Department of Mathematical Sciences

Course Structure and Syllabus of M.A./M.Sc. in Mathematics

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	
MS 403	Linear Algebra	3-1-0	4	4	
MS 405	Real Analysis	3-1-0	4	4	
MS 411	Computer Programming+	3-1-0	4	4	
MS 421	Computer Laboratory	0-0-2	4	2	*Practical Course assigned for MS 411*
One IDC-I (Inter Disciplinary Credit) course				3	*To be chosen from courses offered by other departments*
Total credits				21	

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remark
MS 406	Complex Analysis	3-1-0	4	4	
MS 408	Topology	3-1-0	4	4	
MS 414	Ordinary Differential Equations	3-1-0	4	4	
MS 416	Numerical Analysis+	2-1-0	3	3	
MS 424	Computer Laboratory	0-0-1	2	1	*Practical Course assigned for MS 416*
One IDC-II (Inter Disciplinary Credit) course				3	*To be chosen from courses offered by other departments*
Total credits				19	

IDC (Inter disciplinary credit) courses offered by other departments
MS: Courses offered by the Department of Mathematical Sciences
+ 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	
MS 509	Probability and Statistics	2-1-0	3	3	
MS 410	Functional Analysis	3-1-0	4	4	
MS 515	Project	0-0-0	3	3	
	Elective -I	3-1-0	4	4	
One IDC -III (Inter Disciplinary Credit) course				3	*To be chosen from courses offered by other departments*
Total credits				21	

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remark
MS 501	Classical Mechanics	3-1-0	4	4	
MS 503	Mathematical Programming	3-1-0	4	4	
MS 508	Mathematical Methods	3-1-0	4	4	
	Elective -II	3-1-0	4	4	
One IDC -IV(Inter Disciplinary Credit) course				3	*To be chosen from courses offered by other departments*
Total credits				19	

Electives to be offered from the following units:

Course Code	Course Name	L-T-P	CH	CR	Prerequisite
MS 540	Mathematical Methods in Finance	3-1-0	4	4	Nil
MS 541	Fluid Mechanics	3-1-0	4	4	Nil
MS 542	Electrodynamics	3-1-0	4	4	Nil
MS 543	Relativity	3-1-0	4	4	Nil
MS 544	Operation Research	3-1-0	4	4	Nil
MS 545	Elliptic Curves	3-1-0	4	4	MS 401
MS 546	Algebraic Number Theory	3-1-0	4	4	MS 401
MS 547	Numerical Linear Algebra	3-1-0	4	4	Nil
MS 548	Mathematical Logic	3-1-0	4	4	Nil
MS 549	Graph Theory	3-1-0	4	4	Nil
MS 550	Discrete Mathematics	3-1-0	4	4	Nil

MS 551	Introduction to Category Theory	3-1-0	4	4	MS 401, 403, 406, 408
MS 552	Operator Theory-I	3-1-0	4	4	Nil
MS 553	Number Theory-I	3-1-0	4	4	Nil
MS 554	Advanced Algebra-I	3-1-0	4	4	Nil
MS 556	Quantum Mechanics-I	3-1-0	4	4	Nil
MS 557	Mathematical Modeling-I	3-1-0	4	4	Nil
MS 558	General Theory of Relativity	3-1-0	4	4	MS 543
MS 559	Magneto Hydrodynamics & Plasma	3-1-0	4	4	Nil
MS 560	Sampling Techniques-I	3-1-0	4	4	Nil
MS 561	Stochastic processes-I	3-1-0	4	4	Nil
MS 562	Statistical Quality Control	3-1-0	4	4	Nil
MS 563	Advanced Analysis-I	3-1-0	4	4	MS 405
MS 564	Multivariate Analysis-I	3-1-0	4	4	Nil
MS 565	Fuzzy Sets and Applications-I	3-1-0	4	4	Nil
MS 566	Fourier Analysis	3-1-0	4	4	MS 410
MS 567	Continuum Mechanics	3-1-0	4	4	Nil
MS 568	Theory of Distribution and Sobolev Spaces	3-1-0	4	4	MS 410
MS 572	Operator Theory –II	3-1-0	4	4	MS 552
MS 573	Number Theory-II	3-1-0	4	4	MS 553
MS 574	Advanced Algebra-II	3-1-0	4	4	MS 554
MS 576	Quantum Mechanics –II	3-1-0	4	4	MS 556
MS 577	Mathematical Modeling-II	3-1-0	4	4	MS 557
MS 578	High Energy Astrophysics	3-1-0	4	4	MS 558
MS 579	MagnetoHydrodynamics & Plasmaphysics-II	3-1-0	4	4	MS 559
MS 580	Sampling Techniques-II	3-1-0	4	4	MS 560
MS 581	Stochastic Processes –II	3-1-0	4	4	MS 561
MS 582	Reliability Theory	3-1-0	4	4	Nil
MS 583	Advanced Analysis-II	3-1-0	4	4	MS 563
MS 584	Multivariate Analysis-II	3-1-0	4	4	MS 564
MS 585	Fuzzy Sets and Applications-II	3-1-0	4	4	MS 565
MS 586	Parallel Numerical Algorithms	3-1-0	4	4	Nil
MS 587	Finite Element Method	3-1-0	4	4	Nil
MS 588	Applied Matrix Theory	3-1-0	4	4	Nil
MS 591	Computational Fluid Dynamics	3-1-0	4	4	MS 541
MS 592	An Introduction to Fourier Theory	3-1-0	4	4	Nil
MS 593	Wavelets and Applications	3-1-0	4	4	Nil

MS 594	Advanced Topology-I	3-1-0	4	4	Nil
MS 595	Numerical Solutions of ODE	3-1-0	4	4	Nil
MS 596	Advanced Topology-II	3-1-0	4	4	MS 594
MS 597	Numerical Solutions of PDE	3-1-0	4	4	MS 507
MS 598	Algebraic Geometry	3-1-0	4	4	Nil
MS 599	Probability Theory	3-1-0	4	4	MS 405

(Electives are to be chosen out of the courses offered from the above list)

Details of Syllabi

MS 401 Abstract Algebra

(L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Group: Definition, elementary properties of groups, order of an element, examples of groups, subgroups, examples of subgroups, subgroup tests, subgroup generated by a subset, cosets, properties of cosets, Lagrange's theorem.

Unit-2
Cyclic groups: Definition and examples, properties of cyclic groups, classification of subgroups of cyclic groups.

Unit-3
Permutation groups: Definition and notation, cycle notation, properties of permutation, even and odd permutations, generators for symmetric group Sn, alternating group An.

Unit-4
Group homomorphisms: Definition and examples, propertis of homomorphisms, normal subgroups, factor groups, isomorphisms, isomorphism theorems, Caley's theorem, automorphisms of groups.

Unit-5
Direct products: Definition and examples of external direct products, properties of external direct products, definition and examples of internal direct products, fundamental theorem of finite Abelian groups and applications.

Unit-6
Group Action: Definition and examples, properties of group action, class equation of finite groups, Sylow's theorems, applications of Sylow's theorems, normal series, and solvable groups.

Unit-7
Rings: Definition and examples, elementary properties of rings, subrings, ideals, factor rings, ring homomorphisms, definition and examples of fields, embedding theorems, polynomial rings, division algorithm, irreducible polynomials, finite fields, structure of finite fields.

Unit-8
Factorization theory in integral domains, PID, Euclidean domains, Gaussian domain, Separable and inseparable extension of fields, elements of Galois theory.

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).
3. Gopalakrishnan, N. S. *University Algebra* (New Age International (P) Ltd, New Delhi, 2001).

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

Unit-1
Vector Space: Vector Spaces; bases and dimension; direct sum; dual space; quotient space (Revision).

Unit-2
Linear transformations: The algebra of linear transforms; representation of linear transforms by matrices; linear functionals; the double dual.

Unit-3
Eigen values and eigen vectors; annihilating polynomials; triangulation and diagonalization.

Unit-4
Primary Decomposition theorem; rational and Jordan forms.

Unit-5
Inner product spaces: inner product; Gram-Schmidt orthogonalization process.

Unit-6
Linear functionals and adjoints; self adjoint, normal and unitary operators; orthogonal projections; spectral theorem for normal operators on a finite dimensional vector space.

Unit- 7 Bilinear forms: bilinear, positive and quadratic forms.

Textbook(s)
1. Hoffman, K. and Kunze, R. *Linear Algebra* (Prentice Hall, 1984).

Reference(s)
1. Halmos, P. R. *Finite dimensional vector spaces* (Springer Verlag, New York, 1987).
3. Halmos, P. R. *Linear Algebra Problem Book* **(**The Mathematical Association of America (MAA), USA, 1995).
3. Williams, G. *Linear Algebra with Applications* **(**Jones and Burlet Publishers, 2001).

MS 405 Real Analysis (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Elements of set theory, finite, countable and uncountable sets, Axiom of choice, Real number system.

Unit-2

Metric space, Open, closed sets, Interior, closure and boundary of sets, convergence of sequences, completeness, Cantor's Intersection Theorem, Baire category Theorem.

Unit-3

Continuity, Uniform continuity, open and closed maps, Homeomorphism.

Unit-4

Compactness in metric spaces, Bolzano Weiertrass Property, Lebesgue Number, Totally bondedness, Heine-Borel Theorem.

Unit-5

Connectedness, Components, Path connectedness, Intermediate Value theorem.

Unit-6

Riemann-Stieltjes integrals, properties, Mean value theorem, Fundamental theorem of calculus.

Unit-7

Sequences and series of functions, uniform convergence and its relation to continuity, differentiation and integration.

Textbook(s)

1. Apostol, T. M. *Mathematical Analysis* (Narosa Publishing House, 1985).
2. Rudin, W. *Principles of Mathematical Analysis* (McGraw Hill, 1982).

Reference book(s)

1. Goldberg, R. R *Methods of real analysis (*Oxford & IBH, 1970).
2. Simmons, G. F. *Introduction to Topology and Modern Analysis* (Tata McGraw Hill Book Co. Ltd., 1963).

MS 406 Complex Analysis (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Analytic functions, Cauchy-Riemann Equations, analyticity of elementary functions.

Unit-2

Complex integration, contour integrals, antiderivatives, Cauchy-Gaursat's theorem.

Unit-3

Cauchy integral formula, Morera's theorem, Maximum moduli of functions, Liouville's theorem, the Fundamental Theorem of Algebra.

Unit-4

Convergence of sequences and series, Taylor series, Laurent series.

Unit-5
Classification of singularities, Residues, Cauchy Residue Theorem.

Unit-6
Evaluation of improper integrals and definite integrals involving sines and cosines, integration through a branch cut.

Unit-7
Logarithmic residues and Rouche's theorem, the Argument Principle.

Unit-8
Linear fractional transformations, cross ratios, mappings of the half planes and circles, conformal mapping.

Unit-9
Condition under which a function is identically zero, Schwarz Reflection Principle, Analytic continuation, Riemann Surfaces.

Textbook(s)

1. Churchill, R. V. and Brown, J.W. *Complex Variables and Applications*, 8th Edition (McGraw-Hill Publishing Company, New Delhi, 2008).
2. Conway, J. B. *Functions of One Complex Variable*, 2nd Edition (Narosa Publishing House, India, 1994).

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).

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

Unit-1
Topological spaces, basis and sub-basis, Subspaces, closure, interior and boundary.

Unit-2
Continuity, open functions, homeomorphisms, embeddings, strong and weak topologies.

Unit-3
Quotient and product spaces.

Unit-4
Countability axioms, separability, Lindelof spaces, Separation axioms (T_0, T_1, T_2, T_3, T_4), regularity, complete regularity, normality.

Unit-5
Compactness, local compactness, Tychonoff's product theorem, compactification.

Unit-6
Connectedness, local and path connectedness, components, products of connected spaces.

Textbook(s)

1. Kelley**,** J. L. *General Topology*, Graduate Texts in Mathematics, Vol. 27 (Springer, Berlin, 1991).
2. Munkres**,** J. R. *Topology : A first course* (2/e) (Prentice-Hall, 2000 or (1/e) Prentice Hall of India, New Delhi, 1983).

Reference book(s)

1. Joshi**,** K. D. *Topology* (Wiley-Eastern, New Delhi, 1988).

MS 410: 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)

1. Rudin, W. *Functional Analysis* (McGraw Hill, 2000).
2. Yosida, K. *Functional Analysis* (Springer, 1995).
3. MacCluer, B. *Elementary Functional Analysis* (GTM 253, AMS, 2009).

MS 411 Computer Programming[+] **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Computer fundamentals: major hardware and software components of a digital computer, concepts of machine language, assembly language and high level language.

Unit-2

Number systems: binary, octal, hexadecimal; algebraic operations and conversions. Algorithms and flow charts.

Unit-3

Fundamentals of C: introduction to C; comments in 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.

Unit-4

Loops and decisions: for loop, while loop, do…while loop, if statement, if…else statement, switch statement, conditional operators. The break statement, the continue statement, the goto statement.

Unit-5

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

Unit-6

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

Unit-7

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-8

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

Unit-9

Object and classes: class, types of accesses, difference between structure and classes, accessing members of a class, constructors, destructors.

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 I.*

MS 414 Ordinary Differential Equation (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
Series Solutions for ODE, Types of singularity, Solution at an Ordinary Point, Solution at a Singular Point.

Unit 4
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 5
Theory of two point BVP, Greens function, Greens matrix, properties of greens functions, Adjoint and self adjoint BVP.

Unit 6
Strum-Liouvilles problem, Orthogonal functions, eigen values & eigen functions, Completeness of the Eigen functions.

Unit 7
Orthogonal trajectory of a system of curves on a surface solution of pfaffian differential equations in three variables.

Text book(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. S. J. Farlow, S. J. *An Introduction to Differential Equations and Their Applications*, (McGraw-Hill International Editions, 1994).

MS 416 Numerical Analysis [+] **(L2 -T1 -P0 -CH3 -CR 3)**

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

Interpolation, extrapolation and inverse interpolation, Newton divided difference, Lagrange, Hermite interpolation. Finite differences, divided differences are their properties.

Unit-3

Spline interpolation, B-splines. Special emphasis on cubic spline. Curve fitting.

Unit-4

Numerical solution of algebraic and transcendental equations, Iterative methods, Theory of one point iterative method, Newton Raphson method, rate of convergence, multipoint iterative methods.

Unit-5

Solution of system of linear algebraic equations using Gauss elimination and Gauss-Seidel methods, Numerical solution of non-linear simultaneous equations, Newton's method.

Unit-6

Trapezoidal and Simpson's method and error, composite integration. Double integration. Integration formulae: Gauss, Gauss-Legendre, Gauss-Hermite and Gauss-Laguerre quadrature formulae; Newton's formula for repeated 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).

[+] *Practical unit for the course MS 416 to be done in the course MS 424 Computer Laboratory II.*

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 -P1 -CH2 -CR 1)**

[+] *Practical unit for the course MS 416 Numerical Analysis.*

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 503 Mathematical Programming (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Introduction to Mathematical Programming Problems, Formulation techniques of LP problems, Graphical solution of two-variable problem. Standard form of linear programming problem, Fundamental theorem of Linear Programming.

Unit-2

Simplex method for standard canonical form: Two-phase simplex method, degeneracy problem. Solution of simultaneous equations by simplex, inverse of a matrix by simplex method.

Unit-3

Duality in linear programming, comparison of solutions of primal and its dual. Development of computer software for the solution of LPP using simplex.

Unit-4

Formulation of LP problem in revised simplex form. Computational procedure (algorithms). Advantage of revised simplex over simplex.

Unit-5

Introduction to dual simplex method along with its limitations. Development of computer software for the solution of LPP using Dual Simplex algorothm.

Unit-6

Importance of Integer programming problems. Gomory's All IPP technique. How to construct Gomory's constraint.

Unit-7

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. Hadley, G. *Linear Programming* (Narosa Publishing House, New Delhi, 1987).
2. Kanti Swaroop, P.K. Jain and Mohan, M. *Operation Research: An Introduction* (S. Chand & Company, New Delhi, 1996).
3. Sharma, S.D. *Operations Research and Statistical Analysis* (Kedar Nath Ram Nath & Co., India, 1989).

Reference book(s)

1. Taha, H.A. *Operation Research: An Itroduction (*Macmilllan, New York,1992).
2. Kambo, N.S. *Mathematical Programming Techniques* (Affiated East West Press, New Delhi., 1990).

3. Luenberger, D.G. *Introduction to Linear and Nonlinear Programming* (Addison Wesley, Massachusetts, 1973).
4. Bazarra, M.S. and Shetty, C. M. *Nonlinear Programming Theory and Algorithms* (John Wiley & Sons, New York, 1979).

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

Unit-1
Origin of first order partial differential equations (PDE). Solutions of linear equations of first order of the form Pp + Qq = R. Integral surfaces passing through a given curve, Surfaces orthogonal to a given system of surfaces.

Unit-2
Nonlinear partial differential equation of the first order, Cauchy's method of characteristics, Compatible systems of first order equations, Lagrange's, Charpit's and Jacobi's method. Application of first order PDE.

Unit-3
Linear PDE with constant coefficients, reducible and irreducible equations. Different methods of solution.

Unit-4
Second order PDE with variable coefficients. Characteristic curves of second order PDE. Reduction to canonical forms. D'Alembert's solution of wave equation. Solutions of PDE of second order by the method of separation of variables.

Unit-5
Solutions of PDE of second order by the use of Green's function, 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.

Unit-7
Parabolic differential equations. Occurrence and detailed study of the diffusion equation.

Unit-8
Hyperbolic differential equations. Occurrence and detailed study of the wave equation.

Textbook(s)

1. Sneddon, I.N. *Partial Differential Equations* (McGraw-Hill, 1957).
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).

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
Special functions: General solution of Bessel equation, Recurrence relations, Orthogonal sets of Bessel functions, Modified Bessel functions, Applications. General solution of Legendre equation, Legendre polynomials, Associated Legendre polynomials, Rodrigues formula, Orthogonality of Legendre polynomials, Application.

Unit-4
Integral transform: Fourier Series, Generalized Fourier series, Fourier Cosine series, Fourier Sine series, Fourier integrals. Fourier transform, Laplace transform. Solution of differential equation by Laplace and Fourier transform methods. Concept and calculation of Green's function, Approximate Green's function, Green's function method for differential equations

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).

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 509 Probability & Statistics (L2 -T1 -P0 -CH3 -CR 3)

Unit-1
Sample spaces, events and probabilities, discrete probability, conditional probability, Baye's theorem, random variables.

Unit-2
Basic Statistics, Measure of central tendencies-Mean, Median and Mode; Measure of dispersion-Range, variance and standard deviation, Frequency distribution and cumulative frequency distribution.

Unit-3
Discrete and continuous probability distribution, Distributions-Binomial, Poisson, Hyper Geometric; Probability density function and distribution function, Uniform, Exponential, Normal, Student's t-distribution, F-distribution.

Unit-4
Moments and moment generating functions, correlation coefficient, Linear regression, Multiple correlation and multiple regression.

Unit-5
Population and sample, SRS and Stratified s sampling schemes. Estimation of population total, mean etc.(finite populations only).

Textbook(s)

1. Groom, A.M., Gupta, M.K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. I & II, (The World Press Pvt. Ltd., Calcutta, 1994).

Reference book(s)

1. Rohatgi, V. K. *Introduction to Probability and Mathematical Statistics* (Wiley Eastern, New Delhi, 1976).

MS 540 Mathematical Methods in Finance (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
An introduction to the basic concepts of financial markets. Various terms associated with Options. Different types of options. Payoff functions. Introduction to Martingale and the concept of fair price. (Proofs and technical details of stochastic calculus are beyond the scope of this course).

Unit-2
First principles, viz. no arbitrage, continuous compounding of risk free interest rates. Present value. Call-put parity. Bounds for present value of option price. Effect of expiry date and strike price on option valuation. Introduction to the concept of risk neutrality.

Unit-3
Discrete models in finance. Self financing strategy. Viable and complete market. Martingale based option pricing. CRR model and exact formulae for present value of European options based on a single asset.

Unit-4
Continuous time asset price model. ARCH / GARCH models for dynamically estimating volatility. Fitting these models using R. Exotic Options. . Approximation of expected option pay-off by Monte Carlo Simulation. Monte- Carlo Integration.

Unit-5
Introduction to Brownian Motion Process and Geometric Brownian motion process and Black -Scholes Model. Solution of a linear SDE.

Textbook(s)

1. D.J. Higham *An Introduction to Financial Option Valuation (*Cambridge University Press, 2004).

Reference book(s)

1. Glasserman, P. *Monte Carlo Methods in Financial Engineering (*Springer, 2000).

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).

MS 542 Electrodynamics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Electrostatic force on charges, Coulombs Law, Electrostatic Field and Potential, Conservative force, Divergence and Curl of Electrostatic field, Gauss Law, Poisson and Laplace Equation.

Unit-2
Boundary conditions on Electrostatic field, Green's Function, Fourier series and Fourier Transform, Solution Electrostatic Poisson and Laplace Equation, Electrostatic Mirror Image.

Unit-3
Electrostatics in Media, Free and bound charges, Polarisation Vector, Permittivity and Susceptibility of media, Displacement Vector. Clausius-Mosotti Equation.

Unit-4
Moving charges and current, Conductors and Insulators, Current density, Magnetic effects of current, Bios-Savart Law, Magnetic field around an infinitely long current carrying wire, an infinite sheet and a solenoid, Divergence and Curl of Magnetic field, Amperes circuital Law. Megnetic Vector Potential.

Unit-5
Time varying electric and magnetic fields, Electromagnetic Induction, Faraday law, Lenz's law, Self and Mutual Inductance.

Unit-6
Maxwell Equations in free space and material media, Wave equation, Electromagnetic Waves, Plane wave solution, Transverse waves, Poynting Vector, Maxwell equations in conducting media, Attenuation of Electric and Magnetic fields.

Unit-7
Reflection, Refraction and Polarisation of Electromagnetic Plane waves, Brewster Angle, Fresnel's Equations.

Unit-8
Special Theory of Relativity, Lorentz Transformation and consequences, Minkowski Diagram, Four dimensional spacetime continuum, Four vector formulation of Maxwell Equations, Electromagnetic field Tensor.

Textbook(s)

1. Griffiths, D. J. *Introduction to Electrodynamics* (Pearson Education Limited, 2012).
2. Jackson, J. D. *Classical Electrodynamics* (Wiley Eastern Ltd., 1989).

Reference book(s)

1. Reitz, J. R., Milford, F. J. & Christy, R. W. *Foundations of Electromagnetic theory* (Narosa Publishing House, 1988).
2. Miah, M. A. W. *Fundamentals of Electrodynamics* (Tata McGraw Hill, 1986).
3. Laud, B. B. *Electromagnetics* (Wiley Eastern Ltd., 1990).

MS 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 548 Mathematical Logic **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1
Zermelo-Fraenkel set theory, Ordinals and well-ordering, Axiom of choice cardinal Arithmetic.

Unit-2
Boolean algebra and proportional calculus. First order theories, validity, consistency, completeness.

Unit-3
Skolem-Iowenheim Theorem, compactness theorem, categoricity, Decidability; Godel's numbering. Godel's incompleteness theorems.

Unit-4
Propositional calculus, Truth on algebraic systems. The calculus of predicates. Model theory.

Textbook(s)
1. Cori, R. and Lascar, D. *Mathematical logic (*Oxford, 2001).

Reference book(s)
1. Halmos, P. R. *Naïve Set Theory* (Springer-Verlag, New York, 1974).

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

Unit-1
Graphs: History, The Konigsberg Bridge Problem, Basic Ideas: Definitions of Graph, Sub Graph, Spanning and Induced Subgraph (with diagrams), Degree and Incidence, Multi and Pseudo Graphs, Diagraph. Isomorphism and Homeomorphism of graphs.
Operations on Graphs: Union, Intersection and Ring-Sum of graphs, addition and removal of Edges and Vertices.

Unit-2
Connectivity: connectivity, walk, path, circuit, cut-vertex, cut-set, Non_Separable Graph, Components of a Graph, Complete Graph. Edge and Vertex Connectivity and related theorems.

Unit-3
Trees: Characterizations of trees, Theorems on tree, Forest, Rooted Tree, Binary Tree, Spanning Tree, Fundamental Cycles (to construct spanning Tree).

Unit-4
Traversability: Definition of Eularian graph, Properties of Eulerian Graphs: Necessary and sufficient conditions, Definition of Hamiltonian graph, Properties of Hamiltonian Graphs: Necessary and sufficient conditions .
Structure-based Connectivity and bipartite graph and and its necessary and sufficient condition.
Some Applications: The shortest path problem, The chinese postman problem and Travelling Salesman Problem.

Unit-5
Coverings and Colourings: Covering, Independence and Domination, Colouring Vertices (Chromatic Number, 4, 5 and 6 – Colourable Graphs, k-Colourable Graph), Colouring edges, Chromatic Polynomials.

Unit-6
Planarity: The Utilities Problem, Plane and Planar Graph, Planar Graph Representation, Planarity Detection (Kuratowski's theorem), Duality, Thickness and Crossing Numbers.

Unit-7
Diagraphs: Connectivity, Traversibility, Directed Trees, More Diagraph Matrices, The principle of Directional Duality, Tournaments.

Unit-8
Matrices: The Adjacency Matrix, The Incedence Matrix, The Cycle Matrix, The Cut-set Matrix, The Path Matrix.

Textbook(s)
1. Foulds, L. R. *Graph Theory Applications* (Narosa Publishing House, New Delhi, 1992).
2. Wilson, R. J. *Introduction to Graph Theory* (Longman, England, 1996).

Reference book(s)
1. Deo, N. *Graph Theory with Applications to Engineering and Computer Science*, (Prentice Hall of India, 1974).

MS 550 Discrete Mathematics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Set Theory: Sets and classes, Relations and Functions, Equivalence relations and Equivalence classes, Principle of mathematical induction, Recursive definitions.

Unit-2
Poset: Definitions and properties of poset, Chains and well-ordered sets.

Unit-3
Axiom of choice, Cardinal and ordinal numbers, Cantor's lemma, Set theoretic paradoxes.

Unit-4
Combinatorics: Permutation and combinations, Principles of addition and multiplication, Arrangements, Multinomial theorem, Partitions and allocations, Pigeonhole principle, Inclusion-exclusion principle. Generating functions, Recurrence relations.

Textbook(s)
1. Lovasz, L., Pelikan, J. and Vesztergombi, K. *Discrete Mathematics* (Springer, 2003).
2. Balakrishnan, V. K. *Introductory Discrete Mathematics* (Dover, 1996).

References book(s)
1. Johnsonbaugh, R. *Discrete Mathematics* (Prentice Hall, 2008).
2. Grimaldi, R. *Discrete and Combinatorial Mathematics*, 5th Edition (Pearson Education, 2003).

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 553 Number Theory - I

Unit-1
Divisibility, greatest common divisor, least common multiple, Euclidean Algorithm.

Unit-2
Prime numbers, factorization in prime numbers, fundamental theorem of arithmetic.

Unit-3
Divisor functions, perfect numbers, Mersenne numbers, Fermat numbers.

Unit-4
Greatest integer function (Gauss function), Mobius function, Euler function.

Unit-5
Concept of congruences and its elementary properties, congruences in one unknown, complete residue system, reduced residue system.

Unit-6
Diophantine equations, linear Diophantine equations, Pythagoras equation, sum of two squares.

Unit-7
Quadratic residues and congruences of second degree in one unknown, Legendre symbol, Jacobi symbol, congruences of second degree with prime modulus and with composite modulus.

Unit-8
Primitive roots and indices, order, necessary and sufficient condition for the existence of primitive roots, construction of reduced residue system.

Unit-9
Continued fractions, simple continued fractions, approximation of irrational numbers by continued fractions, solution of Pell's equation.

Textbook(s)

1. Burton, D. M. *Elementary Number Theory*, 6th Edition (Tata McGraw-Hill, New Delhi, 2007).
2. Niven, I. and Zuckerman, H. *An Introduction to the Theory of Numbers*, 5th Edition (Wiley Eastern, New Delhi, 2000).

Reference book(s)

1. Hardy, G.H. and Wright, E. M. *An Introduction to the Theory of Numbers*, 4th Edition (Oxford University Press, 1960).
2. Andrews, G.E. *Number Theory* (Hindustan Publishing Corporation, New Delhi, 1992).
3. Telang, S. G. *Number Theory* (Tata McGraw-Hill, New Delhi, 1996).

MS 554 Advanced Algebra -I **(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 556 Quantum Mechanics I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Inadequacy of classical mechanics, Specific Heat at low temperature, Dulong and Petit law, Amagat's experiment, Photoelectric effect, Properties of electromagnetic waves, Davisson and Garmer experiment.

Unit-2

Frank and Hertz Experiment, G.P. Thomspon experiment, Blackbody radiation, Wein's and Rayleigh-Jean's law, plack's quantum idea, de Broglie waves.

Unit-3

Heisenberg uncertainty principle, wave packet, phase velocity and group velocity. Time independent and time dependent schrodinger equation, interpretation of wave function.

Unit-4

Particle constrained in one dimension, in three dimension, potential well, rectangular potential barrier, theory of alpha decay.

Unit-5

Schordinger equations for Simple Harmonic Oscillator, Solution by the method of separation of variables, Quantisation of energy levels, Hermite polynomials.

Unit-6

Hydrogen atoms and orbitals, Lauguerre polynomials, Quantum Theory of Angular Momentum, Quantisation of angular momentum, Ladder operators, Spherical Harmonics.

Unit-7

Addition of angular momenta, Pauli spin matrices, Space quantisation, spin quantisation, Addition of orbital and spin angular momentum, Clebsch-Gordon coefficient.

Unit-8

Formal Structure of Quantum Mechanics, Postulates, Linear vector space, basis, quantum mechanical operators, Dirac bra and ket notation, unitary transformation, Matrix Mechanics.

Textbook(s)

1. Schiff, L. I. *Quantum Mechanics* (McGraw Hill, 1986).
2. Enderson, E. E. *Introduction to Modern Physics and Quantum Mechanics* (Macmillan India Ltd, 1979).
3. Ghatak, A. K. and Loknathan, S. *Quantum Mechanics* (Macmillan India Ltd, 1982).

Reference book(s)

1. Methews, P.M. and Venkatesan, K. *Quantum Mechanics* (Tata McGraw Hill, 1990).
2. Merzbacher, *Quantum Mechanics* (John Wiley & Sons, NY, 1970).
3. Dirac, P. A. M. *The Principles of Quantum Mechanics* (Oxford University Press, 1958).

MS 557 Mathematical Modelling-I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Background of Mathematical Modelling, need and Techniques. Classification and its characteristics.

Unit-2
Autonomous System, Nonautonomous System, Sylvester criterion.

Unit-3
Liapunov's Theorems, Stability by Liapunov's Direct Method. Krasovskii's method.

Unit-4
Construction of Liapunov function for linear system with constant coefficients.

Unit-5
Test for stability based on first approximations, Two-dimensional nonlinear system and linearization technique.

Unit-6
Limit sets and Limit cycles, Extent of Asymptotic Stability, Lienard Equation.

Unit-7
Stability, Perturbation Theorems, Poincare's Linearization Theorem, Bifurcation and Chaos.

Textbook(s)

1. Glendinning, P. *Stability, Instability and Chaos* (Cambridge University Press, 1994).
2. Yoshizawa, T. *The Stability Theory by Liapunov's Second Method* (Mathematical Society of Japan, Tokyo, 1966).

Reference book(s)

1. Hahn, W. *Stability of Motion* (Springer Verlag, Berlin, 1967).
2. Salle J. La and Lefschetz, S. *Stability by Liapunov's Direct Mehtod* (Academic Press, New York, 1961).

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 559 Magneto Hydrodynamics & Plasma Physics-I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
MHD, the continuum approximation, the electrical properties of the fluid, electric and the magnetic field, action at a distance, the low-frequency approximation

Unit-2
Energetic aspects of MHD.

Unit-3
Magnetic induction equation, the analogy with vorticity, Diffusion and concretion of magnetic field, Magnetic Reynold's number,

Unit-4
Dynamo problem, Aifren's theorem, Cowling's problem, Ferrano's law of isorotation, the two dimensional kinematic problems : (i) Flow only in the direction of no variation (ii) Field in the direction of no variation (iii) Current flow (but no field) in the direction of no variation.

Unit-5
The magnetic force and the inertion force, Magnetohydrostatics, the Linear pinch, the pinch, Force-free fields, the magnetic force in moving fluids.

Unit-6
Kelvin's theorem and vorticity, the case of irrotational force per unit mass, Boundary conditions for magnetic field. Boundary conditions for current, Boundary conditions for electric field.

Textbook(s)
1. Shercliff, J. A. *A Text Book of Magnetohydrodynamics* (Pergamon, New York, 1965).
2. Cambel, A. B. *Plasma Physics and Magnetofluidmechanics*, McGraw Hill, 1966.
3.

Reference book(s)
1. Ferraro, V. C. A. & Plumpton, C. *An Introduction to Magneto-fluid Mechanics (*Oxford University Press, 1961).
2. Pai, S. I. *Magnetohydrodynamics and Magnetogasdynamics (*PN, 1955).

MS 560 Sampling Techniques-I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Introduction of Sampling techniques and methods of estimation.

Unit-2
Various sampling techniques: Simple random sampling with and without replacement, Stratified random sampling, optimal allocations, allocation problem, Systematic sampling, Two stage sampling, Multistage sampling, Multiphase sampling, Sequential sampling.

Unit-3
Methods of estimation: Ratio method of estimation, Regression method of estimation, Related estimation problems.

Unit-4
A survey description of sample surveys conducted in India.

Textbook(s)
1. Cochran, W. G. *Sampling Technique* (Wiley Eastern, New Delhi, 1977).
2. Sukhatme, P. V., Sukhatme, B. V., Sukhatme S. and Ashok, C. *Sampling Theory of Survey with Applications* (Iowa State University Press, Ames, Iowa, 1984).
3. Murthy, M. N. *Sampling Theory & Methods*, 2nd edition (Stat. Pub. Soc., Calcutta., 1977).

Reference book(s)
1. Mukhopadhyay, P. *Theory and Methods of Survey Sampling* (Prentice-Hall of India Pvt. Ltd, New Delhi, 1998).

2. Hansen, M. H., Hurwitz, H.N. and Madow, W. G. *Sample Survey Methods and Theory*, Vols. I and II (Wiley, N.Y., 1953).
3. Lish, L. *Survey Sampling* (Wiley, N.Y., 1965).
4. Jensen, R. J. *Statistical Survey Techniques* (Wiley, N.Y., 1978).
5. Des, R. and Chandhok, P. *Sample Survey Theory* (Narosa Publishing House, New Dehi, 1998).

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 562 Statistical Quality Control (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Statistical control of processes, Concept of quality and meaning of control, Various control charts.

Unit-2
Properties of control charts, Special procedures in process control.

Unit-3
Estimating process average, single, double and sequential sampling plans.

Unit-4
Natural tolerance limits and specification limits, OC and ASN functions, AOQL and ATI

Unit-5
Acceptance sampling by variables, tolerance limits.

Textbook(s)

1. Hansen, B. L. and Ghare, P. M. *Quality control and application* (PHI, N.J., 1993).

2. Guttman, I., Wilks S. S. and Hunter, J. J. *Introductory Engineering Statistics* (John Wiley, N.J., 1982).
3. Montgomery, D. C. *Introduction to Statistical Quality Control* (John Wiley, N.Y., 1985).

Reference book(s)

1. Hansen, B. L. *Quality Control: Theory and Applications* (Englewood Cliffs, N. J.: Prentice Hall, 1963).
2. Grant. E. L. and Leavenworth, R.S. *Statistical Quality Control*, 5th Ed., N. Y. (McGraw Hill, 1980).
3. Hines,W.W. and Montgomery, D. C. *Probability and Statistics in Engineering and Statistics*, 2nd Ed., N.Y. (John Wiley, 1980).

MS 563 Advanced Analysis I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Algebra of sets, Set function.

Unit-2

Construction of Lebesgue measure, Lebesgue outer measure, Measurable sets, Non-measurable sets.

Unit-3

Measurable functions, Borel measurability, Simple functions, Approximation of every function as a simple function, Littlewood's principles.

Unit-4

Step function, Lebesgue integral of bounded functions, Bounded convergence theorem, Integral of non-negative functions, Fatou's Lemma, Monotone convergence theorem, Comparison with Riemann integral, Lebesgue general integral, Convergence in measure.

Unit-5

Differentiation and integration, absolutely continuity, Convex functions, Jensen’s inequality.

Unit-6

L^p Space, Holder and Minkowski's inequalities, Convergence and completeness, Bounded linear functionals on L^p Space.

Unit-7

Measure spaces, Signed mesure, Hahn decomposition theorem, Mutually singular measures, Radon-Nikodym theorem, Lebesgue decomposition, Riesz representation theorem.

Unit-8

Measure and outer measure, Extension theorem (Caratheodory), Lebesgue-Stieltjes integral, Product measures, Fubinies theorem.

Textbook(s)

1. Royden, H. L. *Real Analysis*, 3rd Edition (Macmillan Publishing Company, New York, 1988).
2. Jain P. K. and Gupta, V. P. *Lebesgue Measure and Integration (*New Age International (P) Limited, New Delhi, 1986).

Reference book(s)

1. Halmos, P. R. *Measure Theory* (Springer-Verlag, 1974).
2. Barra, G. de. *Measure Theory and Integration* (Wiley-Eastern, 1981).
3. Rana, I. K. *An introduction to Measure and Integration* (Narosa Publishing House, India).

MS 564 MULTIVARIATE ANALYSIS-I (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Bivariate Moment Generating Functions, Characteristics Functions, Bivariate Normal Distributions and its Properties.

Unit-2
Multivariate Normal Distributions, Singular and non-singular Multivariate Distributions.

Unit-3
Marginal and Conditional Distributions, Distributions of Linear forms, and Quadratic forms

Unit-4
Multiple Regression and Correlation, Correlation coefficient of a Bivariate sample.

Unit-5
The distribution when the population coefficient is non-zero, Cochran's Theorem

Unit-6
Tests of hypotheses and confidence region, the asymptotic distribution of a sample correlation coefficient.

Unit-7
Fisher's z, Partial correlation coefficient, Multiple Logistic Regression.

Unit-8
Multinomial Distributions, Multivariate Multinomial Distributions.

Textbook(s)

1. Anderson, T. W. *An Introduction to Multivariate Analysis*, 2nd edition (Wiley, 1984).
2. Khirsagar, A. M. *Multivariate Analysis* (Marcell Dekker, New York).
3. Krishnaiah, P. R. (eds), *Some recent developments on real multivariate distributions*, *Development in Statistics*, Vol. I (Academic Press, New York, 1978).
4. Johnson N. L., and Kotz, S. *Continuous Multivariate Distributions* (John Wiley, New York).

Reference book(s)

1. Kendall, M. G. *Multivariate Analysis* (NY, Hamer Press, 1975).
2. Maxwell, A. E. *Multivariate Analysis in Behavioural Research* (Chapman & Hall, London 1977).
3. Chatterjee, S. and Price, B. *Regression Analysis by Examples* (John Wiley, NY, 1977).
4. Johnson, R. A. and Wichern, D. W. *Applied Multivariate Statistical Analysis*, 3rd edition (PHI, 1998).

5. Johnson, N.L., Kotz, S. and Balakrishnan, N. *Discrete Multivariate Distributions* (Wiley,N.Y., 1997).
6. Johnson, N. L., Kotz, S., and Kemp, A. W. *Univariate Discrete Distributions*, 2nd edition (Wiley, 1993).

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 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 Number Theory - II **(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 Advanced Algebra-II (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 576 Quantum Mechanics-II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Time independent and time dependent schrodinger equation, interpretation of wave function. Particle constrained in three dimension, potential well, rectangular potential barrier, theory of alpha decay.

Unit-2
Schordinger equations for Simple Harmonic Oscillator, Solution by the method of separation of variables, Quantisation of energy levels, Hermite polynomials.

Unit-3
Hydrogen atoms and orbitals, Lauguerre polynomials, Quantum Theory of Angular Momentum, Quantisation of angular momentum, Ladder operators, Spherical Harmonics.

Unit-4
Addition of angular momenta, Pauli spin matrices, Space quantisation, spin quantisation, Addition of orbital and spin angular momentum, Clebsch-Gordon coefficient.

Unit-5
Formal Structure of Quantum Mechanics, Postulates, Linear vector space, basis, quantum mechanical operators, Dirac bra and ket notation, unitary transformation, Matrix Mechanics.

Unit-6
Time independent perturbation theory, variational method, WKB approximation, Time dependent perturbation theory, Quantum theory of scattering, motion in a magnetic field.

Unit-7
Relativistic quantum mechanics: Klein Gordon equation, equation of continuity and interpretation in Klein Gordon equation and its limitations.

Unit-8
Dirac equation for a free fermion, Dirac gamma matrices, bilinear forms, conservation of angular momentum, inherent existence of spin in Dirac theory, interpretation of negative energy solution of Dirac equation, concept of antiparticle and fermi sea.

Textbook(s)

1. Schiff, L. I. *Quantum Mechanics* (McGraw Hill, 1986).
2. Enderson, E. E. *Introduction to Modern Physics and Quantum Mechanics* (Macmillan India Ltd, 1979).
3. Ghatak, A. K. & Loknathan, S. *Quantum Mechanics* (Macmillan India Ltd, 1982).
4. Bjorken, J. D. & Drell, S. D. *Relativistic Quantum Mechanics* (McGraw Hill, New York, 1964).

Reference book(s)

1. Methews, P.M. and Venkatesan, K. *Quantum Mechanics* (Tata McGraw Hill, 1990).
2. Merzbacher *Quantum Mechanics* (John Wiley & Sons, NY, 1970).
3. Dirac, P. A. M. *The Principles of Quantum Mechanics* (Oxford University Press, 1958).
4. Parthasarathy, R. *Relativistic Quantum Mechanics* (Alpha Science Int. Ltd., 2010).
5. Schwabl, F. *Advanced Quantum Mechanics* (Springer-Verlag, 2008).

MS 577 Mathematical Modeling II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Fundamentals of Mathematical Modelling. Characteristics of Mathematical Models.

Unit-2
Single-species growth, Malthusian and Logistic growth models.

Unit-3
Gompertz and Weibull growth models. Examples of some Mortality Models

Unit-4
The general autonomous and Non-autonomous growth Model. Predation and parasitism.

Unit-5
Solutions of Lotka-Volterra Systems for predator-prey interactions, Increasing and diminishing returns, Perturbed models.

Unit-6
Existence of limit cycle for perturbed models, Intermediate predator-prey models, A generalized Gauss model.

Unit-7
Lotka-Volterra competition models, The competitive exclusion principle, Competition for fixed resources, Competition for renewable resources.

Unit-8
Lotka-Volterra Cooperation models, Kolmogorov Type models. Diffusion and pollution models, Models for fishery resources.

Textbook(s)

1. Freedman, H.I. *Deterministic Mathematical Models in Piopulation Ecology* (Marcel Decker, 1980).
2. Renshaw, E. *Modelling Biological Populations in Space and Time* (Cambridge University Press, 1991).

Reference book(s)

3. Goh, B.S. *Management and Analysis of Biological Populations* (Elsevier Scientific Publishing Company, 1980).

MS 578 High Energy Astrophysics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Basic equations of nonrelativistic stellar structure, Equations of Hydrostatic Equilibrium, Polytropic fluid spheres, Lane-Emden Equation and solutions.

Unit-2
Integral Theorems on stellar structures, Betti-Ritters formula, Simple Stellar Models.

Unit-3
Nuclear energy generation, PP and CNO Cycles, Energy transport equations, Stellar Luminosity, Mean free path, Roseland Opacity, Stellar atmosphere.

Unit-4
Stellar Equations of state, Nonrelativistic and Relativistic Degeneracy pressure, Hurtzsprung-Russel Diagram, Stellar evolution and nucleosynthesis for low, intermediate and high mass stars.

Unit-5
End state of stars, Gravitational collapse, Supernova Explosion, Stellar remnants, Compact stellar objects, basic properties.

Unit-6
Tolman-Openheimer-Volkof equation, White Dwarf, Chandrasekhar Mass limit neutron star, Pulars, Radio and X-ray Observation of Pulsars and Neutron stars.

Unit-7
Schwarzschild and Kerr Black hole and their basic properties, Event Horizon and possible violent phenomena near event horizon.

Unit-8
Gravitational wave and their basic properties, generation, propagation and detection of gravitational waves, Gravitational Wave Astronomy.

Textbook(s)

1. Chandrasekhar, S. *Introduction to the study of stellar structure* (Dover Publications, 1957).
2. Kippenhahn & Weigert *Stellar Structure and Evolution* (Springer-Verlag, 1991).
3. Shapiro, S.L. & Teukolsky, S.A. *Black Hole, White Darf and Neutron Star* (Willey and Sons, 1983).

Reference book(s)

1. Weinberg, S. *Gravitation and Cosmology* (John Wiley & Sons, 1972).
2. Bohm-Vitense, E. *Introduction to stellar astrophysics*, *Vols. I, II & III* (Cambridge University Press, 1989).
3. Hartle, J. B. *Gravity: An Introduction to Einstein's General Relativity* (Pearson Education, 2003).

MS 579 Magneto Hydrodynamics & Plasma Physics-II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Linear, one-dimensional problem, Two-dimensional problem, Staedy Hartmann Flows, Linear Alfven waves, MHD-Rayleigh problems,

Unit-2
Two-dimensional linear problems, Steady laminar flow in or pipe under a uniform transverse field, Flow in a circular pipe with axial current in the fluid.

Unit-3
Alfven waves, MHD waves in non-uniform magnetic fields, Reflection and refraction of MHD waves, Dissipative effects, Plane polarized waves,

Unit-4
Torsional oscillations, Elements of the theorem of characteristics.

Unit-5
Instability of linear pinch, flute instability, the method of small oscillation the energy priciple, Stewart's and Lock's condition.

Unit-6
The problems of thermal instability in presence of a magnetic field, Variational principle.

Textbook(s)

1. Shercliff, J. A. *A Text Book of Magnetohydrodynamics* (Pergamon, New York, 1965).
2. Cambel, A. B. *Plasma Physics and Magnetofluidmechanics*, McGraw Hill, 1966.

Reference book(s)

1. Ferraro, V. C. A. & Plumpton, C. *An Introduction to Magneto-fluid Mechanics (*Oxford University Press, 1961).
2. Pai, S. I. *Magnetohydrodynamics and Magnetogasdynamics (*PN, 1955).

MS 580 Sampling Techniques-II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Double Sampling, Cluster Sampling**,** Probability proportion to size with replacement sampling, varying probability without replacement sampling.

Unit-2
Hurwitz-Thomson estimator, Midzuno-Lahiri-Sen Sampling Strategy, Des Raj's, Murthy's Sampling strategies, etc.

Unit-3
Errors of Surveys: Sampling and non-sampling error.

Unit-4
Some problem of Inference under a fixed population set-up, Interpenetrating samples, Small area estimation.

Textbook(s)

1. Cochran, W. G. *Sampling Technique* (Wiley Eastern, New Delhi, 1977).
2. Sukhatme, P. V. Sukhatme, B. V., Sukhatme S., and Ashok, C., *Sampling Theory of Survey with Applications* (Iowa State University Press, Ames, Iowa, 1984).
3. Murthy, M. N. *Sampling Theory & Methods*, 2nd edition (Stat. Pub. Soc., Calcutta., 1977).

Reference book(s)

1. Mukhopadhyay, P. *Theory and Methods of Survey Sampling* (Prentice-Hall of India Pvt. Ltd, New Delhi, 1998).
2. Hansen, M. H., Hurwitz, H.N. and Madow, W. G. *Sample Survey Methods and Theory*, Vols. I and II (Wiley, N.Y., 1953).
3. Lish, L. *Survey Sampling* (Wiley, N.Y., 1965).
4. Jensen, R. J. *Statistical Survey Techniques* (Wiley, N.Y., 1978).
5. Des Raj and Chandhok, P. *Sample Survey Theory* (Narosa Publishing House, New Dehi, 1998).

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 582 Reliability Theory **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1
Exponential failure model: properties of exponential distributions, estimation of mean life with complete samples.

Unit-2
Reliability estimation: Estimation of reliability in Stress-Strength Models, estimation with censored samples, estimation based on components of order statistics: *k* out of *n*.

Unit-3
Gamma and Weibull distributions (one, two and three parameters)

Unit-4
Estimation of complete samples, truncated and censored samples. An application of the Kaplan-Meier estimator and its extensions.

Unit-5
Reliability estimation of Normal and related distributions.

Unit-6
Reliability estimation: mixture distributions and competing risks.

Unit-7
Reliability of series / parallel systems : Series system with identical components

Unit-8
Reliability bounds - classical approach and - Bayesian approach.

Textbook(s)

1. Polvoko, A. M. *Fundamental of Reliability Theory* (Academic Press, New York, 1968).
2. Zacks, S. *Theory of Statistical Inference* (Wiley, New York, 1971).
3. Sinha, S. K. *Reliability and Life Testing* (Wiley Eastern Ltd., New Delhi, 1986).

Reference book(s)

1. Ravichandran, N. *Stochastic Methods in Reliability Theory* (Wiley Eastern Ltd., 1990).
2. Trivedi, Kishor Shribharbhai. *Probability & Statistics with reliability*, *Queueing and Computer Science Applications* (PHI, 1992).
3. Bazowsky, I. *Reliability*: *Theory and Practice*, Englewood Cliffs (N.J., Prentice Hall, 1961).
4. Kapur, K. *Reliability in Engineering Design* (N.Y., Wiley, 1977).

MS 583 Advanced Analysis II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Baire sets, Baire measure, continuous functions with compact support. Regularity of measures on locally compact spaces. Integration of continuous functions with compact support, Riesz-Markoff theorem.

Unit-2
Radon measure, positive linear functional on $C_c(X)$, Dual of $C_0(X)$, Products of Radon Measures.

Unit-3
Homogeneous spaces, Topological Groups, Invariant Measure (Haar measure), Hausdorff measure, Integration on manifolds.

Unit-4
Distributations, Sobolev Spaces.

Unit-5
Fourier Analysis of measures.

Textbook(s)

1. Royden, H. L. *Real Analysis*, 3rd Edition (Macmillan Publishing Company, New York, 1988).
2. Folland, G. B. *Real Analysis –Modern Techniques and Their Applications* (John Wiley & sons, New work 1984).

Reference book(s)

1. Rudin, W. *Real and complex Analysis* (McGraw-Hill Book Company, New Delhi).
2. Halmos, P. R. *Measure Theory (*Springer-Verlag, 1974).
3. Bartle, R.G. *The elements of Integration* (John Wiley & sons, New work 1966).

4. Wheeden, R.L. Antoni Z. *Measure and integral : An introduction to real analysis*, (Marcel, Dekker Inc,1977).

MS 584 Multivariate Analysis-II (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Inference on parameters of Multivariate normal distributions, One population and Two Population cases.

Unit-2
Wishart Distributions, Hotellings T^2.

Unit-3
Discriminant analysis, Mahalanobis $D^{2.}$.

Unit-4
Testing general linear hypotheses: Estimation of parameters in multivariate linear regression, distribution of and , Computation of and .

Unit-5
Likelihood ratio criteria for testing linear hypotheses about regression coefficients, Moments of Likelihood ratio criterion.

Unit-6
Principal Components: Definition of Principal Components in the Population, Maximum likelihood Estimates of the Principal Components and their Variances.

Unit-7
Computation of the Maximum Likelihood Estimates of the Principal Components.

Unit-8
Canonical Correlation and Canonical Variables: Canonical Correlations and Variables in the Population, Estimation of Canonical Correlations and Variables, Computation. Cluster Analysis.

Textbook(s)

1. Anderson, T. W. *An Introduction to Multivariate Analysis*, 2nd Edition (Wiley, 1984).
2. Khirsagar, A. M. *Multivariate Analysis* (Marcell Dekker, New York).
3. Krishnaiah, P. R. *Some recent developments on real multivariate distributions*, Development in Statistics, Vols. I & II (Academic Press, New York, 1978).

Reference book(s)

1. Johnson, N. L. and Kotz, S. *Continuous Multivariate Distributions* (John Wiley, New York).
2. Kendall, M. G. *Multivariate Analysis* (NY, Hamer Press, 1975).
3. Maxwell, A. E. *Multivariate Analysis in Behavioural Research*, London (Chapman & Hall, 1977).
4. Chatterjee, S. and Price, B. *Regression Analysis by Examples* (John Wiley, NY, 1977).
5. Johnson, R. A. and Wichern, D. W. *Applied Multivariate Statistical Analysis*, 3rd Ed, (PHI, 1998).

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 586 Parallel Numerical Algorithms (L3 -T1 -P0 -CH4 -CR 4)

Unit-1
Fundamentals of Parallel computing. Parallel techniques and algorithms.

Unit-2
Theoretical models of parallel computation: Variants of the PRAM model. Performance of parallel algorithms.

Unit-3
Basic Techniques: Balanced trees, recursive doubling, divide and conquer, partitioning. Pipe lining, Accelerated cascading, symmetry breaking. List ranking, the Euler tour techniques, tree contraction. Algorithms for searching, merging and sorting.

Unit-4
Graph algorithms: Connected components, colouring. Parallel algorithms on interconnection networks and other architectures. Limits to parallelisability. P-completeness.

Unit-5
Parallel algorithms for linear algebraic equations; Design of parallel algorithms for eigen value problem; parallel issues of factorization. Parallel implementation of classical iterative methods.

Unit-6
Parallel methods for ordinary and partial differential equations.

Textbook(s)
1. Quinn, Michael J. *Parallel computing theory and practice*, 2nd ed (Mc-Graw Hill, 2000).
2. Joseph, Jaja. *An introduction to parallel algorithms* (Addision Wesley, 1992).

Reference book(s)
1. Reif H.H. *Synthesis of parallel algorithms* (Morgan Kaufmann publishers, San Mateo, California, 2000).
2. Leighton, F.T. *Introduction to parallel algorithms and architectures: Arrays trees, Hypercubes (*Morgan Kaufmann publishers, San mateo, California, 2000).

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 592 An Introduction to Fourier Theory (L3 -P1 -T0 -CH4 -CR 4)

Unit 1
Fourier Transform, Fourier Transform Properties: scaling, shifting, convolution.

Unit 2
Correlation theorems, Parseval's theorem, Sampling Theorem.

Unit 3
Discrete Fourier Transform, Fast Fourier Transform , Applications.

Textbook(s)

1. Bracewell, Ronald N., *The Fourier Transform and Its Applications* (McGraw-Hill International Editions, 2000).
2. Walker, James S., *Fast Fourier Transforms,* CRC Press, 1996.

Reference book(s)

1. Burrus C.S. and Parks, T.W. *DFT/FFT and Convolution Algorithms: Theory and implementation* (John Wiley & Sons, New York, 1985).
2. Gaskill, Jack D. *Linear Systems, Fourier Transforms, and Optics*, New York (John Wiley & Sons, 1978).

MS 593 Wavelets and Applications (L3 -T1 -P0 -CH4 -CR 4)

Unit 1

Introduncton: Reviews of Fourier analysis and L^p spaces, Wavelets and atomic decomposition of functions.

Unit 2

Multi resolution analysis: Multi-resolution signal decomposition, Multi-resolution analysis and the construction of wavelets, Examples of wavelets, QMF and fast wavelet transform.

Unit 3

Continuous Wavelet transform: Localization, Regularity and approximation properties of wavelets,Construction of compactly support wavelets, Orthonormal bases of compactly supported wavelets.

Unit 4:

Wavelets sampling techniques, Convergence of wavelet expansion.

Unit 5

Time frequency analysis: Time frequency analysis for signal processing, Application of wavelets in image and signal processing.

Textbook(s)

1. Daubechies, I.. *Ten Lectures on Wavelets*, SIAM, 1992

Reference book(s)

1. Meyer, Y. *Wavelets: Algorithm and Application*, SIAM, 1993
2. Kaiser, G. *A Friendly guide to Wavelets*, Birkhauser, 1994

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, measure induced by a measurable function.

Unit-2

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 with respect to 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).