Department of Mathematical Sciences

Course Structure and Syllabus of Integrated M.Sc. in Mathematics

(for 2018 entry batch onwards)

Minimum credit requirement : 210
Minimum duration : 5 years (10 semesters)
Maximum duration : 7 years (14 semesters)

****For lateral exit after 3 years with B. Sc. Degree, Minimum credit requirement is 130.**

COURSE STRUCTURE

Semester I

Course Code	Course Name	L-T-P	CH	CR	Remark
PI 101	Physics-I	2-1-0	3	3	GE
CI 101	Chemistry-I	3-0-0	3	3	GE
CI 107	Chemistry-Lab	0-0-3	6	3	GE
BI 101	Biology-I	3-0-0	3	3	GE
*MI 101	Mathematics -I	2-1-0	3	3	GE
MI 103	Foundation of Mathematics	2-1-0	3	3	CORE
MI 105	Real Analysis-I	2-1-0	3	3	CORE
EG 110	Communicative English	3-0-0	3	3	AEC
Total credits				**21**	

***** MI 101(Mathematics –I) is only for students not having Mathematics Major

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remark
PI 102	Physics-II	2-1-0	3	3	GE
PI 197	Physics-Lab	0-0-3	6	3	GE
CI 102	Chemistry-II	3-0-0	3	3	GE
BI 107	Biology-Lab	3-0-0	3	3	GE
*MI 102	Mathematics -II	2-1-0	3	3	GE
MI 104	Real Analysis-II	2-1-0	3	3	CORE
MI 106	Group Theory	2-1-0	3	3	CORE
ES 103	Environmental Studies	4-0-0	4	4	AEC
Total credits				**22**	

***** MI 102(Mathematics –II) is only for students not having Mathematics Major

Semester III

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 221	Introductory Statistics & Probability	2-1-0	3	3	CORE
MI 223	Calculus-I	3-1-0	4	4	CORE
MI 225	Combinatorics	3-1-0	4	4	CORE
PI 201	Physics-III	2-1-0	3	3	GE
CI 201	Chemistry-III	3-0-0	3	3	GE
*MI 219	Mathematics III	2-1-0	3	3	GE
CS 535	Introduction to Scientific computing	2-0-1	3	3	AEC
NS 102	National Service Scheme	0-0-2	4	2	SEC
Total credits				**22**	

*****MI 219 (Mathematics–III) is only for students having Physics and Chemistry Major

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 218	Introductory ODE & PDE	3-1-0	4	4	CORE
MI 220	Linear Algebra-I	3-1-0	4	4	CORE
MI 222	Co-ordinate Geometry	3-1-0	4	4	CORE
MI 224	Numerical Methods and Boolean Algebra	3-1-0	4	4	CORE
MI 226	Introductory Topology	3-1-0	4	4	CORE
DM 101	Disaster Management	3-0-0	3	3	SEC
Total credits				**23**	

Semester V

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 311	Calculus-II	3-1-0	4	4	CORE
MI 313	Programming, Algorithm and Mathematical Software	2-0-2	6	4	CORE
MI 315	Statics and Dynamics	3-1-0	4	4	CORE
MI 317	Elementary Complex Analysis	3-1-0	4	4	CORE
MI 319	Graph Theory	3-1-0	4	4	CORE
Total credits				**20**	

Semester VI

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 312	Ring Theory	2-1-0	3	3	CORE
MI 314	Elementary Number Theory	3-1-0	4	4	CORE
MI 316	Introduction to Optimization	3-1-0	4	4	CORE
MI 318	Elementary Integral Transforms and Special Functions	3-1-0	4	4	CORE
MI 322	Seminar	0-0-3	6	3	CORE
MI 320	Elementary Coding and Information Theory	3-1-0	4	4	CORE
Total credits				**22**	

Semester VII

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 412	Abstract Algebra	3-1-0	4	4	CORE
MI 417	Linear Algebra-II	3-1-0	4	4	CORE
MI 413	Real Analysis-III	3-1-0	4	4	CORE
MI 414	Computer Programming+	3-1-0	4	4	CORE
MI 415	Lebesgue Measure and Integration	3-1-0	4	4	CORE
MI 421	Computer Lab	0-0-1	2	1	CORE
Total credits				**21**	

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

Semester VIII

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 408	Complex Analysis	3-1-0	4	4	CORE
MI 418	Theory of Ordinary Differential Equations	3-1-0	4	4	CORE
MI 419	Topology	3-1-0	4	4	CORE
MI 416	Numerical Analysis+	3-1-0	4	4	CORE
MI 424	Computer Lab	0-0-1	2	1	CORE
	Open Elective-I[#]	2-1-0	3	3	Open Elective
Total credits				**20**	

List to be notified by the CoE from time to time

Semester IX

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

Semester X

Course Code	Course Name	L-T-P	CH	CR	Remark
MI 599	Probability Theory	3-1-0	4	4	CORE
MI 508	Mathematical Methods	3-1-0	4	4	CORE
MI 509	Classical Mechanics	3-1-0	4	4	CORE
	DSE-II	3-1-0	4	4	DSE
	DSE-III	3-1-0	4	4	DSE
Total credits				**20**	

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

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

MI 566	Fourier Analysis	3-1-0	4	4
MI 567	Continuum Mechanics	3-1-0	4	4
MI 568	Theory of Distribution and Sobolev Spaces	3-1-0	4	4
MI 569	Coding Theory-I	3-1-0	4	4
MI 570	Coding Theory-II	3-1-0	4	4
MI 572	Operator Theory –II	3-1-0	4	4
MI 573	Analytic Number Theory	3-1-0	4	4
MI 574	Galois Theory	3-1-0	4	4
MI 581	Stochastic Processes –II	3-1-0	4	4
MI 585	Fuzzy Sets and Applications-II	3-1-0	4	4
MI 587	Finite Element Method	3-1-0	4	4
MI 588	Applied Matrix Theory	3-1-0	4	4
MI 591	Computational Fluid Dynamics	3-1-0	4	4
MI 594	Advanced Topology-I	3-1-0	4	4
MI 595	Numerical Solutions of ODE	3-1-0	4	4
MI 596	Advanced Topology-II	3-1-0	4	4
MI 597	Numerical Solutions of PDE	3-1-0	4	4
MI 598	Algebraic Geometry	3-1-0	4	4

Detailed Syllabus

MI 101: Mathematics I (L2 -T1 -P0 -CH3 -CR 3)

Unit-1

Inequalities involving arithmetic, geometric, and harmonic means, Cauchy-Schwarz inequality.

Unit-2

Sequences: Cauchy sequence, Cauchy's General principle of convergence, Subsequences, Convergence and divergence of monotonic sequences, Sandwich theorem.

Infinite series: statements of basic properties of infinite series (without proofs), Convergence, Absolute and conditional convergences. Tests for convergence: Comparison test, Ratio test, Raabe's test, Leibnitz's test.

Unit-3

Functions of one variable: Limit, Continuity, Differentiability, Rolle's Theorem, Mean value theorems and applications, Taylor's theorem.

Unit-4

Critical points, convexity, curvature of plane curves, Asymptotes.

Curve tracing: tracing of catenary, cissoids, asteroid, cycloid, folium of Descartes, cardioid, lemniscate.

Unit-5

Functions of two or more variables: Limit, Continuity, Partial derivatives, Euler's theorem on homogeneous functions, Differentiability, Chain rule, Directional derivatives, Gradient vectors and Tangent planes, Taylor's theorem (statement only), Criteria for Maxima/Minima/Saddle points, Lagrange's method of multipliers.

Textbook(s)

1. Thomas and Finney, *Calculus and Analytic Geometry*, (Pearson Education, Eleventh (Indian) Edition).

2. Bartle, R. G. and Sherbert, D. R. *Introduction to Real Analysis*, (John Wiley and Sons, Third (Indian) Edition).

Reference book(s)

1. Apostol, T. M. Calculus, Vol I & II, (John Wiley and Sons, Second (Indian) Edition).
2. Mapa, S.K. *Higher Algebra*, (Asoke Prakashan, Kolkata).

MI 102: Mathematics II (L2 -T1 -P0 -CH3 -CR 3)

Unit-1

Ordinary differential equations(ODE): Basic definitions: order and degree of differential equation, primitives, solutions of differential equations, Integral curves, isoclines, formulation of ODE, Linear and non-linear differential equations.

Unit-2

Variables separable equation, homogeneous and non-homogeneous equation, exact equations and integrating factors, linear and Bernoulli's equation, equations reducible to first order Clairaut's equation.

Unit-3

Second order Differential Equations: Linear equations with constant coefficients. Standard methods for solution of homogeneous and non-homogeneous linear differential equations, linear differential equations with variable coefficients and Method of Variation of Parameter.

Unit-4

Line integral, Double integral, triple integral, Jacobian, Surface integral and their applications. Space co-ordinates, lines and planes, Polar coordinates, Cylinders, Quadric surfaces, Volume, Area, length, volume and surface area of solids of revolution.

Unit-5

Vector Calculus, vector point function, continuity and differentiation of vector point function, partial derivative of vectors, Curl, Grade, Divergence; Green, Gauss and Stokes Theorem.

Textbook(s)

1. Boyce, William E. and Dprima, Richard, C. *Elementary Differential Equations*, (John Wiley, Indian Edition, 2000).
2. Spiegel, M. R. *Vector Analysis, Schaum's outline series, (*Publishing House India).
3. Thomas *and* Finney, *Calculus and Analytic Geometry*, (Pearson Education, Eleventh (Indian) Edition).

Reference book(s)

1. Jain, R. K. and Iyengar, S. R. K. *Advanced Engineering Mathematics*, Third Edition, (Narosa publishing house, India).
2. Ramana, B. V. *Higher Engineering Mathematics*, (McGraw Hill, India).

MI 103: Foundation of Mathematics (L2 -T1 -P0 -CH3 -CR 3)

Unit-1

Statements, quantifiers, negation, compound statements (conjunction, disjunction, conditional and bi-conditional), contra-positive statement, proofs in Mathematics.

Unit-2

Set, subset, superset, operations viz. union, intersection, complement etc. of sets; power set, cartesian product.

Unit-3

Equivalence relations, equivalence classes, partition, fundamental theorem of equivalence relation.

Unit-4

Functions, injection, surjection and bijection; image and pre-image of set under function, composition of functions, invertible function.

Unit-5

Partial order relation, poset, chain, upper & lower bounds in poset, greatest & least elements, maximal & minimal elements, supremum & infimum, Zorn's lemma, introduction to lattice theory.

Unit-6

Peano's axioms, principle of mathematical induction, well ordering principle, axiom of choice.

Unit-7

Finite and infinite sets, countable and uncountable sets, Schroeder Bernstein Theorem, Continuum hypothesis.

Unit-8

Ordinal numbers, sum and product of ordinal numbers, structure of ordinal numbers.

Text Book(s):

1. Halmos, P. R. *Naive Set Theory* Springer, 2009.
2. Kumar, A., Kumaresan, S. and Sarma, B. K. *A foundation course in Mathematics*, Narosa, 2018.

Reference Book(s):

1. Hrbacek, K. and Jech, T. *Introduction to Set Theory* , 3rd edition, CRC press, 1999.
2. Bartle, R. G. and Sherbert, D. R. *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons, 2005 (reprint, Wiley India, 2011).

MI 104: Real Analysis-II (L2-T1-P0–CH3-CR3)

Unit-1

Limits of functions, sequential criterion of limits, squeeze theorem, one sided limits, infinite limits and limits at infinity, continuity of a function, sequential criterion, algebra and composition of continuous functions.

Unit-2

Continuous functions on intervals, maximum-minimum theorem, location of roots and Bolzano's intermediate value theorem. Uniformly continuity. Lipshitz function. Continuous extension theorem.

Unit-3

Differentiability, Rolle's Theorem, Mean value theorems and applications, Taylor's theorem, Expansion of functions by Maclaurin's theorem.

Unit-4

Weierstrass approximation theorem. Bernstein Approximation theorem. Monotone and inverse functions, continuous inverse theorem.

Unit-5

Riemann Integration: definition and properties up to fundamental theorem of integral calculus.

Text Books:

1. Bartle, R. G. and Sherbert, D. R. *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons, 2005 (reprint, Wiley India, 2011).
2. Kumar, A. and Kumaresan, S. *A Basic Course in Real Analysis*, CRC Press, 2014.

MI 105: Real Analysis-I (L2-T1-P0–CH3-CR3)

Unit-1

Real Numbers: algebraic and ordered properties, completeness property, supremum and infimum and applications. Absolute value and triangle inequality.

Unit-2

Archimedean property and its applications, density theorem. Intervals, nested interval property. Binary and decimal representation, Cantor's proof of unaccountability of [0,1]. Cantor set.

Unit-3

Sequences, bounded sequences, tails of a sequence, Cauchy sequence, convergent sequence and its limit, algebra of limits. Monotone sequences, monotone convergence theorem. Subsequences, divergence criterion. Construction of R.

Unit-4

Infinite series, sequence of partial sums. Convergent and absolutely convergent series. Test of convergence. Alternating series. Rearrangement of infinite series.

Text Books:

1. Bartle, R. G. and Sherbert, D. R. *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons, 2005 (reprint, Wiley India, 2011).
2. Kumar, A. and Kumaresan, S. *A Basic Course in Real Analysis*, CRC Press, 2014.

MI 106: Group Theory (L2 -T1 -P0 -CH3 -CR 3)

Unit-1

Binary operation, semigroup, monoid, group, elementary properties of groups, subgroup, order of an element, coset, Lagrange's theorem and its applications.

Unit-2

Conjugacy class, class equation, normal subgroups and quotient groups.

Unit-3

Subgroup generated by a set, cyclic subgroups, properties of cyclic groups, fundamental theorem of cyclic group.

Unit-4

Permutation, cycle notation, even and odd permutation, order of a permutation, symmetric group and alternating group. Dihedral group and presentation of group.

Unit-5

Homomorphism and isomorphism of groups, isomorphism theorems, Cayley's theorem.

Unit-6

Direct product of groups, properties of direct products.

Textbook(s)

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

Reference book(s)

1. Fraleigh, J. B. *A First Course in Abstract Algebra*, 7th edition (Pearson Education India, New Delhi, 2008).
2. Herstein, I. N., *Topics in Algebra*, 2nd edition (John Wiley & Sons, Indian reprint, New Delhi, 2006).

MI 218: Introductory ODE & PDE (L3 -T1 -P0 –CH4 -CR 4)

Unit -1

First order linear and nonlinear ODE: Exact differential equations and integrating factors, separable equations and equations reducible to this form, Bernoulli equation, integrating factors and transformations, Clairaut form, singular solution. Orthogonal and oblique trajectories, rate problems.

Unit -2

Explicit methods of solving higher order linear differential equations: Basic theory of linear differential equations, homogeneous linear differential equations with constant coefficients, method of undetermined coefficients, variation of parameters, Cauchy_euler equation, Wronskian. Statements and proofs of theorems on second order homogeneous linear equations.

Unit -3

Laplace Transforms: Laplace Transforms of some elementary functions, Linearity property, First and second translational or shifting theorem. Change of scale property, Laplace transforms of derivatives, multiplication by powers of t, and related problems. Laplace transform of periodic functions. Inverse Laplace transforms, Convolution theorem. Solution of ordinary differential equations by Laplace transform.

Unit -4

Series Solutions for ODE, Types of singularity, Solution at an Ordinary Point, Solution at a Singular Point. Method of Frobenius. General solution of Bessel and Legendre equation.

Unit -5

Introduction, Origins of First order PDE, Cauchy Problem for First order equations, Linear equations of first order, Lagrange equation, Integral Surface passing through a given curve, surface orthogonal to a given system of surfaces.

Unit -6

Nonlinear PDE of first order, Compatible systems of first order equation, Charpit's Method, special types of first order equations, solution satisfying given conditions

Text Book(s):

1. Ross, S.L., Differential equationsm 3rd edition, (Wiley, 2016).
2. Sneddon, I. Elements of Partial Differential Equations, (Dover, 2006).

MI 219: Mathematics III (L2-T1 -P0 -CH3 -CR 3)

Unit-1

Definitions of Statistics, population, sample, data and characteristics of data. Measures of central tendency, dispersion. Histogram, frequency curve and boxplot.

Unit-2

Skewness and its measures. Normal and student's-t curves. Kurtosis and its measures. Effects of change of origin and scale. Definition of Probability and some properties of the probability function.

Unit-3

Random variable, Probability distribution and distribution function. Discrete and continuous distribution. Some important discrete and continuous distributions.

Unit-4

Random sampling and sampling fluctuation, Simple random sampling, variance of sample mean under SRS WOR, Estimation of population size (capture-release- capture method), Correlation and simple linear regression. Rank correlation.

Textbook(s)

1. Medhi, J. *Statistical Methods: An introductory Text*, (New Age International (P) Ltd, 2000).
2. Gupta, S.C. and Kapoor, V. K. *Fundamentals of Mathematical Statistics*, (S. Chand & Co., 2007).
3. Cochran, W.G., Sampling Techniques, third edition (John Wiley & Sons, 1977).

Reference book(s)

1. Feller, W. An *Introduction to Probability Theory and Its Applications*, Vol. I, (Wiley, 2005).
2. Uspensky, J.V. *Introduction to Mathematical Probability*, (McGraw Hill, 2005).

MI 220: Linear Algebra-I (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Matrices and System of linear equations, Reduced Row-Echelon form and its relevance to Linear systems, Elementary operation, Gaussian reduction.

Unit-2

Vector spaces and Subspaces, Direct sum of subspaces, Quotient space.

Unit-3

Linear combination and Span, Linear Independence, Exchange lemma, Basis of a vector space and Dimension Theory.

Unit-4

Linear transformation, Linear transformations and Linearly Independent Sets, Matrix representation of linear transformations, Transition matrix and similar matrices, Rank of a linear Transformation and Rank of a matrix.

Unit-5

Determinants, Multilinear Transformations, Determinant of a Family of Vectors, of a Matrix, and of a Linear Transformation.

Unit-6

Eigenvalues and eigenvectors, Characteristic polynomial, Cayley-Hamilton Theorem, Diagonalizable Matrices and Linear Transformations .

Text Book(s):

1. Stephen H. F., Arnold J. I. and Lawrence E. S., Linear Algebra, 4th edition, Prentice Hall, 2003
2. Hoffman, K. and Kunze, R., Linear Algebra, Prentice Hall, 1984.

Reference book(s)

1. Halmos, P. R., Finite dimensional vector spaces, Springer Verlag, New York, 1987.
2. Poole, David, Linear Algebra: A modern introduction, 3rd edition, Brroks/Cole Cengage learning, 2011.

MI 221: Introductory Statistics & Probability (L2-T1 -P0 -CH3 -CR 3)

Unit-1

Definitions of Statistics, population, sample, data and characteristics of data. Measures of central tendency, dispersion. Histogram, frequency curve and boxplot.

Unit-2

Skewness and its measures. Normal and student's-t curves. Kurtosis and its measures. Effects of change of origin and scale. Definition of Probability and some properties of the probability function.

Unit-3

Random variable, Probability distribution and distribution function. Discrete and continuous distribution. Some important discrete and continuous distributions.

Unit-4

Random sampling and sampling fluctuation, Simple random sampling, variance of sample mean under SRS WOR, Estimation of population size (capture-release- capture method), Correlation and simple linear regression. Rank correlation.

Textbook(s)

1. Medhi, J. *Statistical Methods: An introductory Text*, (New Age International (P) Ltd, 2000).
2. Gupta, S.C. and Kapoor, V. K. *Fundamentals of Mathematical Statistics*, (S. Chand & Co., 2007).
3. Cochran, W.G., Sampling Techniques, third edition (John Wiley & Sons, 1977).

Reference book(s)

1. Feller, W. *An Introduction to Probability Theory and Its Applications*, Vol. I, (Wiley, 2005).
2. Uspensky, J.V. *Introduction to Mathematical Probability*, (McGraw Hill, 2005).

MI 222: Co-ordinate Geometry (L3-T1 -P0 –CH4 -CR 4)

Unit-1

Transformation of co-ordinate axes. Pair of straight lines. General equation of second degree and the conditions for representing a pair of straight lines, a parabola, an ellipse, a hyperbola and a circle.

Unit-2

Reduction to standard forms: The centre of a conic, Reduction of the equation of a central conic, Equation of the axes and length of the axes, Reduction of the equation of a non-central conic.

The equation of tangent, Condition of tangency of line, Equation of normal, Pair of tangents and director circle, Chord of contact, Pole and polar, Chord in terms of middle points, Diameter and conjugate diameters, Asymptotes.

Unit-3

Polar equation of a conic, tangent and normal, properties. Circle and its parametric form, Orthogonal circle, condition of orthogonality of circles.

Unit-4

Change of axes: shift of origin, rotation of axes. Sphere, Cone and Cylinder.

Unit-5

Central Conicoids: Ellipsoid, Hyperboloid of one and two sheets. Intersection of a conicoid and a line: Tangent line, tangent plane, condition of tangency, Director sphere. Normal: Equation of the normal, number of normals from a given point, cubic curve through the feet of the normal, cone through six normal. Polar plane and polar lines, Enveloping cone, Enveloping cylinder, Diameters and diametral planes, conjugate diameters and diametral planes.

Unit-6

The paraboloid. Reduction of second degree equations.

Text book(s)

1. Jain, P.K. and Ahmad, K. *Text Book of Analytical Geometry of two & three Dimensions*, New Age Publications, 2014.
2. Das, B., *Analytical Geometry and Vector Analysis*, (Orient Book Company, 1995).

Reference book(s)

1. Khan, R.M., *Analytical Geometry & Vector Analysis*, (New Central Book Agency Pvt. Ltd., 2004).
2. Askwith, E. H., *A Course of Pure Geometry*, Michigan Historical Reprint Series (University of Michigan Library, 2005).
3. Askwith, E. H. and Askwith, E., *A Course of Pure Geometry* (Hard Press, 2007).
4. Spain, B. *Analytical Conics* (Dover, 2007).
5. McCrea, W. H. *Analytical Geometry of Three Dimensions* (Dover, 2006).

MI 223: Calculus I (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Indeterminate forms, L'Hospital's Rule, Successive differentiation.

Unit-2

Convexity and point of inflexion; Tangent and Normal; Curvature of plane curves; Asymptotes; Envelopes; Singular points.

Unit-3

Curve tracing: tracing of catenary, cissoids, asteroid, cycloid, folium of Descartes, cardioid, lemniscate.

Unit-4

Functions of two variables: Limit, Continuity, Partial derivatives, Directional derivatives, Euler's theorem on homogeneous functions, Total Derivative and total differentials, Chain rule, Directional derivatives, Gradient vectors and equations of Tangent planes.

Unit-5

Partial derivatives of higher order, Taylor's theorem, Criteria for Maxima/ Minima/ Saddle points, Lagrange's method of multipliers.

Unit-6

The relation between integration and differentiation: the derivative of an indefinite integral, the first fundamental theorem of calculus, primitive functions and the second fundamental theorem of calculus, the Leibniz notation for primitives, integration by substitution, integration by parts

Textbook(s)

1. Thomas and Finney, *Calculus and Analytic Geometry*, (Pearson Education, Eleventh (Indian) Edition), 1998.
2. Bartle, R. G. and Sherbert, D. R. *Introduction to Real Analysis*, (John Wiley and Sons, Third (Indian) Edition), 2007.

Reference book(s)

1. Apostol, T. M. *Calculus*, Vol I & II, (John Wiley and Sons, Second (Indian) Edition), 2007.
2. G. A. Osborne, Differential and Integral Calculus with examples and applications, Forgotten Books' Classic Reprint Series, 2011.
3. B. C. Das and B. N. Mukherjee, Differential Calculus, U N Dhur & Sons Private Ltd, (19^{th} Editions) 1957
4. R. Cournat, Differntial and Integral Calculus, John Wiley & Sons, 1970.

MI 224: Numerical Methods and Boolean Algebra (L3-T1 -P0 –CH4 -CR 4)

Unit -1

Finite Difference operators and their operations on functions of a single variable. Existence and uniqueness of interpolating polynomial, Lagrange interpolation, Newton divided

difference, forward and backward interpolation, central difference interpolation and associated error terms. Extrapolation and inverse interpolation. Properties of divided differences.

Unit -2

Roots of algebraic and transcendental equations: Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method, their geometrical interpretation and derivation.

Unit -3

Numerical differentiation, Richardson's extrapolation.

Numerical integration: Newton –Cotes quadrature formula, Trapezoidal rule, Simpson's 1/3rd and 3/8th rule of integration. Use, interpretation and derivation. Composite Trapezoidal and Simpson's rules. Double integration.

Unit -4

Solution of system of linear algebraic equations: Direct methods- Gauss elimination, pivoting and Gauss-Jordan methods. LU-factorization.

Unit-5

Boolean ring and Boolean algebra, principle of duality, fields of sets, elementary relations.

Textbook(s)

1. Atkinson, K.E., An introduction to Numerical Analysis, 2nd edition (John Wiley and Sons. 2004).
2. Burden, R.L., and Faires, J.D., Numerical analysis theory and applications (Cengage Learning, 2005).
3. Jain, R.K., and Iyenger, S.R.K., Advanced Engineering *Mathematics* (CRC Press, 2002).
4. Givant, S., Halmos, P., Introduction to Boolean algebras, (Springer, 2009).

Reference book(s)

1. 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).
2. Sastry, S.S. *Introductory methods of Numerical Analysis* (Prentice Hall of India, New Delhi, 1997).

MI 225: Combinatorics (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Basic counting rules, Permutations: Allocation Problem, Circular and Ring Permutations, Generalized Permutations, Combinations: Allocation Problem, Pascal's formula, Generalized combinations, The Multinomial Theorem, Properties of Binomial Coefficients.

Unit-2

Partitioning of a set, The pigeonhole Principle: simple form, strong form, The inclusion-Exclusion principle, Calculating in two ways: Fubini's Principle, Derangements.

Unit-3

Generating Functions: Ordinary generating Functions, Exponential generating Function.

Unit-4

Recurrence Relations: Homogeneous Recurrence Relations, Inhomogeneous Recurrence Relation.

Text Book(s)

1. V. K. Balakrishnan, Introductory Discrete Mathematics, Dover Publications, New York, 1996.
2. Richard A. Brualdi, Introductory Combinatorics, 5th Edition, Pearson, 2010.

Reference Book(s):

1. K. H. Rosen, Discrete Mathematics & its Applications, 6th Edition., Tata McGraw-Hill, 2007.
2. S. Lipschutz, M. Lipson, Theory and Problems of Discrete Mathematics, 3rd Edition, Schaum's Outline Series, McGraw-Hill.

MI 226: Introductory Topology (L3-T1 -P0 –CH4 -CR 4)

Unit-1

Definition and examples of metric spaces, Neighborhoods, Limit points, Interior and boundary points, Open and closed sets, Closure and interior of a set, Equivalent metrics.

Unit-2

Subspaces, Cauchy sequences, Completeness, Cantor's intersection theorem, Baire's category theorem.

Unit-3

Continuous functions, Uniform continuity, Isometry.

Unit-4

Topological spaces, examples, basis and sub-basis, subspaces, closure, interior, exterior and boundary.

Unit-5

Continuity, open functions, homeomorphisms, embeddings, strong and weak topologies.

Textbooks:

1. O'Searcoid, M., *Metric Spaces*, Springer, 2006.
2. Shirali, S. and Vasudeva, H. L., *Metric Spaces*, Springer, 2007.
3. Munkres, J. R. *Topology : A first course* (2/e), Pearson Education, 2000

Reference Books:

1. Kumersan, S., *Topology of Metric Spaces*, Narosa, 2011.
2. Simmons, G. F., *Topology and Modern Analysis*, McGraw Hill Education, 2017.

MI 311: Calculus II (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Reduction formulae for integration. Improper Integral, Beta and Gamma functions.

Unit -2

Line integral, Double integral, triple integral, Jacobian, Surface integral and their applications. Volume, Area, length, volume and surface area of solids of revolution.

Unit-3

Vector Calculus, vector point function, continuity and differentiation of vector point function, partial derivative of vectors, Curl, Gradient, Divergence. Vector Integration.

Unit-4

Green, Gauss and Stokes Theorems and their applications

Textbook(s)

1. Apostol, T. M. *Calculus*, Vol I & II, (John Wiley and Sons, Second (Indian) Edition), 2007.

References:

1. Spiegel, M. R. *Vector Analysis, Schaum's outline series, (*Publishing House India), 2009.
2. Thomas and Finney, Calculus and Analytic Geometry, (Pearson Education, Eleventh (Indian) Edition), 1998.

3. B. C. Das and B. N. Mukherjee, Integral Calculus, U N Dhur & Sons Private Ltd, (19th Editions) 1977.
4. R. Cournat, Differntial and Integral Calculus, John Wiley & Sons, 1970.
5. G. A. Osborne, Differential and Integral Calculus with examples and applications, Forgotten Books' Classic Reprint Series, 2011.

MI 312: Ring Theory (L2 -T1 -P0 –CH3 -CR 3)

Unit-1

Ring, properties of rings, subring, ideal and quotient ring.

Unit-2

Integral domain, division ring, field, characteristic of ring.

Unit-3

Ideal generated by a set, principal ideals, prime ideals, maximal ideals.

Unit-4

Homomorphism, isomorphism and isomorphism theorems.

Unit-5

Polynomial rings, Division algorithm and consequences, factorization of polynomials, reducibility and irreducibility tests.

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. Musili, C. *Introduction to rings and modules*, 2nd revised edition, Narosa, 2010.

Reference book(s)

1. Fraleigh, J. B. *A First Course in Abstract Algebra*, 7th edition (Pearson Education India, New Delhi, 2008).
2. Herstein, I. N., *Topics in Algebra, 2nd* edition (John Wiley & Sons, Indian reprint, New Delhi, 2006).

MI313: Programming, Algorithm and Mathematical Software

(L2–T0–P2–CH6–CR4)

Unit-1

Algorithms and flowcharts. Divide and conquer strategy.

Unit-2

Fundamentals of C: Data types in C, variables in C, input output statements, constant declaration, arithmetic operators in C, arithmetic expressions, assignment statements, arithmetic assignment operators, increment and decrement operators, type conversions, operator precedence.

Unit-3

Basic techniques: sum of numbers, swapping contents of variables, computing area, simple interest etc. Decision making: if statement, if…else statement, the break statement, the continue statement, the go-to statement.

Unit-4

Looping techniques: for loop, while loop, do…while loop.

Unit-5

Basic operations through Matlab, Input through keyboard and its illustration, Flow Control statements.

Unit -6
Iterative Method for Solving Non-linear Equation, Numerical Integration, Numerical Solution of 1st order IVP.
Unit -7
Numerical Differentiation and BVP.
Unit -8
Introduction to Mathematica, Symbolic Computation.

Textbook(s)

1. Rajaraman, V., Fundamentals of Computers, (PHI, 2002).
2. Venkateshmurthy, M.G., Programming Techniques through C-A Beginner's Companion, (Pearson Education, 2002).
3. Pratap, R. *Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers* (Oxford University Press, USA , 2005)
4. Otto, S.R. & Denier, J. P. *An Introduction to Programming and Numerical Methods in MATLAB* (Springer, 2009).
5. Torrence, Bruce F. & . Torrence, Eve A. *The student's introduction to Mathematica*, 2nd edition (Cambridge University Press, 2009).

Reference book(s)

1. Hunt, B. R., Lipsman, R. L., Osborn, John E. & Rosenberg, J. *Differential Equations with Matlab*, (Wiley, 2005).
2. Wolfram, S. *The Mathematica Book* (Wolfram Media, 2008).
3. Gray, T. W. & Glynn, G. *The Beginners Guide to Mathematica*, Version 4, Addision-(Wesley, 2008).

MI 314: Elementary Number Theory (L3 -T1 -P0 -CH4 -CR 4)
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).
4. Hsiung, Y. Elementary Theory of Numbers (World Scientific, 1992; First Indian Reprint, Allied Publishers Limited, 1995).

MI 315: Statics and Dynamics (L3-T1-P0-CH4-CR4)

Unit-1

Centre of Mass, Radius of gyration, Centre of gravity of a plane area, arc and sector of acurve. Centre of gravity of solids and surface of revolution.

Unit-2

Friction, laws of friction, limiting friction, equilibrium of a particle in rough inclined plane.

Unit-3

Buoyancy, Hydrostatic equilibrium, Archimedes' Principle, Capillary rise, Surface Tension.

Unit-4

Principle of virtual work in two dimensions, Neutral, Stable and Unstable equilibrium.

Unit-5

Velocities and acceleration, Newton's laws of motion, velocity and acceleration in curvilinear coordinates, tangential and normal components of velocity, acceleration, momentum, force etc.

Unit-6

One dimensional motion in resisting medium; motion of particles of variable mass, Rocket motion. Two dimensional motion, motion of a projectile.

Unit-7

Central force reduced mass, angular momentum; motion under central force, inverse square law of motion, polar equation of orbit, Keplar's laws of motion.

Unit-8

Periodic motion; Simple harmonic motion, Differential equation of simple harmonic motion and solution, Kinetic and Potential energies of Simple harmonic motion, Compound pendulum.

Unit-9

Kinematics of rigid bodies, Euler's theorem, moments and products of inertia. Parallel axes theorem, theorem of six constants. Principal axes.

Textbook(s)

1. Whittaker, E.T. and McCrea, W. A Treatise on the Analytical Dynamics of Particles and Rigid Bodies: with an Introduction to the Problem of Three Bodies (Cambridge University Press, 1988).
2. Loney, S. L., Elements of Statics & Dynamics, Part I (Maxford Books, 2003).
3. Rao, S. Engineering Mechanics - Statics and Dynamics (Pearson Education, 2008).

Reference book(s)

1. Spiegel, M. R., Schaum's Outline of Theory and Problems of Theoretical Mechanics: with an Introduction to Lagrange's Equations and Hamiltonian Theory (McGraw-Hill, 2007).
2. Ramsey, A. T., Dynamics, 2nd Edition (The University Press, 2007).
3. Chorlton, F. Textbook of Dynamics, 2nd edition (Horwood, 1983).
4. Loney, S. L., An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies, (AITBS Publishers, 2016).

MI 316: Introduction to Optimization (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

General linear programming problems, Standard form of L.P.P., Graphical method for L.P.P.

Unit-2

Geometry of linear programming: Polyhedra and Convex sets, Extreme point, vertices and basic solutions, basic feasible solutions,, Convex function, Convex hull of a set, Convex polyhedrons, Existence of extreme points, optimality of extreme points.

Unit-3

Supporting hyperplanes and extreme points, Development of Simplex method, Applications of Simplex Technique, Column geometry and the simplex method, Solution of Simultaneous Equations, Inverse of a Matrix By Simplex Method, Problem of Degeneracy.

Unit-4

The dual Problem, duality theorem, comparison of solutions of primal and its dual. Standard form problems and the dual simplex method along with its limitations, Farkas' lemma and linear inequalities, Separating hyperplane and duality General linear programming duality.

Unit-5

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

Text Book(s):

1. Hadley, G., Linear Programming, (Narosa Publishing House, New Delhi, 1987).
2. Kanti Swaroop, P.K. Jain and Man Mohan, Operation Research: An Introduction, (S. Chand & Company, New Delhi, 1996).

Reference Books:

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).

MI 317: Elementary Complex Analysis (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Complex numbers as ordered pairs, Geometric representation of complex numbers, Riemann sphere and Stereographic Projection.

Unit-2

Continuity and differentiability of complex functions, Analytic functions, Cauchy-Riemann equations, harmonic functions.

Unit-3

Elementary analytic functions (exponential function, trigonometric functions and logarithm function) and their mapping properties.

Unit-4

Complex integration, Cauchy-Goursat theorem, Cauchy's integral formula.

Unit-5

Cauchy's Integral formula for derivatives, Cauchy's inequality and Liouville's theorem, the fundamental theorem of algebra, Maximum-modulus theorem, Morera's theorem.

Textbook(s)

1. Churchill R. V. and Brown, J. W. *Complex variables and applications*, McGraw-Hill International edition, 2006.
2. Mathews, J. H. and Howell, R. W., *Complex Analysis for Mathematics and Engineering*, 3rd Edition, Narosa, 1998.
3. Ponnusamy, Foundations of Complex Analysis. 2nd Edition , Narosa Book Distributors Pvt Ltd , 2008.

Reference Book(s)

1. Saff, E. B. and Snider, A. D., *Fundamentals of Complex Analysis with applications to Engineering and Science*, 3rd Edition, Pearson, 2003 (ISBN 978-81-317-2019-6)

MI 318: Elementary Integral Transforms and Special Functions

(L3 -T1 -P0 –CH4 -CR 4)

Unit -1

Bessel function and recurrence relations, Orthogonal sets of Bessel functions, Modified Bessel functions, Applications.

Unit -2

Orthogonal polynomials: Legendre polynomials, Associated Legendre polynomials, Hermite polynomials, Laguerre polynomials, Chebyshev polynomial.

Unit-3

The Hypergeometric functions and confluent hypergeometric functions.

Unit-4

Fourier Series, Generalized Fourier series, Fourier Cosine series, Fourier Sine series, Fourier integrals.

Unit-5

Definition of Fourier Transform and Examples, Basic Properties of Fourier Transforms. Fourier sine Transform, Fourier cosine Transform. Linearity, Change of scale property, Shifting property, modulation theorem. Convolution Theorem for Fourier transform, Parseval's Identity. Finite Fourier Sine Transform, Finite Fourier Cosine Transform, Inversion formula for sine and cosine Transforms only statement and related problems.

Unit-6

Mellin transform, Hankel transform, Z-transform

Text Book:

1. Whittaker E.T., Watson G.N., A course of Modern Analysis, Cambridge Mathematical Society.
2. Andrews L.C., Shivamoggi B.K., Integral Transform for Engineers, PHI.
3. Debnath L., Bhatta, D., Integral transforms and their applications, 3rd edition, (CRC Press, 2015).

MI319: Graph Theory **(L3 -T1 -P0 –CH4 -CR 4)**

Unit-1

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

Unit-2

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

Unit-3

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

Unit-4

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

Unit-5

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

Unit-6

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

Unit-7

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

Textbook(s):

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

Reference Book(s):

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

MI 320: Elementary Coding and Information Theory (L3-T1-P0-CH4-CR4)

Unit-1

Coding and Decoding: Coding, Unique Decoding, Block Codes and Instantaneous Codes, Some Important Block Codes, Construction of Instantaneous Codes, Kraft's Inequality, McMillan's Theorem.

Unit-2

Huffman Codes : Information Source, Huffman Codes, Construction of Binary Huffman Codes, Construction of General Huffman Codes.

Unit-3

Data Compression and Entropy: An Example of Data Compression, The Idea of Entropy, The Definition of Entropy. Maximum and Minimum Entropy, Extensions of a Source, Entropy and Average Length, Shannon's Noiseless Coding Theorem.

Unit-4

Reliable Communication Through Unreliable Channels: Binary Symmetric Channels, Information Rate, Hamming Distance, Detection of Errors, Correction of Errors, Channel Capacity, Shannon's Fundamental Theorem.

Unit-5

Error-Correcting Codes: Binary Addition and Multiplication, Codes Described by Equations, Binary Linear Codes, Parity Check Matrix, The Probability of Undetected Errors.

Text Book(s)

1. Jiří Adámek, *Foundations of Coding: Theory and Applications of Error-Correcting Codes with an Introduction to Cryptography and Information Theory*, John Wiley & Sons, INC, 1991.
2. Richard W. Hamming, *Coding and Information Theory (2nd Ed.)*. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 1986.

Reference Book(s):

1. Steven Roman, *Coding and Information Theory*, Springer-Verlag New York, 1992.
2. Raymond Hill, *A First Course in Coding Theory*, Oxford University Press, 1990.

MI 408: Complex Analysis (L3-T1-P0-CH-CR 4)

Unit-1

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

Unit-2

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

Unit-3

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

Unit-4

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

Unit-5

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

Unit-6

Schwarz Reflection Principle, Analytic continuation, Riemann Surfaces.

Textbook(s)

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

Reference book(s)

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

MI 412: Abstract Algebra (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

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

Unit-2
Group action, properties of group action, class equation of finite groups, Sylow's theorems, applications of Sylow's theorems.
Unit-3
Subnornmal, normal series, derived group, solvable groups, composition series, nilpotent groups, Jordan-Holder theorem.
Unit-4
Word, reduced word, free group, rank of a free group, fundamental theorem of free groups, presentation of groups.
Unit-5
Polynomial rings, rings of formal power series, embedding theorems, field of fractions.
Unit-6
Factorization theory in integral domains, PID, UFD and Euclidean domains.
Unit-7
Field extensions, algebraic and transcendental elements, geometrical constructions, splitting field, finite fields, structure of finite fields, normal, separable and inseparable extension of fields.

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

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

MI 413: Real Analysis-III (L3-T1-P0–CH4-CR4)
Unit-1
Sequence of functions, pointwise and uniform convergence, interchange of limits. Functions of bounded variation. Reimann Stieltjes integral. Integration by parts.
Unit-2
Compactness, Sequential compactness, Bolzano-Weierstrass Property, Totally bounded spaces, compactness and completeness, finite intersection property. Continuous functions on compact spaces. Characterization of complete metric spaces. Arzela Ascoli Theorem.
Unit-3
Connectedness, intermediate value theorem, Completeness, Bolzano Weierstrass Theorem, nested set theorem. Fixed point theorem. Completion.
Unit-4
Functions of several variables, directional derivatives, differentiability and total derivative. Jacobians, chain rule, higher order partial derivatives, Taylor's theorem. Inverse function theorem, Implicit function theorem, extremum problem with constraints, Lagrange's method of multiplier.

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

Reference Books:

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

MI 414: Computer Programming^{+} (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

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

Unit-2

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

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

Unit-3

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

Unit-4

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

Unit-5

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

Unit-6

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

Unit-7

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

Textbook(s)

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

Reference book(s)

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

MI 415: Lebesgue Measure and Integration (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

Algebra of sets, Borel sets, Extended real numbers.

Unit-2

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

Unit-3

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

Unit-4

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

Unit-5

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

Unit-6

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

Textbook(s)

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

Reference book(s)

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

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

Unit-1

Definition and sources of errors, Propagation of errors, Error analysis, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors.

Unit-2

Solution of system of linear algebraic equations: Iterative methods- Jacobi, Gauss-Seidel, Successive over-relaxation (SOR), symmetric SOR (SSOR). Numerical solution of non-linear simultaneous equations, Newton's method, General iteration method.

Unit-3

Review of interpolation, Hermite interpolation. Spline interpolation, B-splines. Special emphasis on cubic spline.

Unit-4

Approximation of function: The Weierstrass and Taylor theorem, Minimax and least square approximations, Orthogonal polynomials.

Unit-5

Numerical solution of algebraic and transcendental equations: Methods based on first and second degree equations, rate of convergence. Theory of one point iterative methods and its convergence analysis, multipoint iterative methods. Numerical evaluation of multiple roots.

Unit-6

Overview of Nwton-Cotes method. Composite integration. Gaussian quadrature, one point, two point and three point formulae. Orthogonal polynomials, Gauss-Legendre, Gauss-Hermite and Gauss-Laguerre quadrature formulae. Romberg integration**.**

Unit-7

Solution of ordinary differential equations. Picard method, Euler method, backward Euler method, modified Euler method, Runge-Kutta class of methods.

Unit-8

Solving problems with C codes.

Textbook(s)

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

Reference book(s)

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

MI 417: Linear Algebra-II (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

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

Unit-2

Primary Decomposition theorem; rational and Jordan forms.

Unit-3

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

Unit-4

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

Unit- 6

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

Text Book(s) :

1. Stephen H. F., Arnold J. I. and Lawrence E. S., Linear Algebra, 4th edition, Prentice Hall, 2003.
2. Halmos, P. R., Finite dimensional vector spaces, Springer Verlag, New York, 1987.
3. Hoffman, K. and Kunze, R., Linear Algebra, Prentice Hall, 1984.

Reference Book(s) :

1. Halmos, P. R., Linear Algebra Problem Book, The Mathematical Association of America (MAA), USA, 1995.
2. Williams, G., Linear Algebra with Applications, Jones and Burlet Publishers, 2001.

MI 418: Theory of Ordinary Differential Equations (L3 -T1 -P0 -CH4 -CR 4)

Unit -1

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

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

Unit -2

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

Unit -3

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

Unit -4

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

Unit -5

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

Unit -6

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

Unit -7

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

Textbook(s)

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

Reference book(s)

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

MI 419: Topology (L3 -T1 -P0 –CH4 -CR 4)

Unit-1

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

Unit-2

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

Unit-3

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

Unit-4

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

Unit-5

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

Unit-6
Connectedness, Local connectedness, Path connectedness, Components, Products of connected spaces.

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

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

MI 421 Computer Laboratory (L0-T0-P1 –CH2 -CR 1)

Practical unit for the course MI 414 Computer Programming

MI 424: Computer Laboratory (L0 -T0 –P1–CH2 -CR 1)
Practical unit for the course MI 416 Numerical Analysis.

MI 507: Partial Differential Equations (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Linear and nonlinear partial differential equation of the first order. Cauchy's method of characteristics, Compatible systems of first order equations, Charpit's and Jacobi's method.
Unit-2
Linear PDE with constant coefficients, reducible and irreducible equations. Different methods of solution.
Unit-3
Second order PDE with variable coefficients. Characteristic curves of second order PDE. Reduction to canonical forms. Solutions of PDE of second order by the method of separation of variables.
Unit-4
Fourier transform, Laplace transform. Solution of partial differential equation by Laplace and Fourier transform methods.
Unit-5
Solutions of PDE of second order by the use Riemann's method. Adjoint operators. Solutions of PDE of second order by the method of integral transforms.
Unit-6
Elliptic differential equations. Occurrence and detailed study of the Laplace and the Poisson equation. Maximum principle and applications, Green's functions and properties.
Unit-7
Parabolic differential equations. Occurrence and detailed study of the heat equation. Maximum principle. Existence and Uniqueness of solutions of IVPs for heat conduction equation. Green's function for heat equation.
Unit-8
Hyperbolic differential equations. Occurrence and detailed study of the wave equation. Solution of three dimensional wave equation. Method of decent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions.

Text Book(s):

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

Reference Book(s):

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

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

Unit-1

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

Unit-2

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

Unit-3

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

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

Unit-4

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

Textbook(s)

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

Reference book(s)

1. Gupta, A, S. *Calculus of Variations with Applications* (Prentice Hall of India, New Delhi 2003).
2. Mikhlin, S. G. *Integral equations* (The MacMillan Company, New york, 1964).

MI 509: 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).

MI 510: Functional Analysis (L3 -T1 -P0 -CH4 -CR 4)
Unit-1
Recap pre-requisite topics: Sets and relations, Linear spaces and linear maps, Metric spaces and continuous functions.
Unit-2
Introduce normed linear spaces with examples. Properties of nls, Riesz lemma, particular study of finite dimensional normed linear spaces, Discuss the interplay between linear structure and metric structure.
Unit-3
Define stronger, weaker and equivalent norms. Continuity and boundedness of linear maps, introduce complete normed linear spaces with examples. Function spaces and operator norm, bounded linear functional. Definition of Schauder basis. Dual spaces.
Unit-4
Hahn Banach separation and extension theorems. Applications of HBT.

Unit-5

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

Unit-6

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

Unit-7

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

Unit-8

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

Textbook(s)

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

Reference book(s)

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).
4. Siddiqi, A. H., Ahmad K and Manchanda P., *Introduction to Functional Analysis with Applications*, Real World Education Publishers, New Delhi, 2014.

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

Unit -1

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

Unit -2

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

Unit -3

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

Unit -4

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

Textbook(s)

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

Reference book(s)

1. John, F. , *Partial Differential Equations,* 3rd ed., (Narosa Publ. Co., New Delhi, 1979).

2. Gilbarg, D. and Trudinger, N. , Elliptic *Partial Differential Equations of Second Order* (Springer-Verlag Berlin Heidelberg 2001).

3. Jost, J. , *Partial Differential Equations* (Springer-Verlag New York, 2002).

4. Renardy, M. and Rogers, R.C. , *An Introduction to Partial Differential Equations*, 2nd ed., (Springer Verlag International Edition, New York, 2004).

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

Unit-1

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

Unit-2

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

Unit-3

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

Unit-4

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

Unit-5

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

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

Textbook(s)

1. Watkins, D. S. *Fundamental of Matrix Computations*, 2nd edition (Wiley-Interscience, 2002).

2. Smith, G. D. Numerical *Solution of Partial Differential Equations: Finite Difference Methods*, 3rd edition (Oxford University Press, 1986).

3. Reddy, J. N. *An Introduction to the Finite Element Method*, 3rd Edition (McGraw Hill India, 2006).

Reference book(s)

1. Trefethen, L. N and Bau, David *Numerical Linear Algebra* (SIAM, 1997).

2. Hoffman, Joe D. *Numerical Methods for Engineers and Scientist*, 2nd edition (Mc-Graw Hill 2004).

3. Ciarlet, P. G. *The Finite Element Method for Elliptic Problems* (North Holland, 1978).

4. Johnson, C.*Numerical Solution of Partial Differential Equations by the Finite Element Method* (Cambridge University Press, 1987).

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

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

Unit-1

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

Unit-2

Localization of commutative rings and their basic properties.

Unit-3

Noetherian and Artinian rings, examples.

Unit-4

Integral extensions, Dedekind domains.

Unit-5

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

Unit-6

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

Unit-7

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

Unit-8

Modules over Principal Ideal Domain.

Textbook(s)

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

Reference book(s)

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

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

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

Unit - 1

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

Unit – 2

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

Unit - 3

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

Unit - 4

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

Text Book(s):

1. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.
2. Torleiv Klove, Codes for error Dectection, Series on Coding Theory and Cryptology, vol. 2, World Scientific Publishing Co. Pte. Ltd., 2007

Reference Book(s):

1. Raymond Hill, A First Course in Coding Theory, Oxford University Press, 1990.
2. J.H. Van Lint, Introduction to Coding theory, Graduate Texts in Mathematics, 86, Springer, 1998.
3. A. Neubauer, J. Freudenberger, V. Kuhn, Coding Theory: Algorithms, Architectures and Applications, John Wiley & Sons Ltd, England, 2007.
4. L.R. Vermani, Elements of Algebraic Coding, Chapman and Hall, 1996.
5. W. C. Huffman and V. Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.
6. Shu Lin and Daniel J. Costello, Error Control Coding-Fundamentals and Applications, Pearson Education India, 2011.

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

(Prerequisite Coding Theory I)

Unit – 1
Zero of polynomials, Algebraic extension of a field, Galios field, Primitive elements, Minimum polynomials, order, Multiplcative group of a Galios fields, structure of finite fields.
Unit – 2
Error detection with cyclic codes, Error-correction procedure for cyclic codes, Shortended cyclic codes, Pseudo cyclic codes. Code symmetry, Invariance of codes under transitive group of permutations.
Unit - 3
BCH codes, Minimum distance and BCH Bounds, Decoding of BCH codes, Reed-Solomon codes.
Unit - 4
Tree codes, Convolutional codes, Description of linear tree and convolutional codes by matrices, distance for convolutional codes, Maximum likelihood decoding of Convolutional codes, Vitorbi decoding algorithm.

Text Book(s):

1. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.
2. Shu Lin and Daniel J. Costello, Error Control Coding-Fundamentals and Applications, Pearson Education India, 2011.

Reference Book(s):

1. Man Young Rhee, Error Correcting Coding Theory, McGraw-Hill Publishing, 1989.
2. Robert H. Morelos-Zaragoza, The art of Error Correcting Codes, 2nd Edition, John Wiley & Sons Ltd, England, 2006.
3. A. Neubauer, J. Freudenberger, V. Kuhn, Coding Theory: Algorithms, Architectures and Applications, John Wiley & Sons Ltd, England, 2007.
4. L.R. Vermani, Elements of Algebraic Coding, Chapman and Hall, 1996.
5. Jiri Adamek, Foundations of Coding: Theory and Applications of Error-Correcting Codes with an Introduction to Cryptography and Information Theory, John Wiley & Sons, USA, 1991.
6. W. C. Huffman and V. Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.

MI 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).

MI 573 Analytic Number Theory (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Arithmetical functions and Dirichlet multiplication, averages of arithmetical functions.

Unit-2

Elementary theorems on the distribution of primes, the prime number theorem, Chebyshev's functions and their relations.

Unit-3

Dirichlet's theorem for primes of the form *4n-1* and *4n+1*, distribution of primes in arithmetic progressions.

Unit-4

Quadratic residues and quadratic reciprocity law, applications of the reciprocity law, Gauss sums.

Unit-5

Dirichlet series, Euler products, Riemann zeta function and Dirichlet *L*-functions.

Unit-6

Introduction to partitions, geometric representation, generating functions, Euler's Pentagonal number theorem, Jacobi triple product identity, recursion formula for *p(n).*

Unit-7

Partition identities of Ramanujan.

Textbook(s)

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

Reference book(s)

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

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

Unit-1

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

Unit-2

Splitting fields.

Unit-3

Automorphisms of extensions, the fundamental theorem of Galois theory.

Unit-4

Finite fields.

Unit-5

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

Unit-6

Solution of polynomial equations by radicals, Kummer theory.

Textbook(s)

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

Reference book(s)

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

MI 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).

MI 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).

MI 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).

MI 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.)

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

MI 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).

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

Unit-1

Measurable space, Measure and its properties, finite and sigma-finite measures, Axiomatic definition of Probability, Measurable functions , definition of Random Variable.

Unit-2

Measure induced by a measurable function, definition of Probability distribution and distribution function, properties of distribution function and classification of distributions.

Unit-3

Some basic theorems Integration theory(integration of measurable functions w. r. t. an arbitrary measure): Fatou's lemma , Monotone Convergence theorem, Dominated convergence Theorem. Definition of Mathematical Expectation of a random variable and its properties. Moments and moment inequalities.

Unit-4

Convergence of a sequence of random variables (Weak convergence or convergence in probability, almost sure convergence and convergence in Law). Borel-Cantelli-lemma, Weak and Strong law of large numbers, Central limit theorem.

Textbook(s)

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

Reference book(s)

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