Punjab Technical University
Kapurthala

Scheme and Syllabus
of
M.Sc. Mathematics

Batch 2012 onwards

By
Board of Studies (Mathematics)

M. Sc. Mathematics is a post graduate level course of the Department of Mathematics which is a 2 years course. It is consisting of semester system (4 semesters) with two semesters per year.

Programme Code: MMS *(Masters in Mathematical Sciences)*

Eligibility: B.A/B.Sc. with Honours in Mathematics or B.A./B.Sc. (pass course) with Mathematics as one of thesubjects having at least 50% marks in aggregate and at least 55% marks in Mathematics subject.

First Semester **Contact Hours: 26 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MMS-101	Algebra-I	4	1	0	50	100	150	5
MMS-102	Real Analysis-I	4	1	0	50	100	150	5
MMS-103	Complex Analysis	4	1	0	50	100	150	5
MMS-104	Ordinary Differential Equations & Special functions	4	1	0	50	100	150	5
MMS-105	Fundamentals of Computer and C Programming	4	0	0	50	100	150	4
MMS-106	Fundamentals of Computer and C Programming Lab	0	0	2	50	-	50	1
	Total	**20**	**04**	**02**	**300**	**500**	**800**	**25**

Second Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MMS-201	Algebra-II	4	1	0	50	100	150	5
MMS-202	Real Analysis-II	4	1	0	50	100	150	5
MMS-203	Mechanics	4	1	0	50	100	150	5
MMS-204	Tensors and Differential Geometry	4	1	0	50	100	150	5
MMS-205	Numerical Analysis	4	1	0	50	100	150	5
MMs-206	Numerical Analysis Lab	0	0	2	50	-	50	1
	Total	**20**	**05**	**02**	**300**	**600**	**800**	**26**

Third Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MMS-301	Topology	4	1	0	50	100	150	5
MMS-302	Operations Research	4	1	0	50	100	150	5
MMS-303	Mathematical Statistics	4	1	0	50	100	150	5
MMS-304	Functional Analysis	4	1	0	50	100	150	5
MMS-XXX	Elective –I	4	0	0	50	100	150	4
MMS-305	Seminar	0	0	2	50	-	50	1
	Total	**20**	**05**	**02**	**300**	**500**	**800**	**25**

Fourth Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MMS-401	Discrete Mathematics	4	1	0	50	100	150	5
MMS-402	Mathematical Methods	4	1	0	50	100	150	5
MMS-403	Partial differential equations	4	1	0	50	100	150	5
MMS-YYY	Elective –II	4	1	0	50	100	150	5
MMS-ZZZ	Elective –III	4	0	0	50	100	150	4
MMS-404	Seminar	0	0	2	50	-	50	1
	Total	**20**	**05**	**02**	**300**	**500**	**800**	**25**

Elective –I MMS XXX (Any one subject to be opted)

MMS-501 Fluid Mechanics
MMS-502 Solid Mechanics
MMS-503 Coding Theory
MMS-504 Advanced Complex Analysis

Note1: Student is to adopt one course from the list of Elective II and one course from list of Elective III

Elective – II Courses: MMS 505, MMS 506, MMS 510, MMS 512

Elective – III Courses: MMS 507, MMS 508, MMS 509, MMS 511

MMS-505 Advanced Operations Research
MMS-506 Advanced Fluid Mechanics
MMS-507 Advanced Solid Mechanics
MMS-508 Number Theory and Cryptography
MMS-509 Theory of Linear Operators
MMS-510 Advanced Numerical Methods
MMS-511 Topological Vector Spaces
MMS-512 Fractional Calculus

Note 2:

Instructions for paper setters and candidates:

(a) Eight questions are to be set preferably two questions from the each unit.

(b) The students are required to attempt any five questions. All questions carry equal marks.

(c) Duration of examination is three hours.

MMS-101: ALGEBRA-I

L	T	P
4	1	0

Unit-I

Review of basic concept of groups, automorphisms and inner automorphisms of a group, Normalizer and Centralizer, Conjugate elements and conjugacy classes, class equation of a finite group and its applications, Cauchy's theorem, Sylow's theorems, Review of Permutation Groups, Alternating Group A_n, simplicity of A_n, Direct Products, fundamental theorem of finitely generated abelian groups, Invariants of finite abelian groups.

Unit-II

Normal and sub normal series, Composition series, Zassenhaus's Lemma, Scherer's refinement theorem and Jordan-Holder theorem, Derived group, Solvable groups, Nilpotent groups, fundamental theorem of arithmetic.

Unit-III

Rings, Subrings, ideals, Sum and direct sum of ideals, Maximal, Prime, Nilpotent & Nil ideals, Statement of Zorn's Lemma, Rings of Fractions, Field of quotients of an integral domain.

Unit-IV

Factorization Theory in Integral Domains, Divisibility, Rings of Gaussian integers, Unique Factorization Domain (UFD), Principal Ideal Domain (PID), Euclidian Domain(ED) and their relationships, Polynomial rings over unique factorization domains.

BOOKS RECOMMENDED

1. Bhattacharya, P.B., Jain, S.K. &Nagpal, S.R.: Basic Abstract Algebra, Cambridge University Press, 1997.

2. Surjeet Singh, QuzaiZameeruddin: Modern Algebra, Vikas Publishing House , New Delhi,8th edition,2006.

3. I.N. Herstein: Topics in Algebra, 2nd edition, Wiley Eastern, 1975.

MMS-102: REAL ANALYSIS-I

L	T	P
4	1	0

UNIT-I

Elementary set theory, finite, countable and uncountable sets. Metric spaces: definition and examples, open and closed sets, compact sets, elementary properties of compact sets, k- cells, compactness of k cells, compact subsets of Euclidean space R^k. Perfect sets, Cantor set, separated sets, connected sets in a metric space, connected subsets of real line.

UNIT-II

Convergent sequences (in Metric spaces), Cauchy sequences, subsequences, complete metric space, Cantor's intersection theorem, category of a set and Baire's category theorem.Examples of complete metric space, Banach contraction principle.

UNIT-III

Limits of functions (in Metric spaces), continuous functions, continuity and compactness, continuity and connectedness, discontinuities, monotonic functions, uniform continuity.

UNIT-IV

Riemann Stieltje'sIntegral : definition and existence of integral, properties of integral, integration and differentiation, Fundamental theorem of Calculus, $1^{st}$and 2^{nd} mean value theorems for Riemann Stieltje's integral

BOOKS RECOMMENDED

1. Walter Rudin, Principles of Mathematical Analysis, 3^{rd} edition, McGraw Hill, Kogakusha, 1976, International student edition

2. H. L. Royden, Real Analysis, 3^{rd} edition, Macmillan, New York & London 1988.

3. Tom M. Apostol, Mathematical Analysis, Addition –Wesley.

4. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Ltd (2008).

MMS 103: COMPLEX ANALYSIS

L	T	P
4	1	0

Unit-I

Function of complex variable, continuity and differentiability, analytic functions, conjugate function, harmonic function. Cauchy Riemann equation (Cartesian and polar form).Construction of analytic functions.Stereographic projection and the spherical representation of the extended complex plane.

Unit-II

Complex line integral, cauchy's theorem, cauchy's integral formula and it's generalized form. cauchy's inequality, Poisson's integral formula, Morera's theorem, Liouville's theorem, power series, Taylor's theorem, Laurent's theorem. Fundamental theorem of algebra and Rouche's theorem, Maximum modulus principle, Schwarz lemma.

Unit-III

Zero's, Singularities, residue at a pole and at infinity. Cauchy's Residue theorem, Jordan's lemma, integration round unit circle, Evaluation of integrals.

Unit-IV

Conformal transformations, bilinear transformations, critical points, fixed points, Problems on cross-ratio and bilinear transformation.

BOOKS RECOMMENDED

1. Complex Analysis (2nd Edition) – L. V. Ahlfors, McGraw-Hill International Student Edition, 1990.

2. An Introduction to the Theory of functions of a complex Variable – E. T. Copson, Oxford university press, 1995.

3. An Introduction To Complex Analysis – A. R. Shastri, Macmillan India Ltd., 2003.

4. Complex Variables and Applications – S. Ponnusamy, and H. Silverman, Birhkäuser, 2006.

5. Complex Variables and Applications- R Churchill R, Brown J.W: 6^{th}edition , New york, McGraw-Hill 1996.

MMS 104: ORDINARY DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS

L	T	P
4	1	0

UNIT-I

Review of linear differential equations with constant & variable coefficients, Power series solution of differential equation about an ordinary point, Solution about regular singular points: The method of Frobenius, System of linear differential equations, An operator method for linear system with constant coefficients, Phase plane method.

UNIT-II

Homogeneous Linear systems with constant coefficients, Complex eigenvalues, repeated eigenvalues, Fundamental Existence and Uniqueness theorem, existence and Uniqueness theorem for system and Higher order equations, Linear homogeneous boundary value problems: Eigenvalues and eigen functions.

UNIT-III

Bessel equation and Bessel functions, Recurrence relations and orthogonal properties., Series expansion of Bessel Coefficients, Integral expression, Integral involving Bessel functions, Modified Bessel function, Ber and Bei functions, Asymptotic expansion of Bessel Functions , Legendre's differential equations, Legendre Polynomials ,Rodrigue's formula, Recurrence relations and orthogonal properties.

UNIT-IV

The Hermite polynomials, Chebyshev's polynomial, Laugrre's polynomial: Recurrence relations, generating functions and orthogonal properties

BOOKS RECOMMENDED

1. S L Ross, Differential Equations, Third Edition, John Wiley & Sons (2004)

2. W E Boyce, R C Diprima, elementary Differential Equations and Boundary Value problems, 4^{th} Edition, John Wiely and Sons (1986)

3. I N Sneddon, Special Functions of Mathematical Physics and Chemistry, Edinburg, Oliver & Boyd (1956)

4. G Andrews, R Askey& R Roy, Special Functions, Cambridge (1999)

5. L Andrews, Special Functions for Engineers and Applied Scientists, Mcmillan (1985)

6. W W Bell, Special Functions for Scientists and Engineers, Dover, (1986)

MMS 105: FUNDAMENTALS OF COMPUTER AND C PROGRAMMINGL T P
4 0 0

Unit 1

Computer's general concepts: historical overview , technological advantages in computers, shape of today's computer as a system, CPU, primary memory , secondary storage devices, input devices, output devices, significance of software system , categories of software system software, applications software, comiler, interpreter , utility program, binary arithmetic for integer and fractional numbers, operating system and its significance.

Unit 1I

Character sets for c , constants and variables, arithmetic expressions input and output statements, comments, data types, statement labels, built in functions and libraries, logical if-else and nested if-else statement, switch , break, continue , go to statements, preprocessor in c

Unit III

While , for and do while loops in c , arrays, array variables, syntax rules, use of multiple subscripts in arrays, reading and writing multi-dimensional araays, storage classes structures and union

Unit IV

Function definition, function prototypes, Arguments, call by value, call by reference, passing array variable to a function, pointer variables, relationship of pointer and array, passing pointer variable to a function, strings handling, and file processing operations in c

BOOKS RECOMMENDED

1. Computer Programming in C – V. Rajaraman, Prentice-Hall of India Pvt. Ltd., 2005.
2. Computer Applications of Mathematics and Statistics – A. K. Chattapadhyay and T. Chattapadhyay, Asian Books Pvt. Ltd., New Delhi, 2005.
3. The C Programming Language – B. W. Kernighan and D. M. Ritchie, Prentice Hall, India, 1995.
4. Primes and Programming – An Introduction to Number Theory with Programming – P. Goblin, Cambridge University Press, 1993.

MMS 106: FUNDAMENTALS OF COMPUTER AND C PROGRAMMING LabL T P

0 0 2

The following programs are to be practiced:

1. Determination of roots of quadratic equations, $Ax^2+Bx+C=0$,
2. Arranging given set of numbers in increasing/decreasing order, calculation of Mean, Mode, Median.
3. Evaluation of sum of power series eg. e^x, sin x, cos x, log (1 + x).
4. Calculation of GCD/LCM of two integers.
5. Evaluation of factorial of a positive integer and evaluation of binomial coefficients.
6. Generation of twin primes, random numbers.
7. Calculation of Coefficient of Correlation.
8. Computation of scalar product of vectors.
9. Addition and multiplication of matrices.
10. Evaluation of Determinants.
11. Inversion of matrices.
12. Solution of System of linear equations.
13. Writing a given number in words using function.
14. Arranging a set of names in alphabetical order.

BOOKS RECOMMENDED

1. Computer Programming in C – V. Rajaraman, Prentice-Hall of India Pvt. Ltd., 2005.

2. Computer Applications of Mathematics and Statistics – A. K. Chattapadhyay and T. Chattapadhyay, Asian Books Pvt. Ltd., New Delhi, 2005.

3. The C Programming Language – B. W. Kernighan and D. M. Ritchie, Prentice Hall, India, 1995.

4. Primes and Programming – An Introduction to Number Theory with Programming – P. Goblin, Cambridge University Press, 1993.

Candidates are required to perform at least 10-12 practicals

MMS-201: ALGEBRA-IIL T P
4 1 0

Unit-I

Modules, sub modules, free modules, Quotient modules, Isomorhism theorem, Direct sums, Modules associated with a linear operator, Cyclic modules, Noetherian and Artinian modules and rings.

Unit-II

Field extension: Finite, Algebraic and Transcendental extensions, Simple, Separable and inseparable Extensions, Algebraically Closed fields, Splitting fields, Existence & uniqueness, Normal Extensions, Finite Fields.

Unit-III

Galois extensions , Galois group of an extension and Fundamental theorem of Galois Theory

Unit-IV

Review of vector spaces, Dual space , Dual basis, Reflexivity ,Annihilators, inner product spaces, orthogonal and orthonormal basis ,Gram schmidthorthogonalisation process.

BOOKS RECOMMENDED

1. Bhattacharya, P.B., Jain, S.K. &Nagpal, S.R.: Basic Abstract Algebra, Cambridge University Press, 1997.

2. Surjeet Singh, QuzaiZameeruddin: Modern Algebra, Vikas Publishing House , New Delhi,8th edition,2006.

3. I.N. Herstein: Topics in Algebra, 2nd edition, Wiley Eastern, 1975.

MMS 202: REAL ANALYSIS-IIL T P
4 1 0

UNIT-I

Preliminaries, Lebesgue outer measure. Measurable sets. Regularity, Lebesgue measure, non-measurable sets. Measurable functions. Borel and Lebesgue measurability, Littlewood's three principles.

UNIT-II

The Lebesgue integral of a simple function and bounded function, comparison of Riemann and Lebesgue integral, Bounded convergence theorem, Integral of non -negative functions, Fatou's Lemma, Monotone convergence theorem, The general Lebesgue Integral, Lebesgue convergence theorem, Integration of series.

UNIT-III

Vitali,s Lemma, The Four derivates, continuous non differentiable functions. Functions of bounded variation.Lebesgue differentiation theorem.Differentiation and integration. The Lebesgue set

UNIT-IV

Convex functions, Jensen's inequality,TheL^p-spaces, Holder and Minkowski inequalities. Convergence in mean, Completeness of L^p, Approximation in L^p spaces.

BOOKS RECOMMENDED

1. H.L. Royden, *Real Analysis,* Macmillan, New York, 1988.

2. G.de Bara, Measure Theory and Integration, Ellis Horwood Limited, England, 2nd Edition 2003.

3. G.B. Folland, *Real Analysis*, second edition, John Wiley, New York, 1999.

4. E. Kreyszig Introductory Functional Analysis with Applications, John Wiley, 1989.

MMS 203: MECHANICS

L	T	P
4	1	0

Unit-I

Generalized coordinates, Holonomic and non-holonomic systems scleronomic and rhenomic systems, Generalized potential, lagrange's equation of first kind and second kind uniqueness of solution, Energy equation for conservative field.

Unit-II

Hamilton variables, donkin's theorem ,Hamilton canonical equation, cyclic coordinates, Routh's equation , Poisson bracket , Poisson's identity , Jacobi -Poisson theorem, Hamilton's principle, principle of least action Poincare- Cartan integral invariant, whittaker's equations lee hwachung's theorem.

Unit-III

Small oscillations of conservative system Lagrange's equation for small oscillations, Nature of roots of frequency equation, Principle oscillations. Normal coordinates, Canonical transformations, free canonical transformations, Hamilton- Jacobi equation, and Jacobi theorem.

Unit-IV

Method of separation of variables, lagrange's bracket' condition of Canonical character of transformation in terms of Lagrange's bracket and Poisson's Bracket. Invariance of Lagrange's bracket and Poisson's bracket and canonical transformation, Lagrange's theorem on the stability of equilibrium position, Lyapunov theorem, Nadchetayev theorem, asymptotic stability of an equilibrium position.

BOOKS RECOMMENDED

1. F. Gantmacher. Lectures in analytic mechanics . Mir Publisher , Moscow, 1975.

2. H. goldstien, c.ppoole and j.l. sofco, classical mechanics , third edition, Addison Wesely, 2002.

3. Mechanics – L. D. Landau and E. M. Lipshitz, Pergamon Press, Oxford, 1976.

4. Lectures on Mechanics – J. E. Marsden, Cambridge University Press, 1992.

MTS 204: TENSORS AND DIFFERENTIAL GEOMETRY

L	T	P
4	1	0

UNIT-I

Systems of Different orders - Summation Convention - Kronecker Symbols - Transformation of coordinates in Sn - Invariants - Covariant and Contravariant vectors - Tensors of Second Order - Mixed Tensors - Zero Tensor - Tensor Field - Algebra of Tensors - Equality of Tensors - Symmetric and Skew – symmetric tensors - Outer multiplication, Contraction and Inner Multiplication - Quotient Law of Tensors - Reciprocal Tensor of Tensor - Relative Tensor - Cross Product of Vectors.

UNIT-II

Riemannian Space - Christoffel Symbols and their properties ,Covariant Differentiation of Tensors - Riemann - Christoffel Curvature Tensor - Intrinsic Differentiation.

UNIT-III

Definition of a surface - curves on a surface - Surface of revolution - Helicoids - Metric - Direction coefficients - families of curves - Isometric correspondence - Intrinsic properties.

UNIT-IV

Geodesics - Canonical geodesic equations - Normal property of geodesics - Existence Theorems - Geodesic parallels - Geodesics curvature - Gauss - Bonnet Theorem - Gaussian curvature - surface of constant curvature.

BOOKS RECOMMENDED

1. Struik, D.T. Lectures on Classical Differential Geometry, Addison - Wesley, Mass. 1950.

2. Kobayashi. S. and Nomizu. K. Foundations of Differential Geometry, Interscience Publishers, 1963.

3. Wilhelm Klingenberg: A course in Differential Geometry, Graduate Texts in Mathematics, Springer-Verlag 1978.

4. J.L.Synge and A.Schild, Tensor Calculus, Toronto, 1949.

5. A.S.Eddington. The Mathematical Theory of Relativity, Cambridge University Press, 1930.

MTS 205: NUMERICAL ANALYSIS

L T P
4 1 0

Unit-I

Numerical Computation and Error Analysis: Numbers and their accuracy, Floating point arithmetic, Errors in numbers, error estimation, general error formulae, error propagation in computation. Algebraic and Transcendental Equations: Bisection method, iteration method, Regula- Falsi method, secant method, Newton-Raphson method. Convergence of these methods. Lin-Bairstow's method, Muller method ,Graeffe's root squaring method , solution of system of nonlinear equations, complex roots by Newton – Raphson method.

Unit-II

System of Linear Algebraic Equations: Guass elimination method, Gauss – Jordon method , LU factorization method , Jacobi and Gauss-Seidal methods, Convergence of iteration methods, Round-off errors and refinement, ill- conditioning, Partitioning method, Inverse of Matrices. Eigen values and eigen vector: Rayleigh Power method , Given's method and House –Holder method.

Unit-III

Interpolation: Finite differences, Newton interpolation formulae, Gauss, Stirling and Bessel'sformulae, Lagrange's, Hermits and Newton's divided difference formulae. Numerical differentiation and integration: differentiation at tabulated and non-tabulated points, maximum and minimum values of tabulated function, Newton-Cotes formulae-Trapezoidal, Simpson's, Booles and Weddle rules of integration , Romberg integration , Gaussian integration, Double integration by Trapezoidal and Simpson rules.

Unit-IV

Ordinary Differential Equations: Taylor series and Picard's methods, Euler and modified Euler methods,

Runge –Kutta methods, Predictor- Corrector methods: Adam-Beshforth and Miline methods. Error analysis and accuracy of these methods. Solution of simultaneous and higher order equations, Boundary values problems: Finite difference and shooting methods

BOOKS RECOMMENDED

1. V. Rajaraman, Computer Oriented Numerical Analysis, Prentice-Hall of India Pvt. Ltd., 2002.
2. J.N. Sharma, Numerical Methods for Engineers and Scientists(2^{nd} edition), Narosa Publ. House New Delhi/Alpha Science international, Ltd, Oxford UK 2007.
3. E. Balagurusamy, Numerical Methods, Tata McGraw Hill, New Delhi, 1999.

4. B. Bradie: A friendly introduction to Numerical Analysis.Pearson Prentice Hall 2006
5. K. E. Atkinson, Introduction to Numerical Analysis (2nd edition), John Wiley,1989.
6. S. D. Conte and C. De Boor, Elementary Numerical Analysis: An Algorithmic Approach (3rd edition), McGraw Hill, New York, 1980.
7. J. B. Scarborough,Numerical Mathematical Analysis, Oxford & IBH Publishing Co., 2001.

MTS 206: NUMERICAL ANALYSIS LAB

L	T	P
0	0	2

The following programs of following methods are to be practiced:

1. To find a real root of an algebraic/ transcendental equation by using Bisection method.
2. To find a real root of an algebraic/ transcendental equation by using Regula-Falsi method.
3. To find a real root of an algebraic/ transcendental equation by using Newton-Raphson method.
4. To find a real root of an algebraic/ transcendental equation by using Iteration method.
5. Implementation of Gauss- Elimination method to solve a system of linear algebraic equations.
6. Implementation of Jacobi's method to solve a system of linear algebraic equations.
7. Implementation of Gauss-Seidel method to solve a system of linear algebraic equations.
8. To find differential coefficients of 1st and 2nd orders using interpolation formulae.
9. To evaluate definite integrals by using Newton - Cotes integral formulae.
10. To evaluate definite integrals by using Gaussian Quadrature.
11. To evaluate double integrals by using Trapezoidal and Simpson method.
12. To compute the solution of ordinary differential equations with Taylor's series method.
13. To compute the solution of ordinary differential equations by using Euler's method.
14. To compute the solution of ordinary differential equations by using Runge -Kutta methods.
15. To compute the solution of ordinary differential equations by using Milne-Simpson method.

BOOKS RECOMMENDED

1. E. Balagurusamy, Object Oriented Programming with C++, Tata McGraw Hill, New Delhi, 1999.
2. J N Sharma, Numerical Methods for engineers and Scientists (2nd Edn) Narosa Publishing House, New
3. Delhi/ Alpha Science International Ltd. Oxford UK, 2007.
4. Conte and de Boor, Numerical Analysis, McGraw Hill, New York, 1990
5. John H. Mathews, Numerical Methods for Mathematics, Science and Engineering (2nd Edn.), Prentice
6. Hall, New Delhi, 2000

Instructions for paper setters and candidates:

Candidates are required to atleast perform at least 10-12 Practical's are to be completed in asemester

TOPOLOGY (MS-301)

L	T	P
4	1	0

Unit-I

Introduction topological spaces, closed sets, Closure, Dense subsets, neighborhoods, interior, exterior and boundary, Accumulation points and derived sets. Bases and subbases, Subspaces and relative Topology, Alternative methods of defining a Topology in terms of Kuratowski closure operator and neighborhood systems.

Unit-II

Open mappings and closed mappings, Continues functions and homomorphism's, Compactness and local Compactness. One -point compactification , connected and arc-wise connected spaces, Components and Locally connected spaces.

Unit-III

T_0 and T_1 spaces, T_2 spaces and sequences . Hausdorffness of one point compactification, Axioms of Countability andSeperability, Equivalence of Separable , second Axiom and Lindelof properties in a metric spaces. Equivalence of compact and countably compact sets in metric spaces.

UNIT -1V

Regular and completely regular, Normal and completely normal spaces. Meric spaces as T_2, completely normal and first axiom spaces , Urysohn's Lemma , Tietze Extension Theorem.

BOOKS RECOMMENDED

1.Topology, a first course – J. R. Munkres, Prentice-Hall of India Ltd., New Delhi,2000.
2. An introduction to general topology (2nd edition) – K. D. Joshi, Wiley Eastern Ltd. New Delhi, 2002.
3. G.F Simmons : Introduction to topology and Modern Analysis.
4. General Topology – J. L. Kelley, Springer Verlag, New York, 1990.
5. Basic Topology – M.A. Armstrong, Springer International Ed. 2005.

OPERATIONS RESEARCH (MS-302)

L T P
4 1 0

Unit-I

Formulation of linear programming problem (LPP) -graphical method, Basic Feasible Solution, Extreme Points, Convex set, Convex linear combination, optimal solution of LPP using Simplex , Big-M and two phase methods, Exceptional cases in LPP i.e., Infeasible, unbounded, alternate and degenerate solutions.

Unit-II

General Primal-Dual pair, Formulating a dual problem, Weak and strong duality theorems, Complementary slackness theorem, Dual simplex method, Economic interpretation of primal-Dual problems. Sensitivity analysis: change in right hand side of constraints, change in the objective function and coefficient matrix addition and deletion of constraint and variables.

Unit III

Initial basic Feasible solution of transportation problem, Balanced and unbalanced transportation problems ,Optimal solutions of transportation problem using U-V /MODI methods, Assignment problems; Mathematical formulation of assignment problem, typical assignment problem, the traveling salesman problem, Test for optimality, degeneracy, Project management with critical path method.

Unit-IV

Concept of convexity and concavity, Maxima and minima of convex functions,Single and multivariate unconstrained problems, constrained programming problems, Kuhn-Tucker conditions for constrained programming problems, Quadratic programming, Wolfe's method.

BOOKS RECOMMENDED

1.Taha, H.A., Operations Research-An Introduction, PHI (2007).

2. KantiSwarup, P.K. Gupta and Man Mohan, Operations Research ,Sultan Chand & Sons, Ninth Edition (2002).

3. Friderick S. Hillier and Gerald J. Lieberman, Operations Research ,Holden-Day Inc,USA,econd Edition (1974)

4.Bazaraa, M.S., Sherali, H.D., Shetty, C.M., Nonlinear Programming: Theory and Algorithms, John Wiley and Sons, (1993).

5.Chandra, S., Jayadeva, Mehra, A., Numerical Optimization and Applications, Narosa Publishing House, (2013).

MATHEMATICAL STATISTICS (MS-303)

L T P
4 1 0

Unit I

Classical and axiomatic approach to the theory of probability, additive and multiplicative law of probability, conditional probability and Bayes theorem.Random variable, function of random variable, and their distributions, probability mass function, probability density function, cumulative distribution function.

Unit II

Two dimensional random variables, joint, marginal and conditional distributions, independence of random variables, expectation, conditional expectation, moments, product moments, probability generating functions, moment generating function and its properties. Chebyshev's, Markov, Jenson, Techebyshey's, inequalities, stochastic convergence, central limit theorem.characteristic function and its elementary properties.

Unit III

Study of various discrete and continuous distributions, Binomial, Poisson, Geometric, Hyper geometric, Multinomial. Uniform, Exponential, Normal distributions, Gamma distribution,cauchy, exponential, Beta and gamma distributions, Bivariate normal distribution and distribution of order statistics and range.

Unit IV

Concept of sampling distribution and its standard error, Derivation of sampling distributions of Chi-square, t and F distribution of sample mean and sample variance Testing of hypotheses, fundamental notions important tests based on normal distributions, Tests of significance: tests based on normal distribution, Chi-square, t and F statistic. Analysis of variance: One way and two way classifications.

BOOKS RECOMMENDED

1. Hogg, R.V &Craige: Introduction to Mathematical Statistics. 7th edition(2005)
2. Mckean, J.W. and Craig, A.T.,Mukhopadhyay, P : Mathematical Statistics.(2000)
3. S.C. Gupta and V.K. Kapoor, Fundamental of Mathematical Statistics 7th ed., (1990)
4. Goon, Gupta and Das Gupta, Fundamentals of Statistics, Edition, 5. Publisher, World Press, 1975.
5. Rohatgi V.K.: Introduction to probability theory & Mathematical Statistics 2009.

FUNCTIONAL ANALYSIS (MS-304)

L T P
4 1 0

Unit-I

Normed linear spaces, Banach spaces, properties of normed spaces, finite dimensional normed spaces and subspaces, linear operator, bounded and continuous linear operators, linear functionals, normed spaces of operators

Unit-II

Equivalent norms, conjugate spaces, Reflexivity. Hahn-banach theorems for real/complex vector spaces and normed spaces, application to bounded linear functional on C [a,b].

Unit-III

Uniform boundedness theorem, open mapping theorem, closed graph theorem, Projections on Banach spaces.

Unit-IV

Inner product spaces, Hilbert spaces, properties of inner product spaces, orthogonal complements, orthonormal sets , Hilbert – adjoint operator, self-ad joint, unitary and normal operators.

BOOKS RECOMMENDED

[1] G.F.Simmons: Introduction to topology and modern Analysis (2008)

[2] Walter Rudin, Functional Analysis, International Series in Pure and Applied Mathematics, McGraw-Hill,inc.,1991.

[3] Erwin Kreyszig, introductory Functional Analysis with Applications, John Wiley and Sons(Asia),Pvt.Ltd.,2006.

[4] George Bachman and Lawrence Narici, Functional Analysis, Dover, 2000.

[5] John B. Conway, A course in Functional Analysis, second edition, Springer-Verlag, 2006.

DISCRETE MATHEMATICS (MS-401) L T P
4 1 0

Unit-I

Mathematical Logic: Basic logical operations, conditional and bi-conditional statements, tautologies, contradiction, predicate calculus and its inference theory.

Recursion and Recurrence Relations: Polynomial expressions, telescopic form, recursion theorem, closed form expression, generating function, solution of recurrence relation using generating function, recursion.

Unit-II

Lattices and Boolean Algebra: Introduction to Binary relations, equivalence relations and partitions, Partial order relations, Hasse diagram.Lattices as partially ordered sets, properties, lattices as algebraic systems, sub lattices, direct products, Homomorphism, some special lattices. Boolean algebra as lattices, Boolean identities, sub-algebra, Boolean forms and their equivalence, sum of product, product of sum of canonical forms. Applications of Boolean algebra to circuit theory.

Unit-III

Graph Theory: Directedgraphs, undirected graphs, paths, circuits, cycles, sub-graphs, induced Sub graphs, degree of vertex, connectivity, planner graph, complete graph, complete bi-partitegraph, matrix representation of graph, adjacency and incidence matrix for graph, Eulerian paths and circuits, Trees and Coloring of the graph, Rooted tree, search tree, tree traversals, spanning trees, minimal spanning trees, Kruskal's algorithm. Chromatic number and polynomial, four-color Theorem(statement only).

Unit-IV

Algebraic Structures: Review of groups, codes and group codes, cyclic codes and coding methods based on entropy, Application of algebraic structure to error corrections and detection codes, discrete codes and first coding theorem.

BOOKS RECOMMENDED:

1. J.P. Tremblay and R.P. Manohar ,Discrete Mathematics with Applications to Computer Science, Tata McGraw Hill , 2008.
2. Ram, Babu, Discrete Mathematics, Pearson Education, (2007).
3. F. Harary, Graph Theory, Narosa, 1995
4. Doerr, Alan and Levsseur, K., Applied Discrete Structures for Computer Science, Galgotia Publication, 2005
5. Liu, C.L, Elements of Discrete Mathematics, Tata McGraw Hill , 2008 3rd Edition
6. Grimaldi, R.P and Ramana, B.V., Discrete and Combinatorial Mathematics-An Applied Introduction, Pearson education (2004) 5thed.
7. Seymour Lipschultz, "Theory and Practice of Data Structures", McGraw-Hill, 1988.

MATHEMATICAL METHODS (MMS-402)L T P
4 1 0

UNIT I

Integral Transforms: Definitions and properties of Laplace transform, inversion formula convolution, Laplace transform of unit step function and impulsive function, application to ordinary and partial differential equations; Fourier transform, properties of Fourier transform, inversion formula, convolution, Parseval's equality; Fourier transform of generalized functions, application of transforms to heat wave and Laplace equation. Hankel Transforms and its applications in boundary value problems.

UNIT II

Integral Equations: Integral equations of Fredholm and Volterra type, solution by successive substitution and successive approximation, integral equations with degenerate kernels. Integral equations of convolution type and their solutions by Laplace transform, Fredholm's theorems, integral equations with symmetric kernel, Eigen values and Eigen functions of integral equations and their simple properties.

UNIT III

Calculus of Variations: The extreme of functionals and its properties, variation of functional, Euler equation in one and several independent variables, sufficient conditions for the extremum of a functional, moving end problems, variation problems with constraints- problem of geodesics and isoperimetric.

UNIT IV

Eigen Value Problems: Ordinary differential equations of the Sturm-Liouville Problem, eigen values and eigen functions, expansion theorem, extrema properties of the eigen values of linear differential operators, formulation of the eigen value problem of a differential operator as a problem of integral equation.

BOOKS RECOMMENDED:

1. The Use of Integral Transforms – I. N. Sneddon, Tata McGraw Hill, 1985
2 Fourier Transforms – R. R. Goldberg, Cambridge University Press, 1970.
3 Laplace Transform Theory – M. G. Smith, Van Nostrand Inc., 2000.
4. Calculus of Variation- L. Elsegolc, Dover Publications, 2010
5. Kenwal, Ram P., Linear Integral Equation; Theory and techniques, Academic Press, 1971
6. Hildebrand, F.B., Methods of applied mathematics, Dover Publications, **(Latest Reprint)**

PARTIAL DIFFERENTIAL EQUATIONS (MMS-403)L T P
4 1 0

UNIT I

First Order PDE: Definition of PDE, origin of first-order PDE; determination of integral surfaces of linear first order partial differential equations passing through a given curve; surfaces orthogonal to given system of surfaces; non-linear PDE of first order, Cauchy's method of characteristic; compatible system of first order PDE; Charpit's method of solution, solutions satisfying given conditions, Jacobi's method of solution.

UNIT II

Second Order PDE: Origin of second order PDE, linear second order PDE with constant coefficients, linear second order PDE with variable coefficients; characteristic curves of the second order PDE; Monge's method of solution of non-linear PDE of second order.

UNIT III

Method of Solution: Separation of variables in a PDE; Laplace, wave and diffusion equations, Elementary solutions of Laplace equations.

UNIT IV

Applications of PDE: Wave equation, the occurrence of wave equations, elementary solutions of one dimensional wave equation; vibrating membranes, three dimensional problems. Diffusion equation, resolution of boundary value problems for diffusion equation, elementary solutions of diffusion equation.

BOOKS RECOMMENDED:

1. Elements of Partial Differential Equation (3rd edition) – I. N. Sneddon, McGraw Hill Book Company, 1998.

2. Partial Differential Equations (2nd edition) – E. T. Copson, Cambridge University Press, 1995.

3. Partial Differential Equations: An Introduction [Hardcover]Walter A. Strauss ,(2nd edition) 2007.

4. J.N. Sharma and K. Singh, Partial differential equations for engineers and scientists, 2nd Edition, Narosa Publication House, New Delhi, 2009

5. Sankara Rao, Introduction to partial differential equations, PHI,2010.

FLUID MECHANICS (MMS-501)

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Unit-I

Lagrangian and Eulerian methods, equation of continuity, stream lines. Path lines and streak lines, velocity potential and stream function, irrotational and rotational motions.

Unit-II

Euler's equation, Bernoulli's equation, equations referred to moving axes, impulsive actions, vortex motion and its elementary properties, motions due to circular and rectilinear vortices, Kelvin's proof of permanence.

Unit-III

Irrotational motion in two-dimensions, complex-velocity potential sources, sinks, doublets and their images, conformal mapping.

Unit-IV

Stress components in a real fluid. Navier- Stokes equations of motion. Plane Poiseiuille and Couette flows between two parallel plates. Flow through a pipe of uniform cross section in theform of circle, annulus, Theory of lubrication.

BOOKSRECOMMENDED

1. Yuan S.W., Foundations of Fluid Mechanics, Prentice Hall of India Private Limited (1976).
2. Chorlton F., Textbook of Fluid Dynamics, C. B. S. Publishers (2005).
3. Besant W.H. and Ramsay A.S., Treatise of Hydro Mechanics, Part II, CBS Publishers (2004).
4. Rathy R.K., An Introduction to fluid Dynamics, Oxford and IBH Publishing Company (1976).

SOLID MECHANICS (MMS 502) L T P
4 1 0

Unit-I

Analysis of Strain: Affine transformations. Infinitesimal affine deformation.Geometrical interpretation of the components of strain.Strain quadric of Cauchy. Principal strains and invariants. General infinitesimal deformation.Equations of compatibility, Finite deformations.Examples of uniform dilatation, simple extension and shearing strain.

Unit-II

Analysis of Stress: Body and surface forces, stress tensor, equations of equilibrium, transformation of coordinates, stress quadric of Cauchy. Principal stress and invariants.Maximum normal and shear stresses, examples of stresses.

Unit-III

Equations of Elasticity: Generalized Hooke's law, homogeneous isotropic bodies, Elastic moduli for isotropic bodies. Equilibrium and dynamic equations for an isotropic elastic solid.Beltrami-Michell compatibility equations.

Unit-IV

Boundary value problems of elasticity: Strain Energy**,** Strain energy function,Uniqueness of solution of the boundary-value problems of elasticity, Saint-Venant's Principle, Bounds on the elastic constants, Related Integral theorems, Principle of virtual work, Principles of minimum potential and complementary energy.

BOOKS RECOMMENDED:

1. I.S. Sokolnikoff, *Mathematical Theory of Elasticity,* Tata McGraw Hill Publishing Company Ltd., New Delhi, 1977.
2. Martin, H. Sadd, *Elasticity, Theory Applications and Numerics,* Elsevier Academic Press, UK, 2006.

CODING THEORY (MMS-503)

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4 1 0

Unit-I

Introduction to Coding Theory: Code words, Distance and weight function, Nearest-neighbour decoding principle, Error detection and correction, Matrix encoding techniques, Matrix codes, Group codes, Decoding by coset leaders, Generator and parity check matrices, Syndrom decoding procedure, Dual codes.

Unit-II

Linear Codes: Linear codes, Matrix description of linear codes, Equivalence of linear codes, Minimum distance of linear codes, Dual code of a linear code, Weight distribution of the dual code of a binary linear code, Hamming codes.

Unit-III

BCH Codes: Polynomial codes, Finite fields, Minimal and primitive polynomials, Bose-Chaudhuri-Hocquenghem codes.

Unit-IV

Cyclic Codes: Cyclic codes, Algebraic description of cyclic codes, Check polynomial, BCH and Hamming codes as cyclic codes.Maximum distance separable codes, Necessary and sufficient conditions for MDS codes, Weight distribution of MDS codes, An existence problem, Reed-Solomon codes.

BOOKS RECOMMENDED

1. Vermani L R, Elements of Algebraic Coding Theory, Chapman and Hall (1996).
2. Vera P.**,** Introduction to the Theory of Error Correcting Codes, John Wiley and Sons (1998).
3. Roman Steven, Coding and Information Theory, Springer Verlag (1992).
4. Garrett Paul, The Mathematics of Coding Theory, Pearson Education (2004).

ADVANCED COMPLEX ANALYSIS (MMS-504)

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Unit-I

Analytic continuation, Analytic continuation by power series method, Natural boundary, Schwarz reflection principle, Analytic continuation along a path, Monodromy theorem, Runge's theorem, simple connectedness, Mittag-Leffler's theorem.

Unit-II

Maximum principle, Schwarz's Lemma, Hadamard's three circle theorem, Phragmen-Lindelof theorem, Weierstrass factorization theorem, Factorization of sine function, Gamma function.Entire functions, Jensen's formula, the genus and order of an entire function, Hadamard factorization theorem.

Unit-III

Harmonic functions, Basic properties, Harmonic functions on a disc, Subharmonic and Superharmonic functions, The Dirichlet problem, Green's function.

Unit-IV

Normal families of analytic functions, Montel's theorem, Hurwitz's theorem, Riemann mapping theorem, Univalent function, Distortion and Growth theorem for the class of normalized univalent functions, Covering theorem, starlike functions, convex functions, Subordination principle.

BOOKS RECOMMENDED

1. Z.Nihari, Conformal Mapping, Conformal Mapping, McGraw-Hill,1952.
2. J. B. Conway, Functions of One Complex Variable, Springer-Verlag,1973
3. T. W. Gamelin, Complex Analysis, Springer, 2004.
4. W.Tutschke and H.L.Vasudeva, An Introduction to Complex Analysis- Classical and Modern Approaches, Chapman & Hall/CRC, 2005
5. E.T. Copson, An Introduction to Theory of Functions of a Complex Variable.

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Advanced Operations Research (MMS-505)

Unit 1

Advanced Linear Programming: Revised simplex method, Sensitivity analysis, Parametric programming, Integer programming branch and bond algorithm, Goal programming, Standard form of LGPP, Partitioning algorithm.

Unit 2

Game Theory: Two person zero sum games pure strategies (minmax and maximum principles), Game with saddle point, Mixed strategies: Game without saddle point, Rule of Dominance, Solution methods for games without saddle point: Graphical method, Linear programming method.

Unit 3

Dynamic Programming: Characteristics of dynamic programming, Recursive relations, continuous and discrete cases, forward recursion, linear programming versus dynamic programming, Dynamic programming approach for Priority Management employment smoothening, capital budgeting, Stage Coach/Shortest Path, cargo loading and Reliability problems.

Unit 4

Inventory Models: (a) Deterministic models: Classic EOQ (Economic order quantity) models, EOQ with price brakes, Multi item EOQ with storage limitation, Dynamic EOQ models(b) Probabilistic models: Probabilistic EOQ models, Single period models and multiperiod models.

Books Recommended

1. Taha, H.A., Operations Research- An introduction , PHI, 2007, Eighth ed.
2. Sharma, J.K, Operation research: Theory & Applications ,Macmillan India, 2007, Third ed
3..Kasana, H.S and Kumar K.D, Introductory Operations Research: Theory & Applications Springer, 2005
4. Pant, J.C, Introduction to Optimization and Operations Research, Jain Brothers, 2004

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ADVANCED FLUID MECHANICS (MMS-506)

UNIT-I

Basic Concepts: Continuum Hypothesis, Viscosity, Most general motion of a fluid element, Rate of strain quadric, stress at a point, Tensor character of stress matrix, Symmetry of stress matrix, stress quadric, Stress in a fluid at rest, stress in a fluid in motion, Relation between stress and rate of strain components (Stoke's law of friction), Thermal conductivity, Generalized law of heat conduction,

Fundamental equations of the flow of viscous fluids: Equation of state, equation of continuity - Conservation of mass, Equation of motion- Navier-Stoke's equations, Equation of energy- Conservation of energy, Symmetry of fundamental equations, Vorticity and circulation in a viscous incompressible fluid motion, (a) velocity transport equation, (b) Circulation

UNIT-II

Dynamical similarity and Dynamical Analysis: Dynamical similarity, Reynold's law, Inspection analysis, Dimensional analysis, Buckingham π-theorem. Method of finding out the pi-products, Application of pi-theorem to viscous and compressible fluid. Physical importance of non-dimensional parameters. Reynolds number, Eckert Number, Froude Number, Mach Number, Pecklet Number, Grashoff Number, Prandtl Number, Brinkman Number, Nussel Number.

Exact Solution of Navier-Stoke's equations of motion- Flow between parallel plates (Velocity and temperature distributions), (i) Plane Couette flows (ii) Plane Poiseulle Flow and (iii) Generalized Couette flow.

UNIT-III

Flow in a circular pipe (Hagen Poiseuille flow) -Velocity and temperature distribution, Flow through tubes of uniform cross section in the form of circle, annulus, ellipse and equilateral triangle under constant pressure gradient. Flow between two concentric rotating cylinders (Couette flow) , Flow in convergent and divergent channels,

UNIT-IV

Steady incompressible flow with variable viscosity: Variable viscosity plane Couette flow and plane poiseulle flow.

Unsteady incompressible flow with constant fluid properties: Flow due to a plane wall suddenly set in motion, Flow due to an oscillating plane wall, Starting flow in plane Couette motion, Starting flow in pipes, Plane coquette flow with transpiration cooling.

Books Recommended

1. Bansal,J L, Viscous Fluid Dynamics, OXFORD & IBH Publishing Company Pvt. Ltd., New Delhi, 1992.

2. Chorlton, F., Textbook of Fluid Dynamics, C.B.S. Publishers, Delhi, 1985.

3. Schlichting, H., Boundary Layer Theory, McGraw Hill Book Company, New York, 1979.

4. Young ,A. D., Boundary Layers, AIAA Education Series, Washington DC, 1989.

5. Yuan, S.W., Foundations of Fluid Mechanics, Prentice Hall of India Private Limited, New Delhi, 1976

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Advanced Solid Mechanics(MMS-507)

Unit-I

Basics and Extension of Beams: Hooke's law, generalized Hooke's law, Elastic moduli and their relationship, strain-energy density function and its connection with Hooke's law, Saint-Venant's principle. Extension of beams: extension of beams by longitudinal forces, beam stretched by its own weight and bending of beams by terminal couples.

Unit-II

Torsion and flexure of beams: Torsion of a circular shaft, cylindrical bars, and elliptic cylinder. Stress function, conformal mapping, solution of torsion problem by conformal mapping. Flexure of beams by terminal loads, bending of rectangular beams.

Unit-III

Two-and Three-dimensional Problems: Plane deformation, plane stress, plane elastostatic problems, Airy's stress function, solution of the bi-harmonic equation, stress and displacement formulae basic problems of circular region: uniform pressure, uniform radial displacement and concentrated loads. Spherical shell under external and internal pressures.

Unit-IV

Thermoelastic problems and VariationalMethods: Thermal stresses in spherical bodies, two-dimensional thermoelastic problems. Variational methods: Theorems of potential energy, minimum complementary energy, work and reciprocity, Ritz method for one- and two-dimensional problems and Galerkin's method. Kantorovich and Trefftz methods. Application of Treffz method.

Books Recommended

1. Sokolnikoff, I S Mathematical Theory of Elasticity, (Ch3: 20,21,23,26,28;Ch4: 31-36,43-44,52,57;Ch:5: 66-71, 77(a,b,c);Ch6: 94,96,99-101; Ch 7: 107-109, 112-113, 115, 117-119) TMH New Delhi 1978.
2. Timoshenko.S. and Young D.H. – "Elements of strength of materials Vol. I and Vol. II"., T. Van Nostrand Co-Inc Princeton-N.J. 1990.

3. Love, A.E.H, A Treatise on the Mathematical theory of Elasticity, Cambridge University Press (4^{th}Edition , Jan 2013).

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Number Theory and Cryptography(MMS-508)

Unit-I

Some Topics in Elementary Number Theory: Time estimates for doing arithmetic, Divisibility and the Euclidean algorithm, Congruence's, some applications to factoring.

Unit-II

Finite Fields and Quadratic Residues: Finite fields, Quadratic residues and reciprocity.

Unit-III

Cryptography: some simple cryptosystems, enciphering matrices.

Unit-IV

Public Key: The idea of public key cryptography, RSA, Discrete log. Elliptic Curves: Basic facts, Elliptic curve cryptosystems.

BOOKS RECOMMENDED:

1. Koblitz N., A Course in Number Theory and Cryptography, Graduate Texts in Mathematics, No.114, Springer-Verlag, New York/Berlin/Heidelberg, 1987.
2. Baker A., A Concise Introduction to the Theory of Numbers, Cambridge University Press, New York/Port Chester/Melbourne/ Sydney, 1990.
3. Parshin A.N. and Shafarevich I.R. (Eds.), Number Theory, Encyclopaedia of Mathe-matics Sciences, Vol. 49, Springer-Verlag, New York/Berlin/Heidelberg, 1995.
4. Stillwell J., Elements of Number Theory, Undergraduate Texts in Mathematics, Springer-Verlag, NewYork/Berlin/Heidelberg, 2003.
5. Tilborg H.C.A. van, An Introduction to Cryptography, Kluwer Academic Publishers, Boston/ Dordrecht/Lancaster, 1988.

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Theory of Linear Operators (MMS-509)

Unit I

Spectral theory in normed linear spaces, resolvent set and spectrum, spectral properties of bounded linear operators. Properties of resolvent and spectrum. Spectral mapping theorem for polynomials.

Unit II

Elementary theory banach algebra, Spectral radius of a bounded linear operator on a complex banach space.

Unit III

General properties of compact linear operators. Spectral properties of compact linear operators on normed spaces. Behaviours of compact linear operators with respect to solvability of operator equations. Fredholm type theorems. Fredholm alternative theorm. Fredholm alternative for integral equations.

Unit IV

Spectral properties of bounded self-adjoint linear operators on a complex Hibert space.

Positive operators. Monotone Sequences theorem for bounded self-adjoint operators on a complex Hilbert space, Square roots of a positive operator.

Books Recommended

1. Kreyszig E., Introductory functional analysis with applications, Johan-Wiley & Sons, New York, 1978.

2. Halmos P.R., Introduction to Hilbert space and the theory of spectral multiplicity, 2nd Edn. Chelsea Pub., Co., N.Y. 1957.

3. Dunford N. and Schwartz,J.T. Linear operators-3 parts, Inter-science Wiley, New York, 1958-71.

4. Bachman G. andNarici,L., Functional analysis, Academic Press, New York, 1998.

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Advanced Numerical Methods(MMS-510)

Unit-I

Iterative Methods for Linear Systems: The classical iterative methods (Jacobi, Gauss-Seidel andSuccessive Over Relaxation (SOR) methods),Krylov subspace methods; Conjugategradient, Bi-conjugate-gradient (BiCG), BiCG stability methods, Preconditioning techniques, parallelimplementations.

Unit-II

Finite Difference Methods: Explicit and implicit schemes, consistency, stability andconvergence, Lax equivalence theorem, numerical solutions to elliptic, parabolic and hyperbolic partial differential equations.

Unit-III

Approximate methods of solution: Rayleigh-Ritz, collocation andGalerkin methods, properties ofGalerkin approximations, Petrov-Galerkin method, Generalized Galerkin method.

Unit-IV

Finite Element Method (FEM): FEM for second order problems, One and two dimensionalproblems, The finite elements (elements with a triangular mesh and a rectangular mesh and threedimensional finite elements), Fourth-order problems, Hermite families of elements,iso-parametric elements, numerical integration.

BOOKS RECOMMENDED:

1. Jain, M.K, Iyengar, S.R.K. and Jain, R.K., Numerical Methods for Scientific and Engineering Computation, New Age international, 2008, 5th Edition.

2. Hoffman Joe D., Numerical methods for Engineers and Scientists, McGrow-Hill, 1993.

3. Atkinson, K.E, An Introduction to Numerical Analysis, John Wiley, 2004, 2nd Edition.

4. Gupta R.S., Elements of Numerical Analysis, McMillan India, 2009

5. Seshu P., Textbook of Finite Element Analysis, Prentice Hall India, 2003.

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Topological Vector Spaces (MMS-511)

Unit-I

Review of basic concepts of topological spaces and vector spaces. Prodect topological spaces, projection maps, compactness of prodect topological spaces-Tichonov's theorem.

Topological vector spaces (TVSs), examples of TVSs, Normed vector spaces as TVSs, Translation and multiplication maps, Neighbourhood of 0, separated TVS, linear maps between TVSs, Bounded subsets of a topological vector space.

Unit-II

Locally convex topological spaces, normable and metrizable topological vector spaces, complete topological vector spaces

Unit-III

Frechet spaces, Uniform boundedness principle, open mapping and closed graph theorems for Frechet spaces.

Unit-IV

Banach-Alaoglu theorem, Variational inequalities, Lion-Stampacchia theory, Physical phenomenon represented by variational inequalities, points and external sets-KreinMiliman theorem.

BOOKS RECOMMENDED:

1. Munkres J. R., Topology – A First Course, Prentice-Hall of India, 1978.

2. Kelley,J.L. Linear topological spaces, Van Nostrand East West Press, New Delhi.

3. Wilansky A., Modern Methods in Topological Vector Spaces, McGraw Hill, 1978.

4. Simmons G. F. – Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.

5. Rudin W., Functional Analysis, McGraw Hill,2nd edition , 1973.

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Fractional Calculus (MMS-512)

Unit-I

Special Functions of the Fractional Calculus. Gamma Function. Mittag-Leffler function, Fractional Derivatives and Integrals. Grunwald-Letnikov Fractional Derivatives. RiemannLiouville Fractional Derivatives. Some Other Approaches.

Unit-II

Geometric and PhysicalInterpretation of Fractional Integration and Fractional Differentiation. SequentialFractional Derivatives. Left and Right Fractional Derivatives. Properties of FractionalDerivatives. Laplace Transforms of Fractional Derivatives. Fourier Transforms ofFractional Derivatives. Mellin Transforms of Fractional Derivatives.

Unit-III

Linear Fractional Differential Equations. Fractional Differential Equation of a GeneralForm. Existence and Uniqueness Theorem as a Method of Solution. Dependence of aSolution on Initial Conditions. The Laplace Transform Method . Standard FractionalDifferential Equations. Sequential Fractional Differential Equations.Fractional Green's Function. Definition and Some Properties. One-Term Equation. TwoTerm Equation. Three-Term Equation. Four-Term Equation. General Case: n-termEquation.

Unit-IV

Other Methods for the Solution of Fractional-order Equations. The Mellin TransformMethod. Power Series Method. Babenko's Symbolic Calculus Method. Method ofOrthogonal Polynomials. Numerical Evaluation of Fractional Derivatives.Approximation of Fractional Derivatives. Order of Approximation.Computation of Coefficients. Higher-order Approximations.

Books Recommended

1. Podlubny, I.: Matrix approach to discrete fractional calculus. Fractional Calculus andApplied Analysis, vol. 3, no. 4, 2000.

2. Carpinteri A, Mainardi F, editors. Fractals and fractional calculus in continuummechanics. New York: Springer-VerlagWien; 1997.

3. Mandelbrot BB. The fractal geometry of nature. New York:W. H. Freeman; 2000.

4. Miller KS, Ross B. An introduction to the fractional calculus. New York:John Wiley;1993.

5. Oldham KB, Spanier J. The fractional calculus. New York: Academic Press; 1974.