law of inertia.

Text Book(s) :

1. Stephen H. F., Arnold J. I. and Lawrence E. S., Linear Algebra, 4th edition, Prentice Hall, 2003.

2. Halmos, P. R., Finite dimensional vector spaces, Springer Verlag, New York, 1987**.**

3. Hoffman, K. and Kunze, R., Linear Algebra, Prentice Hall, 1984.

Reference Book(s) :

1. Halmos, P. R., Linear Algebra Problem Book, The Mathematical Association of America (MAA), USA, 1995.

2. Williams, G., Linear Algebra with Applications, Jones and Burlet Publishers, 2001.

MS 405: Real Analysis (L3-T1-P0–CH4-CR4)

Unit- 1

Sequence of functions, pointwise and uniform convergence, interchange of limits. Functions of bounded variation. Reimann Stieltjes integral. Integration by parts

Unit- 2

Compactness, Sequential compactness, Bolzano-Weierstrass Property, Totally bounded spaces, compactness and completeness, finite intersection property. Continuous functions on compact spaces. Characterization of complete metric spaces. Arzela Ascoli Theorem.

Unit- 3

Connectedness, intermediate value theorem, Completeness, Bolzano Weierstrass Theorem, nested set theorem. Fixed point theorem. Completion.

Unit- 4

Functions of several variables, directional derivatives, differentiability and total derivative. Jacobians, chain rule, higher order partial derivatives, Taylor's theorem. Inverse function theorem, Implicit function theorem, extremum problem with constraints, Lagrange's method of multiplier.

Text Books:

1. N. L. Carothers. Real Analysis.
2. W. Fleming. Functions of several variables

Reference:

1. Apostol, T. M. Mathematical Analysis (Narosa Publishing House, 1985)
2. Simmons, G. F. Introduction to Topology and Modern Analysis
(Tata McGraw Hill Book Co. Ltd.,1963).

MS 406: Complex Analysis (L3-T1-P0-CH-CR 4)

Unit-1

Convergence of sequences and series, Absolute and uniform convergence of power series, Integration and differentiation of power series, uniqueness of series representations.

Unit-2

Taylor series, Zeros of analytic functions, Limit points of Zeros, Singularities and their classification, Behaviour of the function in a neighbourhood of isolated singularities, Laurent's series, Residues, Cauchy Residue Theorem.

Unit-3

Evaluation of improper integrals and definite integrals involving sines and cosines, integration through a branch cut.

Unit-4

The winding number, Logarithmic residues and Rouche's theorem, the Argument Principle.

Unit-5

Mapping by elementary functions, Linear fractional transformations, cross ratios, mappings of the half planes and circles, conformal mapping, Statement of Riemann Mapping Theorem.

Unit-6

Schwarz Reflection Principle, Analytic continuation, Riemann Surfaces.

Textbook(s)

1. Mathews, J. H. and Howell, R. W., *Complex Analysis for Mathematics and Engineering*, 3rd Edition, Narosa, 1998.
2. Conway, J. B. *Functions of One Complex Variable*, 2nd Edition (Narosa Publishing House, India, 1994).
3. Churchill, R. V. and Brown, J. W. *Complex Variables and Applications*, McGraw-Hill Education (India) Edition, 2014,

Reference book(s)

1. Ahlfors, L. V. *Complex Analysis*, 3rd Edition (McGraw-Hill Publishing Company, New Delhi, 1979).
2. Priestly, H.A. *Introduction to Complex Analysis*, 2nd Edition, Cambridge, 2008.
3. Gamelin, T. W., *Complex Analysis*, UTM, Springer, 2003.
4. Narasimhan, R. and Nievergelt, Y., *Complex Analysis in One Variable*, 2nd Edition, Springer (India), New Delhi, 2004.

MS 408: Topology (L3 -T1 -P0 –CH4 -CR 4)

Unit 1

Metric topology, Product and Box topology, Order topology, Quotient spaces

Unit 2

Countability axioms: First countable spaces, Second countable spaces, separable spaces, Lindelof spaces.

Unit 3

Separation axioms: Hausdorff, Regular and Normal spaces, Urysohn's characterization of normality, Urysohn's metrization theorem, Tietze's extension theorem, Completely Regular spaces.

Unit 4

Compactness, limit point compactness, local compactness, one-point compactification.

Unit 5

Tychonoff's product theorem, Stone-Cech compactification, Baire Spaces, Baire Category Theorem.

Unit 6

Connectedness, Local connectedness, Path connectedness, Components, Products of connected spaces.

Text Books:

1. Munkres, J. R. *Topology : A first course* (2/e), Pearson Education, 2000
2. Willard, S., Topology, Dover, 1970.

References:

1. Joshi, K. D.**,** *Topology*, Wiley-Eastern, 1988.
2. Kelley, J. L.**,** *General Topology*, Graduate texts in Math., Springer, 1991.
3. Adams C. and Franzosa, R. Introduction to Topology: Pure and Applied, Pearson, 2009.

MS 411: Computer Programming^{+} (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Revision of fundamentals of C: Data types in C, variables in C, input output statements, constant declaration, arithmetic operators in C, arithmetic expressions, assignment statements, arithmetic assignment operators, increment and decrement operators, type conversions, operator precedence. for loop, while loop, do…while loop, if statement, if…else statement, switch statement, conditional operators. The break statement, the continue statement, the go-to statement.

Unit-2

Arrays: Arrays, declaration of one dimensional arrays, two dimensional arrays.

Structures and Unions: User defined data types, structures, array of structures, unions, enumerated data type.

Unit-3

Searching and Sorting: Bubble sort, selection sort, insertion sort, linear search and binary search.

Unit-4

Function in C: Simple functions, passing arguments to functions with return value, call by value, call by reference, overloaded functions, inline functions, default arguments.

Unit-5

Pointers: Introduction; accessing address of a variable; pointer declaration, initialization, accessing variable through pointer, chain of pointers; pointer expressions, increment and scale factor. Pointers and Arrays. Array of pointers. Pointers as function arguments.

Unit-6

Files in C: Defining and opening a file, closing a file. Input/Output operations on files.

Unit-7

Dynamic Memory Allocation and Linked list: Dynamic memory allocation, Malloc, Calloc, Free, Realloc. Concepts of linked list, advantages of linked list, types of linked list. Creating a linked list.

Textbook(s)

1. Rajaraman, V. *Fundamentals of Computers* (Prentice Hall of India, New Delhi, 2002).
2. Balaguruswamy, E. *Programming in ANSI C* (Tata McGraw-Hill, 2004).

Reference book(s)

1. Kanetkar, Y. P. *Let us C* (BPB Publication, 2001).
2. Venkateshmurthy, M. G. *Programming Techniques through C* (Pearson Education, 2002).

[+] *Practical unit for the course MS 411 to be done in the course MS 421 Computer Laboratory*

MS 414: Theory of Ordinary Differential Equations (L3 -T1 -P0 -CH4 -CR 4)

Unit -1

Review of fundamentals of ODEs, Some basic mathematical models, direction fields, classification of differential equation, Solutions of some differential equation. 1st order non-linear differential equation.

Existence and Uniqueness problem, Gronwall's inequality, Peanao existence theorem, Picard existence and uniqueness theorem, interval of definition.

Unit -2

Second order linear differential equation, General solution for homogeneous equation, superposition of solutions, Methods of solution for non-homogeneous problem: undetermined coefficients, variation of parameters.

Unit -3

nth order differential equation, system of equation, homogeneous system of equation, fundamental matrix, Abel-Liouvelle formula, System of non-homogeneous equations, Stability of linear systems.

Unit -4

Theory of two point BVP, Greens function, Greens matrix, properties of greens functions, Adjoint and self adjoint BVP.

Unit -5

Strum-Liouvilles problem, Orthogonal functions, eigen values & eigen functions, Completeness of the Eigen functions.

Unit -6

Orthogonal trajectory of a system of curves on a surface solution of pfaffian differential equations in three variables.

Unit -7

Stability of linear and non-linear system: Classification of critical points, Lyanpunov stability.

Textbook(s)

1. Boyce, W. E. and DiPrima, R. C. *Elementary Differential Equation and Boundary Value Problems*, 7th Edition (John Wiley & Sons(Asia), 2001).
2. Ross, S. L. *Differential Equations*, 3rd edition (Wiley 1984).

Reference book(s)

1. Simmons, G. F. *Differential Equations with Applications and Historical Notes* (McGraw Hill, 1991).
2. Coddington, E. A. *An Introduction to Ordinary Differential Equations* (Prentice-Hall, 1974).
3. Farlow, S. J. *An Introduction to Differential Equations and Their Applications* (McGraw-Hill International Editions, 1994).

MS 416: Numerical Analysis $^{+}$ **(L3 -T1 -P0 –CH4 -CR 4)**

Unit-1
Definition and sources of errors, Propagation of errors, Error analysis, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors.
Unit-2
Solution of system of linear algebraic equations: Iterative methods- Jacobi, Gauss-Seidel, Successive over-relaxation (SOR), symmetric SOR (SSOR). Numerical solution of non-linear simultaneous equations, Newton's method, General iteration method.
Unit-3
Review of interpolation, Hermite interpolation. Spline interpolation, B-splines. Special emphasis on cubic spline.
Unit-4
Approximation of function: The Weierstrass and Taylor theorem, Minimax and least square approximations, Orthogonal polynomials.
Unit-5
Numerical solution of algebraic and transcendental equations: Methods based on first and second degree equations, rate of convergence. Theory of one point iterative methods and its convergence analysis, multipoint iterative methods. Numerical evaluation of multiple roots.
Unit-6
Overview of Nwton-Cotes method. Composite integration. Gaussian quadrature, one point, two point and three point formulae. Orthogonal polynomials, Gauss-Legendre, Gauss-Hermite and Gauss-Laguerre quadrature formulae. Romberg integration**.**
Unit-7
Solution of ordinary differential equations. Picard method, Euler method, backward Euler method, modified Euler method, Runge-Kutta class of methods.
Unit-8
Solving problems with C codes.

Textbook(s)
1. Atkinson, K.E. *Introduction to Numerical Analysis* (John Wiley, 1989)
2. Jain, M.K., Iyengar, S.R.K. and Jain R.K. *Numerical methods for Scientific and Engineering Computation*, 5th edition (New Age International (P) Ltd., New Delhi, 2006).

Reference book(s)
1. Sastry, S.S. *Introductory methods of Numerical Analysis* (Prentice Hall of India, New Delhi, 1977)
2. *Hilderbrand*, F. B. *Introduction to Numerical Analysis* (Tata McGraw Hill, New Delhi, 1974).
3. Conte, S. D., Boor, Carl de. *Elementary Numerical Analysis - An Algorithmic Approach*, 3rd Edition (McGraw Hill, 1980).

MS 421 Computer Laboratory+ (L0-T0-P2 –CH4 -CR 2)

+ *Practical unit for the course MS 411 Computer Programming*

MS 424: Computer Laboratory+ (L0 -T0 -P2 -CH4 -CR 2)

+ *Practical unit for the course MI 302 Numerical Analysis+.*

MS 425: Lebesgue Measure and Integration (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Algebra of sets, Borel sets, Extended real numbers.

Unit-2

Lebesgue measure on the Real Line: Lebesgue outer measure, Lebesgue Measurable sets and Lebesgue measure, Non-measurable sets.

Unit-3

Lebesgue Measurable functions, Simple functions, Littlewood's principles.

Unit-4

Lebesgue integral of simple functions, Lebesgue integral of bounded functions, Bounded convergence theorem, Comparison of Riemann and Lebesgue integral.

Unit-5

Lebesgue integral of non-negative functions, Fatou's Lemma, Monotone convergence theorem, Lebesgue general integral, Lebesgue dominated convergence theorem.

Unit-6

Convex function and Jensen's inequality, *Lp* spaces, Young, Holder and Minkowski inequalities, Completeness of *Lp* spaces, Bounded linear functionals on *Lp* spaces.

Textbook(s)

1. Royden, H.L. and Fitzpatrick, P. M., Real Analysis, 4th Edition, Pearson, 2010.
2. Barra, G. De. *Measure Theory and Integration* (New Age International(P) Ltd, Publishers, New Delhi 2003).

Reference book(s)

1. Rana, I. K. *An Introduction to Measure and Integration*, 2nd edition, Narosa Publishing House India, 2000.
2. Halmos, P. R. *Measure Theory,* Springer-Verlag, 1974.
3. Jain, P. K. and Gupta, V. P. *Lebesgue Measure and Integration,* New Age International (P) Limited, New Delhi, 1986.

MS 501: Classical Mechanics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Momentum and kinetic energy, motion about a fixed point, Euler's equation, General equation of motion for a single particle and a system of N number of particles, General Solution.

Unit-2

Motion of a heavy sphere in a cylinder and a cone, motion under no force, Torque, Poinst's representation of motion.

Unit-3

Lagrange's equation of motion for holonomic systems, Velocity dependent potential, conservation theorem and symmetric properties, Lagrange's multiplier for holonomic and nonholonomic systems, Lagrange's equation for impulsive motion.

Unit-4

Hamiltonian of a dynamical system, Hamilton's canonical equation of motion, Cyclic coordinate, The Routhian, Conservation of energy and momentum.

Unit-5

Lagrange's method for small oscillation, Normal modes, Equations and examples.

Unit-6

Integral invariants of poincare, Lagrange's and Poisson's brackets and their properties, Equation of Motion and conserved quantities using Poisson's brackets, Infinitesimal contact transformation.

Unit-7

Euler's equation of calculus of variations, Brachistochrone problem, extremes under constraints, Hamilton's principle for conservative and non-conservative system, Holonomic and non-holonomic system.

Unit-8

Derivation of Lagrange's and Hamilton's equations from Hamilton's principle of least action, Hamilton Jacobi theory, Hamilton's Principal Function.

Textbook(s)

1. Goldstein, H. *Classical Mechanics*, 2nd edition (Narosa Publishing House, New Delhi, 2000).
2. Rana, N. C. & Joag ,P. C. *Classical Mechanics* (Tata-McGraw Hill, 1991).

Reference book(s)

1. Takwale, R. G. & Puranik, P. S. *Classical Mechanics* (Tata-McGraw Hill, 1979, 41st reprint, 2010).
2. Yung-Kuo, L. *Problems and Solutions on Mechanics* (World Scientific, 1994).
3. Calkin, M. G. *Lagrangian and Hamiltonian Mechanics* (World Scientific, 1996).
4. Landau, L. & Lifshitz, E.M. *Mechanics: Course of Theoretical Physics, Vol. 1,* 3rd edition (Pergamon Press, 1976).

MS 507: Partial Differential Equations (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Linear and nonlinear partial differential equation of the first order. Cauchy's method of characteristics, Compatible systems of first order equations, Charpit's and Jacobi's method.

Unit-2

Linear PDE with constant coefficients, reducible and irreducible equations. Different methods of solution.

Unit-3

Second order PDE with variable coefficients. Characteristic curves of second order PDE. Reduction to canonical forms. Solutions of PDE of second order by the method of separation of variables.

Unit-4

Fourier transform, Laplace transform. Solution of partial differential equation by Laplace and Fourier transform methods.

Unit-5

Solutions of PDE of second order by the use Riemann's method. Adjoint operators. Solutions of PDE of second order by the method of integral transforms.

Unit-6

Elliptic differential equations. Occurrence and detailed study of the Laplace and the Poisson equation. Maximum principle and applications, Green's functions and properties.

Unit-7

Parabolic differential equations. Occurrence and detailed study of the heat equation. Maximum principle. Existence and Uniqueness of solutions of IVPs for heat conduction equation. Green's function for heat equation.

Unit-8

Hyperbolic differential equations. Occurrence and detailed study of the wave equation. Solution of three dimensional wave equation. Method of decent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions.

Text Book(s):

1. Sneddon, I.N. Partial Differential Equations (Diver, 2006)
2. Rao, K.S. Introduction to partial differential equations (Prentice Hall of India, New Delhi, 2006)

Reference Book(s):

1. John, F. Partial Differential Equations, 3rd edition (Narosa, 1979)
2. Haberman, R. Elementary Applied Partial Differential equations, (Prentice-Hall, New Jersey, 1987)
3. Willams, W.E. Partial Differential Equations (Oxford University Press, 1980)
4. Strauss, W.A. Partial Differential Equations: An Introduction (John Wiley, 1992)
5. McOwen, R. Partial Differential Equations Methods and Applications, Prentice Hall, New Jersey, 1996.

MS 508: Mathematical Methods (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Calculus of variations: Linear functionals, minimal functional theorem, general variation of a functional, Euler-Lagrange equation. Variational problems with fixed boundaries. Sufficient conditions for extremum.

Unit-2

Integral equations: Linear integral equations of the first and second kind of Fredholm and Volterra type, solution by successive substitutions and successive approximations, solution of equations with separable kernels. Fredholm alternative.

Unit-3

Nonlinear programming: formulation of NLPP, General NLPP, Kuhn-Tucker condition. Saddle point and NLPP.

Graphical solutions of NLPP, quadratic programming. Wolfe's modified simplex method, Beale's method.

Unit-4

Game theory: Two-person zero-sum games, maximum criterion, dominance rules, mixed strategies, mini-max theorem, solutions of 2x2 and 2xm games.

Textbook(s)

1. Watson G. N. *A Treatise on the Theory of Bessel Functions* (Cambridge University Press, 1944).
2. Brown J. W. and Churchill, R. *Fourier Series and Boundary Value Problems* (McGraw Hill, 1993).
3. Roach, G. F. *Green's Functions (Cambridge University Press*, 1995).
4. Swarup, K., *Gupta*, P.K., Mohan, M., *Operations Research*, (Sultan Chand & Sons, 2007).

Reference book(s)

1. Gupta, A, S. *Calculus of Variations with Applications* (Prentice Hall of India,

New Delhi 2003).
2. Mikhlin, S. G. *Integral equations* (The MacMillan Company, New york, 1964).

MS 510: Functional Analysis (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Recap pre-requisite topics: Sets and relations, Linear spaces and linear maps, Metric spaces and continuous functions.

Unit-2

Introduce normed linear spaces with examples. Properties of nls, Riesz lemma, particular study of finite dimensional normed linear spaces, Discuss the interplay between linear structure and metric structure.

Unit-3

Define stronger, weaker and equivalent norms. Continuity and boundedness of linear maps, introduce complete normed linear spaces with examples. Function spaces and operator norm, bounded linear functional. Definition of Schauder basis. Dual spaces.

Unit-4

Hahn Banach separation and extension theorems. Applications of HBT.

Unit-5

Refer to the Ascoli-Arzela theorem and the definitions of uniform continuity, uniform boundedness, equicontinuity of a family of functions. Uniform boundedness theorem.

Unit-6

Closed graph theorem, open mapping theorem, bounded inverse theorem. Examples and applications of above theorems.

Unit-7

Inner product and Hilbert spaces, Bessel's inequality, Riesz-Fisher theorem, orthonormal basis. Fourier expansion and relation to orthonormal basis, Parseval formula, Separable Hilbert spaces.

Unit-8

Approximations, projection theorem, Riesz representation theorem. Hilbert adjoint operator, normal, self adjoint and unitary operators.

Textbook(s)

1. Limaye B. V. *Functional Analysis, (*Wiley Eastern Ltd., New Delhi, 1989).
2. Kreyszig E. *Introductory Functional Analysis with Applications*, (John Wiley and Sons, New York, 1978).

Reference book(s)

2. Rudin W. *Functional Analysis*, (McGraw Hill, 2000).
3. Yosida K. *Functional Analysis*, (Springer, 1995).
4. MacCluer B. *Elementary Functional Analysis*, (GTM 253, AMS, 2009).
5. Siddiqi, A. H., Ahmad K and Manchanda P., *Introduction to Functional Analysis with Applications*, Real World Education Publishers, New Delhi, 2014.

MS 538 Theory of Partial Differential Equations (L3 -T1 -P0 –CH4 –CR4)

Unit -1

Overview of PDE. Laplace equation, mean-value fomulas, strong maximum principle. Heat and wave equations, uniqueness by energy methods.

Unit -2

Theory of distributions: test functions, distributions, generalized derivatives, Sobolev Spaces, imbedding theorems, Rellich-Kondrasov theorem, trace theory.

Unit -3

Elliptic Boundary Value Problems: abstract variational problems, Lax-Milgram Lemma, weak solutions, regularity result, maximum principles, eigen value problems.

Unit -4

Semigroup Theory and Applications: exponential map, C0-semigroups, Hille-Yosida and Lummer-Phillips theorems, applications to heat and wave equations.

Textbook(s)

1. Kesavan, S., *Topics in Functional Analysis* (New Age International (P) Ltd. 1989, reprint 2003)
2. Evans, L.C., *Partial Differential Equations* (AMS, Providence, 1998).

Reference book(s)

1. John, F. , *Partial Differential Equations,* 3rd ed., (Narosa Publ. Co., New Delhi, 1979).
2. Gilbarg, D. and Trudinger, N. , Elliptic *Partial Differential Equations of Second Order* (Springer-Verlag Berlin Heidelberg 2001).
3. Jost, J. , *Partial Differential Equations* (Springer-Verlag New York, 2002).
4. Renardy, M. and Rogers, R.C. , *An Introduction to Partial Differential Equations*, 2nd ed., (Springer Verlag International Edition, New York, 2004).

MS 539 Advanced Numerical Analysis (L3 –T1 –P0 –CH -CR 4)

Unit-1

Finite Difference method: Explicit and Implicit schemes, consistency, stability and convergence, Lax equivalence theorem. Numerical solutions of elliptic, parabolic and hyperbolic partial differential equations.

Unit-2

Optimization: Problem formulation, single variable optimization, multi variable optimization.

Unit-3

Krylov subspace methods, Conjugate-Gradient (CG), BiConjugate-Gradient (BiCG), BiCG Stabilised (BiCGStab), Generalised Minimum Residual (GMRES). Preconditioning Techniques, parallel implementations.

Unit-4

Approximate method of solution: Galerkin method, properties of Galerkin aproximations, Petrov-Galerkin method, Generalised Galerkin method.

Unit-5

Review of Sobolev spaces. Weak solution of elliptic boundary value problem, regularity of weak solutions, maximum principle.

Finite Element method: Definition and properties. Element types triangular, rectangular, quadrilateral. Application of finite element method for second order problems, one and two dimensional problems. Isoparametric finite element, non-conformal finite element. Mixed finite element.

Textbook(s)

1. Watkins, D. S. *Fundamental of Matrix Computations,* 2nd edition (Wiley-Interscience, 2002).
2. Smith, G. D. Numerical *Solution of Partial Differential Equations: Finite Difference Methods,* 3rd edition (Oxford University Press, 1986).
3. Reddy, J. N. *An Introduction to the Finite Element Method*, 3rd Edition (McGraw Hill India, 2006).

Reference book(s)

1. Trefethen, L. N and Bau, David *Numerical Linear Algebra* (SIAM, 1997).
2. Hoffman, Joe D. *Numerical Methods for Engineers and Scientist*, 2nd edition (Mc-Graw Hill 2004).
3. Ciarlet, P. G. *The Finite Element Method for Elliptic Problems* (North Holland, 1978).
4. Johnson, C.*Numerical Solution of Partial Differential Equations by the Finite Element Method* (Cambridge University Press, 1987).

MS 541 Fluid Mechanics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Lagrarian and Eulerian methods, Velocity and acceleration, Particle path, Stream lines, Streak lines velocity potential, Steady and unsteady flows.

Unit-2

Conservation of mass and momentum, Equation of continuity. Equations of motion of a fluid, Pressure at a point in fluid at rest, Pressure at a point in a moving fluid, Euler's equation of motion, Bernoulli's equation.

Unit-3

Total energy, Circulation, Boundary surface, Impulsive motion. Irrotational motion, Potential flow, Green's theorem, application of Green's theorem in fluid mechanics, Kinetic energy of liquid, Uniqueness theorem. Vorticity vector.

Unit-4

Motion in two dimensions, Singularities of flow, Source, Sink, Doublets, Rectilinear vortices. Complex variable method for two-dimensional problems, Complex potentials for various singularities, Circle theorem, Blasius theorem, Theory of images and its applications to various singularities.

Unit-5

Three dimensional flow, Irrotational motion, Weiss's theorem and its applications.

Unit-6

Viscous flow, Vorticity dynamics, Vorticity equation, Reynolds number, Stress and strain analysis, Navier-Stokes equation, Boundary layer Equations.

Textbook(s)

1. Munson, B.R.,Young, D.F. & Okiishi, T.H. *Fundamentals of Fluid Mechanics*, 6th ed., (John Wiley & Sons, 2009).
2. White, Frank M. *Fluid Mechanics (*Mc-Graw Hill, 2005).

Reference book(s)

1. Batchelor, G. K. *An Introduction to Fluid Dynamics* (Cambridge University P, 1993).
2. Panton, R. L. *Incompressible Flow* (John Wiley & Sons, 2005).
3. Schlichting, H. *Boundary Layer Theory.(*Mc-Graw Hill, 2005).
4. Chorlton, F. *Textbook of Fluid Mechanics* (C. B. S. Publishers, Delhi, 1985).
5. Besant, W. H & Ramsey, A. *A Treatise on Hydro-mechanics* (ELBS, 1990).

M**S 543 Relativity (L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Postulates of Special Theory of Relativity, Lorentz Transformation and consequences, Minkowski Diagram, Four dimensional spacetime continuum, Four vector formulation, Elementary properties of Tensors.

Unit-2

Rules of Combination of Tensors, Tensor Algebra, Inner and Outer Product Quotient Rule, Metric tensor and Conjugate Metric Tensors, Raising and lowering properties, Christofell symbols of first and second kind, Tranformation properties of Christofell symbols.

Unit-3

Tensor Analysis, Covariant Derivative of Tensors, Gradient, Divergence and Curl of Tensor, Geodesic Equation, Riemannian Tensor, Ricci Tensor, Bianchi Identities, Einstein Tensor.

Unit-4

Transition of Special to General Theory of Relativity, Principle of covariance, Equivalence Principle and consequences, Stress Energy Tensor, Einstein Field Equations and Newtonian limit.

Unit-5

Spherically symmetric solution to Einstein Field Equation in free space and in matter, Schwarzshild line element. Schwarzschild Black Holes.

Unit-6

Equation of Planetary Orbits, Crucial tests of General Theory of Relativity, Advance of Perihelion, Gravitational bending of light and Gravitational Redshift.

Unit-7

Cosmology: Large scale structure of Universe, Galactic Densities and the darkness of the Night Sky, Galactic Number Counts, Olber's paradox, Cosmological principles, Relativistic Universe and models.

Unit-8

Einstein and de-Sitter models of static universe, Dynamical Universe, Comoving time, Red Shifts and Horizons, Friedmann-Robertson-Walker line element, Open and Closed Universe, Hubbles law, Early Universe.

Textbook(s)

1. Narlikar, J.V. *An Introduction to Cosmology*, 3rd edition (Cambridge University Press, 2002).
2. Landau and Lifshitz *Classical Theory of Fields* (Pergamon Press, 1975).

Reference book(s)

1. Dirac, P. A. M. *General Theory of Relativity* (Prentice Hall of India (reprinted), 2001).
2. Weinberg, S. *Gravitation and Cosmology* (John Wiley & Sons, 1972).
3. Kenyon, I. R. *General Relativity* (Oxford University Press, 1991).

MS 544 Operations Research (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Definition and scope of operational research, different types of models.

Unit-2

Replacement model and Sequencing theory. Inventory problems and their analytical structure.

Unit-3

Economic lot size models with uniform rate of demand, with different rate of demand in different cycle**.**

Unit-4

Simple deterministic and stochastic model of inventory control; basic characteristics of queueing system.

Unit-5
Steady state solution of Markovian queueing model; M/M/1, M/M/1 with limited waiting space.
Unit-6
M/M/C, M/M/C with limited waiting space.

Textbook(s)

1. Sharma, J. K. *Operations Research: Theory and Applications* (Macmillan, 1997).
2. Taha, Humdy A. *Operations Research - An Introduction* (Prentice Hall of India, New Delhi, 1999).

MS 545 Elliptic Curves (L3 -T1 -P0 -CH4 -CR 4)
Prerequisite: MS 401
Unit-1
Projective Geometry: Homogeneous coordinates, projective plane, curve in projective plane, intersection of projective curves, Bezout's theorem.
Unit-2
Introduction to algebraic curves, singular and non-singular curves, geometry of cubic curves, elliptic curves, Weierstrass normal form of elliptic curves, Mordell-Weil group law on elliptic curve, explicit formulas for group law, Isogeny.
Unit-3
Points on elliptic curves of order two and three, points of finite order, Nagell-Lutz theorem and its applications.
Unit-4
Group of rational points on elliptic curve, height function, Mordell's theorem, rank of elliptic curves, examples.
Unit-5
Elliptic curves over finite fields, Frobenius endomorphism, trace of Frobenius and number of points on elliptic curves.
Unit-6
Real and complex points on elliptic curves, periods of elliptic curves, lattice associated to elliptic curves.
Unit-7
Complex multiplication: Abelian extension of Q, algebraic points on cubic curves, Galois representation and complex multiplication.

Textbook(s)

1. Silverman, J.H. & Tate, J. *Rational Points On Elliptic Curves* (Springer-Verlag Indian Reprint, New Delhi 2010).
2. Washington, L. C. *Elliptic Curves: Number Theory and Cryptography* (CRC Press, USA, 2006).

Reference book(s)

1. Husemoller, D. *Elliptic Curves*, GTM vol. 111 (Springer-Verlag, New York, 2005).
2. McKean M. & Moll, V. *Elliptic Curves* (Cambridge University Press, 1999).

MS 546 Algebraic Number Theory (L3 -T1 -P0 -CH4 -CR 4)
Prerequisite: MS 401

Unit-1
Algebraic numbers, number fields, Discriminants, Norms and Traces.
Unit-2
Algebraic Integers, rings of integers, Integral Bases, Problems for quadratic and cubic cases.
Unit-3
Arithmetic of Number Fields: Quadratic Fields, Cyclotomic polynomials and fields.
Unit-4
Units in Number Rings, Dirichlet's Unit Theorem.
Unit-5
Ideal Theory: norms of ideals, fractional ideals.
Unit-6
Ideal Classes-The Class Group, Class Numbers of Quadratic Fields and Cyclotomic fields.

Textbook(s)

1. Mollin, R. A. *Algebraic Number Theory* (CRC Press, 1999).
2. Stewart, I. N. & Tall, D. *Algebraic Number Theory and Fermat's Last Theorem,* 3rd ed (A K Peters Ltd, 2008).

Reference book(s)

1. Esmonde, J. & M. Ram Murty, *Problems in Algebraic Number Theory*, GTM Vol. 190 (Springer-Verlag, 2006).

MS 547 Numerical Linear Algebra (L3 -T1 -P0 -CH4 -CR 4)
Unit -1
Fundamentals. Linear systems, LU decompositions, Gaussian elimination with partial pivoting, Banded systems, Positive definite systems, Cholesky decomposition. Vector and matrix norms.
Unit -2
Perturbation theory of linear systems, Condition numbers, Estimating condition numbers, IEEE floating point arithmetic, Analysis of roundoff errors. Gram-Schmidt orthonormal process, Orthogonal matrices, Householder transformation, Givens rotations, QR factorization, Roundoff error analysis of orthogonal matrices, Stability of QR factorization. Solution of linear least squares problems, Normal equations, Singular Value Decomposition(SVD), Polar decomposition, Moore-Penrose inverse,
Unit -3
Rank deficient least squares problems, Sensitivity analysis of least-squares problems. Review of eigenvalues and canonical forms of matrices, Sensitivity of eigenvalues and eigenvectors, Reduction to Hessenberg and tridiagonal forms, Power and inverse power methods, Rayleigh quotient iteration, Explicit and implicit QR algorithms for symmetric and non-symmetric matrices, Implementation of implicit QR algorithm.
Unit -4
Computing the SVD, Sensitivity analysis of singular values and singular vectors. Overview of iterative methods: Jacobi, Gauss-Seidel and successive overrelaxation methods, Krylov subspace method, The Arnoldi and the Lanczos iterations.

Textbook(s)

1. TrefethenL. N. and Bau, David. *Numerical Linear Algebra* (SIAM, 1997).
2. Watkins, D. S. *Fundamentals of Matrix Computation* (Wiley, 1991).

Reference book(s)

1. Golub, G. H. and Loan, C.F.V. *Matrix Computation* (John Hopkins U. Press,

Baltimore, 1996).
2. Stewart, G. W. Introduction *to Matrix Computations* (Academic Press, 1973).
3. Demmel, J.W. *Applied numerical linear algebra* (SIAM, Philadelphia, 1997).

MS 549 Graph Theory (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Preliminaries: Graphs, subgraphs, Isomorphism, degree, degree sequence, operations on graphs.

Unit-2

Walk, Trail, Path, Cycle, circuit, Connected graphs, component, distance between vertices, Bipartite graph, eccentricity, radius, diameter.

Unit-3

Tree, Bridge, Center of a tree, Forest, Spanning tree.

Unit-4

Cut-vertices, Block, vertex-connectivity, edge-connectivity, Eulerian graph and its properties, Hamiltonian graph and its Properties.

Unit-5

Planarity: Basic Concepts, Plane Graphs, Interior face, exterior face, Euler Identity, Maximal Planar graph.

Unit-6

Coloring: vertex coloring, chromatic number, The Four Color Theorem, independence number, Brook's theorem, edge Coloring, edge chromatic number, The Five color Theorem.

Unit-7

Digraph, oriented graph, indgree, outdegree, strong digraph, tournament, transitive tournament.

Textbook(s):

6. G. Chartrand and P. Zhang, *A First Course in Graph Theory*, Dover Publication, NewYork, 2012.
7. J. A. Bondy, U.S. R. Murthy, *Graph Theory with Applications*, London: Macmillan Press; 1976.

Reference Book(s):

1. D. B. West, *Introduction to Graph Theory*, 2nd Edition, Pearson Education, 2015.
2. R, J. Wilson, *Introduction to Graph Theory*, 4th Edition, Longman, England, 1996.
3. F. Harary, *Graph Theory*, Narosa Publishing House, New Delhi, 2001.

MS 551 Introduction to Category Theory (L3 -T1 -P0 -CH4 -CR 4)

Prerequisites: MS 401, MS 403, MS 406, MS 408.

Unit-1

Category, Functors and Natural Transformations: basic introductions and examples.
The notion of universality.

Unit-2

Representablity, and its connections with universality, Yoneda's Lemma and its consequences. Limits, co-limits and their examples.

Unit-3

Algebras, internal algebras, matrices, internal relations, internal equivalence relations, internal groupoids, internal categories.

Unit-4

Adjoints and their examples, Characterising algebras through Beck's Monadicity Theorem.

Unit-5
A second visit to adjoints: Freyds Adjoint Functor Theorem and its applications to adjoints in algebra and topology.
Unit-6
Monoidal Categories, Introduction to Enriched Categories, Introduction to Abelian Categories.

Textbook(s)

1. Mac Lane, S. *Categories for the Working Mathematician,* 2nd ed. (Springer Verlag, New York, 1997).
2. Kelly, G. M. *Basic Concepts of Enriched Category Theory*, volume 64 (London Mathematical Society Lecture Notes, Cambridge University Press, 1982).

Reference book(s)

1. Mac Lane, S. & Birkhofff, G. *Algebra*, 3rd ed. *(*Chelsea Pub. Co., New York, 1988).
2. Borceux, F. *Hand Book of Categorical Algebra-I: Basic Category Theory* (Cambridge University Press, Cambridge, 1994).

MS 552 Operator Theory I (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Uniform, strong and weak convergences.
Unit-2
Compact linear operators on normed linear spaces; the ideal of compact operators; the separability of the Range and spectral properties of a compact operator; operator equations involving compact operators.
Unit-3
Bounded operators on Hilbert spaces; adjoint operators; normal, unitary and self adjoint operators; spectral properties of bounded self adjoint linear operators.
Unit-4
Positive operators and their square root; projection operators; spectral representation of a bounded self adjoint linear operator.
Unit-5
Spectral measure.
Unit-6
Spectral theorem for bounded normal operators.

Textbook(s)

1. Conway, J. B. *A course in Operator Theory* (AMS., GSM Vol. 21, 1999).
2. Kreyszig, E. *Introductory functional analysis with applications* (John Wiley and Sons, 1978).

Reference book(s)

1. Halmos, P. R. *Introduction to Hilbert spaces and theory of spectral multiplicity* (Chelsea Publishing Co., New York, 1957).
2. Abramovich, Y. A. and Aliprantis, C. D. *An Invitation to Operator Theory* (AMS, GSM Vol. 50, 2002).

MS 554 Commutative Algebra (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Ideals in commutative rings, operations on ideals, extension and contraction of ideals, Nilradical and Jacobson radicals, prime spectrum of commutative rings.

Unit-2

Localization of commutative rings and their basic properties.

Unit-3

Noetherian and Artinian rings, examples.

Unit-4

Integral extensions, Dedekind domains.

Unit-5

Hilbert's Nullstellensatz, Noether's normalisation, valuation rings.

Unit-6

Modules: Elementary properties of modules, Quotient modules, module homomorphisms, Isomorphism theorems, Generation of modules, Direct sum of modules, finitely generated modules, free modules.

Unit-7

Tensor product of modules and properties, Exact sequences, projective and injective modules.

Unit-8

Modules over Principal Ideal Domain.

Textbook(s)

1. McDonalds, I. G. & Atiyah, M. F. *Introduction to Commutative Algebra* (Levant Books, Kolkata, 2007).
2. Dummit, D. S. & Foote, R. M. *Abstract Algebra* (Wiley-India, New Delhi, 2011).

Reference book(s)

1. Sharp, R. Y. *Step in Commutative Algebra (*Cambridge University Press, Cambridge, 2000).
2. Lang, S. *Algebra* (Springer, GTM Vol. 211, New Delhi, 2006).

MS 558 General Theory of Relativity (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Elementary properties of Tensors. Rules of Combination of Tensors, Tensor Algebra, Inner and Outer Product Quotient Rule, Riemannian space, Metric tensor and Conjugate Metric Tensors, Raising and lowering properties.

Unit-2

Parallel Transport, Christofell symbols of first and second kind, Tranformation properties of Christofell symbols, Covariant Derivative of Tensors, Gradient, Divergence and Curl of Tensors.

Unit-3

Geodesic Equation, Riemannian Tensor, Ricci Tensor, Bianchi Identities, Scalar Curvature, Einstein Tensor and their properties, Differential Manifolds.

Unit-4

Transition of Special to General Theory of Relativity, Principle of covariance, Equivalence Principle and consequences, Stress Energy Tensor, Einstein Field Equations and Newtonian limit.

Unit-5

Spherically symmetric solution to Einstein Field Equation in free space and in matter, Schwarzshild line element. Schwarzschild Singularity, Eddington-Finkelstein co-ordinates, Kruskal-Szekeres co-ordinates.

Unit-6
Linearised theory of gravity, weak field limit, Hilbert gauge and wave solution to Einstein Field Equations, Gravitational Waves, Polarisation properties, emission of gravitational waves.
Unit-7
Crucial tests of General Theory of Relativity, Advance of Perihelion, Gravitational bending of light, Gravitational Redshift, Shapiro delay.
Unit-8
Large scale structure of Universe, Cosmological principles, Einstein and de-Sitter models of static universe, Dynamical Universe, Comoving time, Red Shifts and Horizons, Friedmann-Robertson-Walker line element, Hubbles law, Elements of Quasi-Steady State Cosmology.

Textbook(s)
1. Narlikar, J.V. *An Introduction to Cosmology*, 3rd edition (Cambridge University Press, 2002).
2. Adler, R., Bazin M. & Schiffer, M., *Introduction to General Relativity* (McGraw Hill, 1975).

Reference book(s)
1. Landau and Lifshitz, *Classical Theory of Fields* (Pergamon Press, 1975).
2. Dirac, P. A. M. *General Theory of Relativity* (Prentice Hall of India (reprinted), 2001).
3. Weinberg, S. *Gravitation and Cosmology* (John Wiley & Sons, 1972).
4. Kenyon, I. R. *General Relativity* (Oxford University Press, 1991).
5. Misner, C., Thorne, K.S. & Wheeler, J.A. *Gravitation* (W.H. Freeman, 1973).

MS 561 Stochastic Processes I (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Simple (one dimensional) random walk.
(To follow the chapter on simple random walk in Feller (1996) Vol. I)
Unit-2
Discrete Markov chains: transition probability matrix, classifications of states and chains.
Unit-3
Introduction to Poisson Processes.
Unit-4
Introduction to Renewal processes.

Textbook(s)
1. Feller, W. *An Introduction to Probability Theory and its Applications*, Vol. I (Wiley, 1966).
2. Medhi,. J. *Stochastic Processes* (Wiley Eastern Ltd., New Delhi, 1994).

Reference book(s)
1. Bhattacharya, R. and Waymire, E. C. *Stochastic processes with applications* (SIAM, 1990).

MS 565 Fuzzy Sets and Applications-I (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Fuzzy sets - basic definitions, α-level sets, convex fuzzy sets.
Unit-2
Basic operations on fuzzy sets, types of fuzzy sets.

Unit-3
Cartesian products, algebraic products, bounded sum and difference, t-norms and t-conorms. Fuzzy sets in contrast of probability theory.
Unit-4
The extension principle - the Zadeh's extension principle, image and inverse image of fuzzy sets.
Unit-5
Fuzzy numbers, elements of fuzzy arithmetic.
Unit-6
Fuzzy relations and fuzzy graphs, composition of fuzzy relations, min-max composition and its properties, fuzzy equivalence relations, fuzzy relational equations, fuzzy graphs.

Textbook(s)

1. Klir, G. J. and Yuan, B. *Fuzzy Sets and Fuzzy Logic : Theory and Applications*, (Prentice Hall of India, New Delhi, 1997)

Reference book(s)

1. Zimmermann, H. J. *Fuzzy set theory and its Applications* (Allied publishers Ltd., New Delhi, 1991).

MS 566 Fourier Analysis (L3 -T1 -P0 -CH4 -CR 4)
Prerequisite: MS 410
Unit 1:
Fourier series: Orthogonal systems, Trigonometric system, Orthogonal polynomials, Genesis of the Fourier series.
Unit 2:
Convergence of Fourier series: Fejer mean and Cesaro mean, Convergence of the Fourier series, Fejer theorem, Uniqueness and convergence, Approximate identity, Fourier series of continuous and smooth functions.
Unit 3:
L^2 theory of Fourier series: Inversion formula and the Parseval identity.
Unit 4:
Fourier transforms, the Schwartz space,Plancherel formula, Maximal function and distributions, Tempered distribution,, Fourier analysis and filters. Bessel functions.
Unit 5
Fourier analysis and complex function theory: Paley Wiener's theorem, Tauberian theorem, Dirichlet problem.,Classical Hardy spaces F and M. Reisz theorem.

Textbook(s)

1. Katznelson, Y. *An Introduction to Harmonic Analysis* (Dover, New York, 1976).

Reference book(s)

1. Dym, I.H. and Mc Kean, H.P. *Fourier Series and Integrals* (Academic Press, 1985).
2. Folland G. B. *Fourier Analysis and Applications* (Brooks/Cole Mathematics Series, 1972).
3. Korner, T. *Fourier Analysis* (Cambridge, 1989).
4. Rudin, W. *Functional Analysis* (Tata Mc. Graw Hill, 1974).
5. Elias M. S. and Shakarchi, R. *Fourier Analysis An Introduction (*Princeton University Press, Princeton, 2004).

MS 567 Continuum Mechanics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Analysis of Strain: Lagrangian and Eulerian finite strain tensor. Geometrical interpretation of the components of atrain. Strain quadric of Cauchy. Principall strains and invariants. General infinitesimal deformation. Saint-Venant's equations of compatibility.

Unit-2

Analysis of stress: Stress tensor. Equations of equilibrium. Transformation of co-ordinates. Stress quadric of Cauchy. Principal stress and invariants. Maximum normal and shear stresses. Two dimensional problems-Plane stress. Generalised plane stress. Airy stress function.

Unit-3

Fundamental laws of continuum mechanics: Continuity equation, Equation of motion, Moment of momentum principle, Second law of thermodynamics. The Clausius-Duhem inequality.

Unit-4

Equations of Elasticity. Generalosed Hooks's law. Homogeneous isotropic media, Strain energy function and its connection with Hooke's law. Four basic elastic constants-Young's modulus, Poisson's ratio, modulus of rigidity, bulk modulus. Uniqueness of solution. Saint-Vernant's principle.

Unit-5

Fluids: Classification, constitutive equations, energy equation, dissipation of energy.

Textbook(s)

1. Mase, G.E. *Schaum's Outline of Continuum Mechanics (Schaum's Outline series)* (Mc- Graw Hill, 1990).
2. Chatterjee, R. *Mathematical Theory of Continuum Mechanics (*Narosa, 1999).

Reference book(s)

1. Truesdell, C. *The elements of continuum Mechanics (*Springer-Verlag, 2000).

MS 568 Theory of Distribution and Sobolev Spaces (L3 -T1 -P0 -CH4 -CR4)

Unit -1

Test Function and distribution: Definition, operations with distributions, convolution of distributions, Fourier transform of tempered distributions.

Unit -2

Sobolev spaces: generalized derivatives, Definition and properties, extension theorem, imbedding and completeness theorem, fractional order Sobolev spaces, trace theory.

Unit -3

Application to Elliptic Problems: Weak solution of elliptic boundary value problem (BVP), regularity of weak solutions, maximum principle, eigenvalue problems, fixed point theorems and their application in semi-linear elliptic BVP.

Textbook(s)

1. Adams, R.A. *Sobolev Spaces* (Academic Press, 1975).
2. Kesavan, S. *Topics in Functional Analysis and Applications* (Wiley Eastern Ltd., New Delhi, 1989).
3. Strihartz, Robert S. *A guide to Distribution Theory and Fourier Transforms, Studies in Advanced Mathematics (*CRC Press,USA,1994).

Reference book(s)

1. Oden, J.T. and Reddy, J.N. *An Introduction to Mathematical Theory of Finite Elements,* (Wiley Interscience, 1976).
2. Brennan, K. E. and Scott., R. *The Mathematical Theory of Finite Element Methods (*Springer-Verlag, Berlin, 1994).
3. Lieb. Elliot H. and Loss, M. *Analysis (*Narosa Publishing House, New Delhi, 1997).
4. Rudin, W. *Functional Analysis* (Tata Mc-Graw Hill, 1974).

MS 569 Coding Theory I (L3-T1-P0-CH4-CR4)

Unit - 1

Comminication channel, Introduction to coding theory, types of codes, ISBN code, Barcodes, Digital codes, Group Theory, Vector spaces over arbitrary fields with examples, linear block codes, Dual codes, Distance of block codes, Standard array, Syndrome decoding and Decoding by coset leaders.

Unit – 2

Error-correction and detection capabilties of linear block codes. Singleton bound, Greismer bound, Plotkin bound, Hamming sphere packing bound, Varshamov-Gilbert-Sacks bound.

Unit - 3

Weight Enumerators and the MacWilliams Theorem, Type of errors, Burst errors, Bounds for burst-error detecting and correcting codes.

Unit - 4

Some Interesting Block Codes and Their Properties: Perect codes, Hamming codes, Golay codes, Hadamard codes, Product codes, Reed-Muller codes, Maximum–Distance Separable (MDS) codes.

Text Book(s):

1. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.

2. Torleiv Klove, Codes for error Dectection, Series on Coding Theory and Cryptology, vol. 2, World Scientific Publishing Co. Pte. Ltd., 2007

Reference Book(s):

1. Raymond Hill, A First Course in Coding Theory, Oxford University Press, 1990.

2. J.H. Van Lint, Introduction to Coding theory, Graduate Texts in Mathematics, 86, Springer, 1998.

3. A. Neubauer, J. Freudenberger, V. Kuhn, Coding Theory: Algorithms, Architectures and Applications, John Wiley & Sons Ltd, England, 2007.

4. L.R. Vermani, Elements of Algebraic Coding, Chapman and Hall, 1996.

5. W. C. Huffman and V. Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.

6. Shu Lin and Daniel J. Costello, Error Control Coding-Fundamentals and Applications, Pearson Education India, 2011.

MS 570 Coding Theory II (L3-T1-P0-CH4-CR4)

(Prerequisite Coding Theory I)

Unit – 1

Zero of polynomials, Algebraic extension of a field, Galios field, Primitive elements, Minimum polynomials, order, Multiplcative group of a Galios fields, structure of finite fields.

Unit – 2

Error detection with cyclic codes, Error-correction procedure for cyclic codes, Shortended cyclic codes, Pseudo cyclic codes. Code symmetry, Invariance of codes under transitive group of permutations.

Unit - 3

BCH codes, Minimum distance and BCH Bounds, Decoding of BCH codes, Reed-Solomon codes.

Unit - 4

Tree codes, Convolutional codes, Description of linear tree and convolutional codes by matrices, distance for convolutional codes, Maximum likelihood decoding of Convolutional codes, Vitorbi decoding algorithm.

Text Book(s):

1. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.

2. Shu Lin and Daniel J. Costello, Error Control Coding-Fundamentals and Applications, Pearson Education India, 2011.

Reference Book(s):

1. Man Young Rhee, Error Correcting Coding Theory, McGraw-Hill Publishing, 1989.

2. Robert H. Morelos-Zaragoza, The art of Error Correcting Codes, 2nd Edition, John Wiley & Sons Ltd, England, 2006.

3. A. Neubauer, J. Freudenberger, V. Kuhn, Coding Theory: Algorithms, Architectures and Applications, John Wiley & Sons Ltd, England, 2007.

4. L.R. Vermani, Elements of Algebraic Coding, Chapman and Hall, 1996.

5. Jiri Adamek, Foundations of Coding: Theory and Applications of Error-Correcting Codes with an Introduction to Cryptography and Information Theory, John Wiley & Sons, USA, 1991.

6. W. C. Huffman and V. Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.

MS 572 Operator Theory II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Functional calculus and spectral mapping theorem for analytic functions; Riesz decomposition theorem.

Unit-2

Numerical range of an operator; spectral radius.

Unit-3
Subnormal and hyponormal operators.
Unit-4
Partial isometries; polar decomposition.
Unit-5
Unbounded linear operators and their Hilbert adjoint operators; symmetric and self adjoint linear operators; spectral properties of self adjoint linear operators; closed linear operators; closable operators and their closures, multiplication operator and differentiation operator.
Unit-6
Spectral representation of unitary and self adjoint linear operators.

Textbook(s)

1. Conway, J. B. *A course in Operator Theory* (AMS., GSM Vol. 21, 1999).
2. Kreyszig, E. *Introductory functional analysis with applications* (John Wiley and Sons, 1978).
3. Conway, J. B. *A course in Functional Analysis (*Springer Verlag, New York, 1985).

Reference book(s)

1. Halmos, P. R. *Introduction to Hilbert spaces and theory of spectral multiplicity* (Chelsea Publishing Co., New York, 1957).
2. Abramovich, Y. A. and Aliprantis, C. D. *An Invitation to Operator Theory* (AMS., GSM Vol. 50, 2002).

MS 573 Analytic Number Theory (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Arithmetical functions and Dirichlet multiplication, averages of arithmetical functions.
Unit-2
Elementary theorems on the distribution of primes, the prime number theorem, Chebyshev's functions and their relations.
Unit-3
Dirichlet's theorem for primes of the form *4n-1* and *4n+1*, distribution of primes in arithmetic progressions.
Unit-4
Quadratic residues and quadratic reciprocity law, applications of the reciprocity law, Gauss sums.
Unit-5
Dirichlet series, Euler products, Riemann zeta function and Dirichlet *L*-functions.
Unit-6
Introduction to partitions, geometric representation, generating functions, Euler's Pentagonal number theorem, Jacobi triple product identity, recursion formula for *p(n).*
Unit-7
Partition identities of Ramanujan.

Textbook(s)

1. Apostol, T. M. *Introduction to Analytic Number Theory*, Springer International Student Edition (Narosa Publishing House, New Delhi, 1993).
2. Hardy, G.H. and Wright, E. M. *An Introduction to the Theory of Numbers*, 4th Edition (Oxford University Press, 1960).

Reference book(s)

1. Niven, I. and Zuckerman, H. *An Introduction to the Theory of Numbers*, 5th Edition (Wiley Eastern, New Delhi, 2000).
2. Andrews, G.E. *Number Theory* (Hindustan Publishing Corporation, New Delhi, 1992).

MS 574 Galois Theory (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Field extensions: Algebraic, normal and separable extensions of field.

Unit-2

Splitting fields.

Unit-3

Automorphisms of extensions, the fundamental theorem of Galois theory.

Unit-4

Finite fields.

Unit-5

Primitive elements, norm and trace, cyclotomic fields, cyclic extension.

Unit-6

Solution of polynomial equations by radicals, Kummer theory.

Textbook(s)

1. Morandi, P. *Field and Galois Theory*, GTM Vol. 167 (Springer-Verlag, 1996).
2. Lang, S. *Algebra* (Springer Verlag, Indian Edition, 2008).
3. Dummit & Foote *Abstract Algebra* (John Wiley & Sons., 2005).

Reference book(s)

1. Cohn, P. M *Algebra*, Vols. I & Vol. II (John Wiley & Sons, 1985 and 1988).

MS 581 Stochastic Process –II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Branching processes- Properties of generating functions of Branching processes, Probability of Extinction, Distribution of the total number of progeny.

Unit-2

Galton-Watson process. Introduction Brownian motion process.

Unit-3

Wiener process, first passage time distribution for Wiener process, Ornstein-Ulhenbech process.

Unit-4

Queueing systems, Single server queueing models (M/M/1/μ, M/M/1/k, M/M/μ/μ, etc.)

Textbook(s)

1. W. Feller *An Introduction to Probability Theory and its Applications*, II (Wiley, 1998).
2. Bhattacharyya, R. and Waymire, E. C. *Stochastic processes with applications* (SIAM, 1990).

Reference book(s)

1. Medhi, J. *Stochastic Processes* (Wiley Eastern Ltd., New Delhi, 1994).

MS 585 Fuzzy Sets and Their Applications-II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Fuzzy logic, fuzzy propositions, fuzzy quantifiers, linguistic variables, inference from conditional fuzzy propositions, compositional rule of inference.

Unit-2

Approximate reasoning - an overview of fuzzy expert systems, fuzzy implications and their selection, multi-conditional approximate reasoning, role of fuzzy relation equation.

Unit-3

An introduction to fuzzy control - fuzzy controllers, fuzzy rule base, fuzzy inference engine.

Unit-4

Fuzzification, defuzzification and the various defuzzification methods.

Unit-5

Decision making in fuzzy environment - individual decision making, multi-person decision making, multi-criteria decision making, multistage decision making, fuzzy ranking methods.

Unit-6

Fuzzy logic as a tool in soft computing.

Textbook(s)

1. Klir, G. J. and Yuan, B. *Fuzzy Sets and Fuzzy Logic : Theory and Applications* (Prentice Hall of India, New Delhi, 1997)

Reference book(s)

1. Zimmermann, H. J. *Fuzzy set theory and its Applications* (Allied publishers Ltd., New Delhi, 1991).

MS 587 Finite Element Method (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Introduction: Basic concepts of process of discretization, subdivision, continuity, convergence, bounds, error. Principle and Laws. Cause and effects.

Unit-2

Finite Element Methods: Introduction, general idea of element configuration, approximation models or functions. Strain (Gradient)-Displacement (unknown) and stress-strain (constitutive) relationships, element equations. Energy methods, methods of wieghted residuals. Introduction to variational calculus.

Unit-3

One-dimensional Stress Deformation: Element configuration, local and global coordinates, interpolation functions, stress-strain relationship, element equations and assembling, direct stiffness method, formulation by Galerkin method.

Unit-4

One-dimensional flow: Theory and formulation, finite element formulation, variational approach, Galerkin method, boundary conditions.

Unit-5

Further Applications: One-dimensional time dependent flow: introduction to uncoupled and coupled problems, beam bending and beam-column, one-dimensional mass transport and one-dimensional stress wave propagation

Unit-6

Two and Three-dimensonal formulations: Introduction, two-dimensional formulation, triangular and quadrilateral elements, three-dimensional formulation, tetrahedron element, brick element.

Unit-7
Applications: Potential, thermal, fluid and electrical flow: a brief theroy and their finite element formulations.
Unit-8
Coding: Computer codes in Matlab/C/C++.

Textbook(s)
1. Desai, C. S. and Kundu, T. *Introductory Finite element method* (CRC Press, 2001).
2. Braess, D. and Schumaker, L. L. *Finite elements: theory, fast solvers and applications in solid mechanics (*Cambridge University Press, 2001).
3. Brenner, S. C. and Scott, L. R. *The mathematical theory of finite element methods*, (Springer, 2008).

Reference book(s)
1. Ciarlet, P. G. *The finite element method for elliptic problems* (North Holland, 1978).
2. Thome\'e, V. *Galerkin finite element methods for parabolic problems* (Springer, 1997).

MS 588 Applied Matrix Theory (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Review of basic linear algebra.
Unit-2
Canonical factorization, Q-forms.
Unit-3
Courant-Fischer minmax & related theorems. Perron-Frobenius theory. Matrix-stability.
Unit-4
Inequalities, g-inverse (A^-, A^m, A^+).
Unit-5
Drect, iterative, projection and rotation methods for solving linear systems & eigenvalue problems.
Unit-6
Applications
Textbook(s)
1. Datta, K. B. *Matrix and Linear Algebra* (PHI, 1991).
2. Watkins, D. S. *Fundamentals of Matrix Computation* (Wiley, 1991).
3. Golub, G. H. and Loan, C. F. Van. *Matrix Computation (*John Hopkin U. Press, Baltimore, 1996.)

Reference book(s)
1. Stewart, G. W. *Introduction to Matrix Computations* (Academic Press, 1973.)

MS 591 Computational Fluid Dynamics (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Basic equations of Fluid Dynamics. Analytical Aspects of PDE. Iterative methods – Stationary Methods. Krylov subspace methods.
Unit-2
Stationary Convection diffusion equations, Non-stationary convection diffusion equations. Conservation laws. Incompressible plane flows, Stream function and vorticity equations,

Conservative form and normalizing systems, Method for solving vorticity transport equation, Basic Conservative property.

Unit-3

Finite volume and finite difference methods. Convergence and stability analysis, Explicit and implicit methods, Stream function equation and boundary conditions, Solution for primitive variables. Finite volume method, Application to Euler equations, Upwind difference scheme, Viscous flow solutions, Total variation diminishing schemes, Godunov-type schemes.

Unit-4

Simple CFD Techniques, Lax-Wendroff Technique, Mac Cormack's Techniques, Staggered grid, SIMPLE Algorithm. Numerical Solutions of Navier-Stokes equations on collocated and on staggered grids.

Textbook(s)

1. Chung, T.J. *Computational fluid Dynamics* (Cambridge University Press, 2005).
2. Fletcher, C. A. J. *Computational Techniques for Fluid Dynamics, Volume 1 & 2*, (Springer Verlag, 1992).

Reference book(s)

1. Chow, C. Y. *Introduction to Computational Fluid Dynamics* (John Wiley, 1979).
2. Holt, M. *Numerical Methods in Fluid Mechanics* (Springer Verlag, 1977).
3. Wirz, H. J. and Smolderen, J. J. *Numerical Methods in Fluid Dynamics* (Hemisphere, 1978).
4. Anderson, J. D. *Computational Fluid Dynamics* (Mc-Graw Hill, 1995).
5. Anderson, D. A., Tannehill, J. C. and Pletcher, R. H. *Computational Fluid Dynamics and Heat Transfer* (McGraw Hill, 1984).

MS 594 Advanced Topology –I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Nets and filters, convergenge in terms of nets and filters, ultrafilters and compactness.

Unit-2

Urysohn's Lemma, Tietze Extension theorem.

Unit-3

Theories of metrization, Urysohn metrization theorem.

Unit-3

Paracompactness, characterisation in regular spaces, metrization based on paracompactness.

Unit-4

Nagata-Smirnov theorem, Stone's theorem, Smirnov's metrization theorem.

Unit-5

Homotopy and the fundamental group, computation of the fundamental group of the circle.

Textbook(s)

1. Joshi, K. D. *Topology* (Wiley-Eastern, 1988).
2. Munkres, J. R. *Topology: A first course* (2/e) (Prentice-Hall, 2000).

Reference book(s)

1. Kelley, J. L. *General Topology* (Graduate texts in Mathematics, Vol. 27, Springer, 1991).
2. Willard, S. *General Topology* (Addision-Wesley, Reading, 1970).

MS 595 Numerical Solutions of ODE (L3 -T1 -P0 -CH4 -CR 4)

Unit -1

Review of some basic concept of Numerical Analysis, Basics of Initial Value Problem (IVP), Explicit and implicit single step Methods, Euler's method, Runge-Kutta methods.

Unit -2

System of differential equations, Adaptive numerical methods, Predator- Corrector methods, explicit and implicit multistep methods, stability analysis.

Unit -3

Higher order differential equations, Non-uniform step methods, Boundary value problems, Convergence of difference schemes.

Unit -4

Linear eigenvalue problems.

Textbook(s)

1. Jain, M. K., Iyenger S. R. K., and Jain, R. K. *Numerical Methods for Scientific and Engineering Computation* (Wiley Eastern, 1993).
2. Lambert, J. D. *Numerical methods for Ordinary Differential equations (*John Wiley & Sons, 1991).

Reference book(s)

1. Henrici, P. *Discrete Variable Methods in Ordinary Differential Equations*. (John Wiley &Sons, New York, 1962).
2. Jain, M. K. *Numerical Solutions of Differential Equations* (Wiley Eastern, 1991).
3. Miller, Richard K. *Introduction to Differential Equations* (Prentice Hall, New Jersey, 1991).
4. Hoffman, J. D. Numerical methods for Engineers and Scientists (Mc-Graw Hill, 2000).
5. Otto, S.R. & Denier, J. P. *An Introduction to Programming and Numerical Methods in MATLAB* (Springer, 2009).

MS 596 Advanced Topology – II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Uniformities, uniform continuity, product uniformities, metrisation.

Unit-2

Completeness and compactness in uniform spaces.

Unit-3

Topological groups, subgroups, quotient groups, homogeneous spaces, product groups.

Unit-4

Uniform structures in topological groups, complete groups, completion of topological groups.

Unit-5

Function spaces, point-wise convergence, uniform convergence, compact-open topology, k-spaces, equi-continuity, Ascoli theorem.

Textbook(s)

1. Joshi, K. D. *Topology* (Wiley-Eastern, 1988).
2. Munkres, J. R. *Topology: A first course* (2/e) (Prentice-Hall, 2000).

Reference book(s)

1. Kelley, J. L. *General Topology* (Graduate texts in Mathematics, Vol. 27, Springer, 1991).

2. Willard, S. *General Topology* (Addision-Wesley, Reading, 1970).
3. Engelking, R. *General Topology* (Polish Scientific Publishers, Warshaw, 1977).
4. Bourbaki, N. *Elements of Mathematics: General Topology*, Vols. I & II, (Springer-Verlag, 1988).

MS 597 Numerical Solutions to PDE (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Finite difference methods for Parabolic, Elliptic and Hyperbolic equations. Dirichlet, Neumann and Mixed problems.

Unit-2

Sparseness and the ADI method, Iterative methods for Laplace equation. Backward Euler, Crank-Nicolson schemes.

Unit-3

Stability, convergence and consistency analysis of finite difference methods, Lax's equivalence theorem.

Unit-4

Method of characteristics, Lax-Wendroff explicit method, CFL conditions, Wendroff implicit approximation.

Unit-5

Three dimensional elliptic problems.

Textbook(s)

1. Hoffman, J. D. *Numerical methods for Engineers and Scientists* (McGraw Hill, 2001).
2. Smith, G. D. *Numerical solutions to Partial Differential Equation* (Clarendon Press, Oxford, 1985.)
3. Johnson, C. *Numerical solution of Partial Differential equations by the Finite Element Method* (Cambridge University Press, 1987.)

Reference book(s)

1. Eriksson, K. et. al, *Computational Differential Equations* (Cambridge University Press, 1996).
2. Lapidus, L. and Pinder, G. F. *Numerical solutions of Partial Differential Equations in Science and Engineering* (John Wiley, 1982).
3. Langtangen, H. P. *Computational Partial Differential Equations (*Springer-Verlag, 1999.)
4. Jain, M. K., Iyenger, S. R. K. and Jain, R. K. *Numerical Methods for Scientific and Engineering Computation (*Wiley Eastern, 1993).
5. Jain, M. K., Iyenger, S. R. K. and Jain, R. K. *Computational Mathods for Partial Differential Equations (*Wiley Eastern, 1994).

MS 598 Algebraic Geometry (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Affine varieties defined over algebraically closed fields.

Unit-2

Projective varieties.

Unit-3

Rational mappings, bi-rational geometry.

Unit-4

Divisors, principal divisors especially on curves and surfaces.

Unit-5
Introduction to the language of schemes.
Unit-6
Riemann-Roch theorem for curves.

Textbook(s)

1. Smith, K.E. etc all, *An Invitation To Algebraic Geometry* (Springer, Indian Reprint 2005).
2. Musili, C. *Algebraic Geometry for Beginners*, TRIM 20 (Hindustan Book Agency, 2001).

Reference book(s)

1. Hartshorne, R. *Algebraic Geometry*, GTM Vol. 52 (Springer, 2005).

MS 599: Probability Theory (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Measurable space, Measure and its properties, finite and sigma-finite measures, Axiomatic definition of Probability, Measurable functions , definition of Random Variable.
Unit-2
Measure induced by a measurable function, definition of Probability distribution and distribution function, properties of distribution function and classification of distributions.
Unit-3
Some basic theorems Integration theory(integration of measurable functions w. r. t. an arbitrary measure): Fatou's lemma , Monotone Convergence theorem, Dominated convergence Theorem. Definition of Mathematical Expectation of a random variable and its properties. Moments and moment inequalities.
Unit-4
Convergence of a sequence of random variables (Weak convergence or convergence in probability, almost sure convergence and convergence in Law). Borel-Cantelli-lemma, Weak and Strong law of large numbers, Central limit theorem.

Textbook(s)

1. Feller, W. *An Introduction to Probability Theory and its Applications*, Vol. II (Wiley, 1966).
2. Chow, Y. and Teicher, H. *Probability Theory* , *Independence, Interchangeability, Martingales,;* 3rd Edition (Springer, 1997).

Reference book(s)

1. Ash, R. B. *Probability and Measure Theory, Second Edition* (Harcourt/Academic Press, 2000).