

UNIVERSITY OF KALYANI
Faculty of Science
DEPARTMENT OF MATHEMATICS



KALYANI 741 235 WEST BENGAL

Phone Office :

25828-750, 25828-286, 25828-477, 25828-220

No

Dated 12.09.07

**SEMESTER SYSTEM COURSE
STRUCTURE**

**M. SC. COURSE IN MATHEMATICS
(PURE AND APPLIED STREAMS)**

DEPARTMENT OF MATHEMATICS

FACULTY OF SCIENCE

UNIVERSITY OF KALYANI

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M. Sc. Course in Mathematics (Pure and Applied Streams)

(Total Marks = 1200)

Semester System Course Structure

(Total Four Semesters and 300 marks in each semester)

The First and Second Semesters

(Unit 1 – Unit 10 : 60 Marks in each Unit)

Semester-Wise Distribution of Subjects with Marks

I. First Semester :

<u>Course Name</u>	<u>Subject-Wise Marks</u>	<u>Total Marks</u>
Unit 1 :	Real Analysis – I : 30 + Complex Analysis – I : 30	60
Unit 2 :	Differential Equations – Ordinary : 25 + Partial : 35	60
Unit 3 :	Functional Analysis–I : 30 + Operations Research–I : 30	60
Unit 4 :	Mechanics – I (Potential Theory) : 30 + Abstract Algebra – I : 30	60
<u>*Unit 1 – Unit 4 (240 marks) are common to both the pure and applied streams.</u>		
Unit 5 :	• Mechanics of Solids – Applied Stream	60
	• Differential Geometry–I : 30 + Topology–1 : 30 - Pure Stream	60

II. Second Semester :

<u>Course Name</u>	<u>Subject-Wise Marks</u>	<u>Total Marks</u>
Unit 6 :	Real Analysis – II : 30 + Complex Analysis – II : 30	60
Unit 7 :	Special Functions : 20 & Integral Equations : 20 + Integral Transforms : 20	60
Unit 8 :	Functional Analysis – II : 30 + Operations Research – II : 30	60
<u>Course Name</u>	<u>Subject-Wise Marks</u>	<u>Total Marks</u>
Unit 9 :	Mechanics – II (Dynamics of Particles) : 30 + Abstract Algebra – II : 30	60
<u>* Unit 6 – Unit 9 (240 marks) are common to both the pure and applied streams.</u>		
Unit 10 :	• Mechanics of Fluids : Applied Stream	60
	• Differential Geometry–II : 30 + Topology–II : 30 – Pure Stream	60

B. B. Pal

(B. B. Pal)

The Head of the Department of Mathematics

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No

Detailed Syllabi for the First Semester and Second Semester of the Semester System :

M. Sc. Course in Mathematics (Pure and Applied Streams)

I. The First Semester

(Unit 1 – Unit 5 : 60 Marks in each Unit)

UNIT – 1

Real Analysis – I

(Pure and Applied Streams)

Marks : 30

Cardinal number : Definition, Schröder-Berstein theorem, Order relation of cardinal numbers, Arithmetic of cardinal numbers, Continuum hypothesis (4)

Cantor's set : Construction and its presentation as an uncountable set of measure zero (2)

Functions of bounded variation : Definition and basic properties, Lipschitz condition, Jordan decomposition, Nature of points of discontinuity, Nature of points of non-differentiability, Convergence in variation (Helly's First theorem). (7)

Absolutely continuous functions : Definition and basic properties, Deduction of the class of all absolutely continuous functions as a proper subclass of all functions of bounded variation, Characterization of an absolutely continuous function in terms of its derivative vanishing almost everywhere. (5)

Riemann-Stieltjes integral : Existence and basic properties, Integration by parts, Integration of a continuous function with respect to a step function, Convergence theorems in respect of integrand, convergence theorem in respect of integrator (Helly's Second theorem). (7)

Gauge partition : Definition of a delta-fine tagged partition and its existence, Lebesgue's criterion for Riemann integrability, Delta-fine free tagged partition and an equivalent definition of the Riemann integral (5)

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References :

1. W. Rudin : Principles of Mathematical Analysis.
2. D. V. Widder : Laplace Transform.
3. H. L. Royden : Real Analysis.
4. B. K. Lahiri and K. C. Ray : Real Analysis.
5. A. G. Das : The Generalized Riemann Integral.
6. A. G. Das : Theory of Integration – The Riemann, Lebesgue and Henstock-Kurzweil Integrals.
7. W. Sierpinsky : Cardinal Number and Ordinal Number.
8. I. P. Natanson : Theory of Integrals of a Real Variable (Vol. I and II).

UNIT – 1

Complex Analysis – I

(Pure and Applied Streams)

Marks : 30

Riemann's sphere, point at infinity and the extended complex plane. (2)

Functions of a complex variable, limit and continuity. Analytic functions, Cauchy-Riemann equations. Complex integration. Cauchy's fundamental theorem (statement only) and its consequences. Cauchy's integral formula. Derivative of an analytic function, Morera's theorem, Cauchy's inequality, Liouville's theorem, Fundamental theorem of classical algebra. (20)

Uniformly convergent series of analytic functions. Power series. Taylor's theorem. Laurent's theorem. (8)

References :

1. A. I. Markushevich : Theory of Functions of a Complex Variable (Vol. I, II and III).
2. R. V. Churchill and J. W. Brown : Complex Variables and Applications.
3. E. C. Titchmarsh : The Theory of Functions.
4. E. T. Copson : An Introduction to the Theory of Functions of a Complex Variable.

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5. J. B. Conway : Functions of One Complex Variable.
6. L. V. Ahlfors : Complex Analysis.
7. H. S. Kasana : Complex Variables – Theory and Applications.
8. S. Narayan and P. K. Mittal : Theory of Functions of a Complex Variable.
9. A. K. Mukhopadhyay : Functions of Complex Variables and Conformal Transformation.
10. J. M. Howie : Complex Analysis.

UNIT – 2

Ordinary Differential Equations

(Pure and Applied Streams)

Marks : 25

Existence of solutions : Cauchy-Peano Existence theorem for equation $dy / dx = f(x,y)$, Gronwall's lemma, Picard-Lindelöf method of successive approximations. (5)

Solutions of linear differential equations of nth order. Wronskian, Abel's identity, linear dependence and independence of the solution set, Fundamental set of solutions. Green's function for boundary value problem and solution of non-homogenous linear equations. Adjoint and self-adjoint equations. Lagrange's identity. Sturm's separation and comparison theorems for second order linear equations. Regular Sturm-Liouville problems for second order linear equations. Eigen values and eigen functions, expansion in eigen functions. (16)

Solution of linear ordinary differential equations of second order in complex domain. Existence of solutions near an ordinary point and a regular singular point. (4)

References :

1. M. Birkhoff and G. C. Rota : Ordinary Differential equations.
2. E. L. Ince : Ordinary Differential Equations.
3. G. F. Simmons : Differential Equations.
4. E. E. Coddington and N. Levinson : Theory of Ordinary Differential Equations.
5. E. T. Copson : An Introduction to the Theory of Functions of a Complex Variable.

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UNIT – 2

Partial Differential Equations

(Pure and Applied Streams)

Marks : 35

Fundamental Concepts : Surfaces and curves in three dimensions. Orthogonal trajectories of a system of curves on a surface. Pfaffian differential equations in three variables. (4)

First Order Partial Differential Equations : Classification, origin of first order PDE. Classification of integrals, Existence of solutions – Cauchy-Kowalewski theorem (statement only). Quasi-linear equations of the first order. Integral surfaces through a given curve. Orthogonal surfaces. Nonlinear equations. Cauchy’s method of characteristics. Charpit’s and Jacobi’s method of solving first order PDEs. Hamilton-Jacobi equations. (7)

Second Order Partial Differential Equations : Linear PDEs. Solutions for constant and variable coefficients (direct and Monge’s). Cauchy-Euler equations. Classification. Reduction to canonical form and solutions. Riemann’s method of solution of linear hyperbolic equations. (6)

Elliptic Partial Differential Equations : Boundary value problems, Mean-value theorem. Maximum-minimum principle. Stability theorem. Laplace’s equation and its solution in Cartesian, cylindrical and spherical polar coordinates by separation of variables. Poisson’s integral formula. (6)

Parabolic Partial Differential Equations : Boundary conditions. Elementary solution. Solution of diffusion equation in Cartesian, cylindrical and spherical polar coordinates by separation of variables. Maximum-minimum principle, uniqueness and stability property. (4)

Hyperbolic Partial Differential Equations : Solution of one-dimensional wave equation by canonical reduction, initial value problem-D’Alembert’s solution, Riemann-Volterra solution, Solution of wave equation in Cartesian, cylindrical and spherical polar coordinates by separation of variables, Duhamel’s principle. (4)

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Green's function : Method of eigen function and Green's function for Laplace's, diffusion and wave equations. Solution of Dirichlet problem for Laplace's equation in the cases of half-space, circle and sphere. (4)

References :

1. I. N. Sneddon : Elements of Partial Differential Equations.
2. E. Epstein : Partial Differential Equations.
3. G. Greenspan : Introduction to Partial Differential Equations.
4. M. G. Smith : Introduction to the Theory of Partial Differential Equations.

UNIT – 3

Functional Analysis–I

(Pure and Applied Streams)

Marks : 30

Metric spaces. Brief discussions of continuity, completeness, compactness. Hölder and Minkowski inequalities (statement only). (8)

Baire's (category) theorem . Banach's fixed point theorem, applications to solutions of certain systems of linear algebraic equations, Fredholm's integral equation of the second kind, implicit function theorem. Kannan's fixed point theorem. (10)

Real and Complex linear spaces. Normed induced metric. Banach spaces, the spaces R^k , C^k , $C [a, b]$ and l_p . Riesz's lemma. Finite dimensional normed linear spaces and subspaces, completeness, compactness criterion, equivalent norm (with topological significance). (12)

References :

1. E. Kreyszig : Introductory Functional Analysis with Applications.
2. G. Bachman and L. Narici : Functional Analysis.
3. W. Rudin : Functional Analysis.
4. N. Dunford and L. Schwartz : Linear Operators (Part I).
5. A. E. Taylor : Introduction to Functional Analysis.

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6. B. V. Limaye : Functional Analysis.
7. K. Yoshida : Functional Analysis.
8. B. K. Lahiri : Elements of Functional Analysis.

UNIT – 3

Operations Research–I
(Pure and Applied Streams)

Marks : 30

Extension of Linear Programming Methods : Theory of Revised Simplex Method and algorithmic solution approaches to linear programs, Dual-Simplex Method, Decomposition principle and its use to linear programs for decentralized planning problems. (8)

Integer Programming (IP) : The concept of cutting plane for linear integer programs, Gomory's cutting plane method, Gomory's All-Integer Programming Method, Branch-and-Bound Algorithm for general integer programs. (6)

Sequencing Models : The mathematical aspects of Job sequencing and processing problems, Processing n jobs through Two machines, processing n jobs through m machines. (4)

Nonlinear Programming (NLP) : Convex analysis, Necessary and Sufficient optimality conditions, Cauchy's Steepest descent method, Fletcher-Reeves' conjugate direction method, Karush-Kuhn-Tucker (KKT) theory of NLP, Wolfe's and Beale's approaches to Quadratic Programs. (8)

Dynamic Programming (DP) : Basic features of DP problems, Bellman's principle of optimality, Multistage decision process with Forward and Backward recursive relations, DP approaches to linear programs and stage-coach problems. (4)

References :

1. Linear Programming – G. Hadley.
2. Mathematical Programming Techniques – N. S. Kambo.
3. Nonlinear and Dynamic Programming – G. Hadley.
4. Operations Research – K. Swarup, P. K. Gupta and Man Mohan.

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5. Operations Research – H. A. Taha.
 6. Operations Research – S. D. Sharma.
 7. Introduction to Operations Research – A. Frederick, F. S. Hillier and G. J. Lieberman.
 8. Optimization : Theory and Applications – S. S. Rao.
 9. Nonlinear and Mixed-Integer Optimization – Christodoulos A. Floudas.
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UNIT – 4

Mechanics – I (Potential Theory)

(Pure and Applied Streams)

Marks : 30

Concept of potential and attraction for line, surface and volume distributions of matter. Laplace's equation, problems of attraction and potential for simple distribution of matter. (5)

Existence and continuity of first and second derivatives of potential within matter. Poisson's equation, work done by mutual attraction, problems. (7)

Integral theorem of potential theory (statement only) Green's identities, Gauss' average value theorem, continuity of potential and discontinuity of normal derivative of potential for a surface distribution, potential for a single and double layer, Discontinuity of potential. (8)

Boundary value problems of potential theory. Green's function, solution of Dirichlet's problem for a half-space. (5)

Solid and surface spherical harmonics. (5)

References :

1. O. D. Kellogg : Theory of Potential.
 2. P. K. Ghosh : Theory of Potential.
 3. A. S Ramsey : Newtonian Attraction.
 4. T. M. MacRobert : Spherical Harmonics.
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UNIT – 4

Abstract Algebra – I

(Pure and Applied Streams)

Marks : 30

Review of the following topics : Group, Subgroups, Normal Subgroups, Permutation Groups, Symmetric Groups, Alternating Groups, Dihedral Groups, Quotient Groups, Homomorphisms and Isomorphisms of Groups, Cayley's Theorem. Ring, Integral Domain, Skew Field, Field, Characteristic of a Ring and Its Basic Properties. (6)

Direct Product on Groups, Fundamental Theorem of Finitely Generated Abelian Groups (Statement only) and Simple Applications, Classification of Groups upto Order 7. (4)

Group Actions, Conjugacy Class Equations, Cauchy's Theorem, P-Groups, Sylow Theorems and Their Applications, Simple Groups (9)

Subnormal Series, Normal Series, Composition Series. Theorem of Jordan-Holder, Solvable Groups, Commutative Subgroups, Necessary and Sufficient Condition for Solvability of Group, Insolubility of S_n ($n \geq 5$). (7)

Boolean Ring, Regular Ring (Definition and simple properties), Ideals, Quotient Rings. (6)

References :

1. I. N. Herstein – Topics in Algebra.
2. Malik, Mordeson and Sen – Fundamentals of Abstract Algebra.
3. M. R. Adhikari and Abhishek Adhikari – Groups, Rings and Modules with Applications.
4. S. Lang – Algebra.
5. J. B. Fraleigh – A First Course in Abstract Algebra.
6. N. Jacobson – Lecturers in Abstract Algebra.
7. B. C. Chatterjee – Abstract Algebra (Vol. 1).
8. J. A. Gallian – Contemporary Abstract Algebra.
9. T. W. Hungerford – Algebra.
10. Luthar & Passi – Algebra (Vol. 1).

*** Unit 1 – Unit 4 : (240 marks) are common to both the pure and applied streams.**

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UNIT – 5

(Applied Stream and Pure Stream Separately)

APPLIED STREAM

UNIT – 5

Mechanics of Solids

(Applied Stream)

Marks : 60

Brief discussion of tensor transformation, symmetric tensor, alternating tensor. Analysis of strain, Normal strain, shearing strain and their geometrical interpretations. Strain quadratic of Cauchy, Principal strains, Invariants, Saint-Venant's equations of compatibility, equivalence of Eulerian and Lagrangian components of strain in infinitesimal deformation. (12)

Analysis of stress, stress tensor, Equations of equilibrium and motion. Stress quadric of Cauchy. Principal stress and invariants, strain energy function. (10)

Graphical representation of elastic deformation. Equations of elasticity. Generalized Hooke's law. Homogeneous isotropic media. Elastic moduli for isotropic media. Equilibrium and dynamical equations for an isotropic elastic solid. connections of the strain energy function with Hooke's Law, uniqueness of solutions. Clapeyron's Theorem, Beltrami-Michell compatibility equations, Saint-Venant's principle. (15)

Equilibrium of isotropic elastic solid : Deformations under uniform pressure. Deformations of prismatical bar stretched by its own weight and a cylinder immersed in a fluid, twisting of circular bar by couples at the ends. (6)

Torsion : Torsion of cylindrical bars, Torsional rigidity, Torsion function, Lines of shearing stress, simple problems related to circle, ellipse and equilateral triangle. (4)

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Two-dimensional problems : Plane strain, Plane stress, Generalised plane stress, Airy's stress function, General solution of biharmonic equation. Stresses and displacements in terms of complex potentials. Simple problems, stress function appropriate to problems of plane stress. (8)

Waves : Propagation of waves in an isotropic elastic medium, waves of dilatation and distortion. Plane waves. (5)

References :

1. S. Sokolnikoff – Mathematical Theory of Elasticity.
2. A. E. H. Love – A Treatise on the Mathematical Theory of Elasticity.
3. Y. C. Fung – Foundations of Solid Mechanics.
4. S. Timoshenko and N. Goodier – Theory of Elasticity.
5. R. V. Southwell – Theory of Elasticity.

PURE STREAM

UNIT – 5

Differential Geometry – I

(Pure Stream)

Marks : 30

Tensor as a generalized concept of a vector in E^3 . Generalization of this idea to an n-dimensional Euclidean space E^n . An n-dimensional space. Transformation of coordinates, invariant, contravariant and covariant vectors, contravariant and covariant tensors. Mixed tensors. Algebra of tensors, symmetric and skew-symmetric tensors, contraction, outer and inner multiplication of tensors, Quotient law. (10)

Riemannian space. Reciprocal metric tensor, Christoffel symbols, Covariant differentiation of vectors and tensors of rank 1 and 2. Riemannian curvature tensor, Ricci tensor and scalar curvature. Space of constant curvature, Einstein space. (8)

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Curvilinear coordinate system in E^3 . Reciprocal base system. On the meaning of covariant derivative. Intrinsic differentiation. Parallel vector field (6)

Serret-Frenet Formulae for a space curve in E^3 . Curvature and torsion of a space curve. Equation of a straight-line. Helix and Burtrand curves. (6)

References :

1. S. Sokoilnikoff : Tensor Analysis, Theory and Applications to Geometry and Mechanics of Continua.
2. L. P. Eisenhart : An Introduction to Differential Geometry (with the use of Tensor Calculus).
3. T. Y. Thomas : Concepts from Tensor Analysis and Differential Geometry.
4. M. C. Chaki : A Text book of Tensor Calculus.
5. U. C. De, Absos Ali Shaikh and Joydeep Sengupta : Tensor Calculus.
6. U. C. De : Differential Geometry of Curves and Surfaces in E^3 (Tensor Approach).

UNIT – 5

Topology–1

(Pure Stream)

Marks : 30

Definition and examples of topological spaces. Basis for a given topology, necessary and sufficient condition for two bases to be equivalent, sub-base, topologizing of two sets from a subbase. Closed sets, closure and interior, their basic properties and their relations. Neighbourhoods, exterior and boundary, dense sets. Accumulation points and derived sets. Subspace or relative topology, relation of closure, interior, base, subbase, accumulation point between the whole space and the subspace. F_6 and G_8 sets. (15)

Various methods of generation of a topology : from Kuratowski's closure operator, interior operator and neighbourhood system. (4)

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Continuous, open, closed mappings, examples and counter examples, their different characterizations and basic properties, Pasting lemma, homeomorphism, topological properties. (5)

First and second countability, lindelöfness and separability, their mutual relations and various examples and counter examples. Convergence of sequence. Characterizations of limit point, closed and open sets in terms of convergence of sequence in first countable spaces. Heine's continuity criterion. (6)

References :

1. J. Dugundji : Topology.
2. S. Willard : General Topology.
3. J. L. Kelley : General Topology.
4. B. C. Chatterjee, S. Ganguly and M. R. Adhikari : General Topology and Elements of Set Theory.
5. K. D. Joshi : General Topology.
6. W. J. Pervin : Foundation of General Topology.
7. T. D. Moore : Elementary General Topology.
8. P. E. Long : An Introduction to General Topology.
9. G. McCarty : Topology.
10. E. T. Copson : Metric Spaces.
11. N. Bourbaki : General Topology (Part – I & Part – II).
12. C. Kuratowski : Topology (Vol. I and Vol. II).
13. J. H. Manheim : The Genesis of Point Set Topology.
14. J. Munkres : Topology.
15. I. M. Singer and J. A. Thrope : Lecture Notes on Elementary Topology and Geometry.

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II. The Second Semester

(Unit 6 – Unit 10 : 60 Marks in each Unit)

UNIT – 6

Real Analysis–II

(Pure and Applied Streams)

Marks : 30

The Lebesgue measure : Definition of the Lebesgue outer measure on the power set of \mathbb{R} , countable subadditivity, Carathéodory's definition of the Lebesgue measure and basic properties. Measurability of an interval (finite or infinite), Countable additivity, Characterizations of measurable sets by open sets, G_α sets, closed sets and F_σ sets. Measurability of Borel sets, Existence of non-measurable sets. (10)

Measurable functions : Definition on a measurable set in \mathbb{R} and basic properties, Simple functions, Sequences of measurable functions, Measurable functions as the limits of sequences of simple functions, Lusin's theorem on restricted continuity of measurable functions, Egoroff's theorem, Convergence in measure (6)

The Lebesgue integral : Integrals of non-negative simple functions, The integral of non-negative measurable functions on arbitrary measurable sets in \mathbb{R} using integrals of non-negative simple functions, Monotone convergence theorem and Fatou's lemma, The integral of Measurable functions and basic properties, Absolute character of the integral, Dominated convergence theorem, Inclusion of the Riemann integral, Riesz-Fischer theorem on the completeness of the space of Lebesgue integrable functions. (10)

Lebesgue integrability of the derivative of a function of bounded variation on an interval. Descriptive characterization of the Lebesgue integral on intervals by absolutely continuous functions. (4)

References :

1. W. Rudin : Principles of Mathematical Analysis.
2. D. V. Widder : Laplace Transform.
3. H. L. Royden : Real Analysis.

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4. B. K. Lahiri and K. C. Ray : Real Analysis.
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6. A. G. Das : Theory of Integration – The Riemann, Lebesgue and Henstock-Kurzweil Integrals.
7. W. Sierpinsky : Cardinal Number and ordinal Number.
8. I. P. Natanson : Theory of Integrals of a Real Variable (Vol. I and Vol. II).

UNIT – 6

Complex Analysis – II

(Pure and Applied Streams)

Marks : 30

Zeros of an analytic function. Singularities and their classification. Limit points of zeros and poles. Riemann's theorem. Weierstrass-Casorati theorem. Theory of residues. Argument principle. Rouché's theorem. Maximum modulus theorem. Schwarz lemma. Behaviour of a function at the point at infinity. (20)

Contour integration. Conformal mapping, Bilinear transformation. Idea of analytic continuation. (7)

Multivalued functions – branch point. Idea of winding number. (3)

References :

1. A. I. Markushevich : Theory of Functions of a Complex Variable(Vol. I, II and III).
2. R. V. Churchill and J. W. Brown : Complex Variables and Applications.
3. E. C. Titchmarsh : The Theory of Functions.
4. E. T. Copson : An Introduction to the Theory of Functions of a Complex Variable.
5. J. B. Conway : Functions of One Complex Variable.
6. L. V. Ahlfors : Complex Analysis.
7. H. S. Kasana : Complex Variables – Theory and Applications.
8. Shanti Narayan and P. K. Mittal : Theory of Functions of a Complex Variable.
9. A. K. Mukhopadhyay : Functions of Complex Variables and Conformal Transformation.
10. J. M. Howie : Complex Analysis.

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UNIT – 7

Special Functions

(Pure and Applied Streams)

Marks : 20

Solutions of Hypergeometric, Bessel, Legendre, Hermite differential equations. (4)

Legendre polynomial : Generating relation, Recurrence relations, Rodrigue's formula, Schlafli's and Laplace's integral formulae, Orthogonal property, Reconstruction of the Legendre differential equations. (4)

Hermite and Laguerre polynomials : Generating relations, Recurrence relations, Rodrigue's formulae, Orthogonal properties, Reconstructions of the respective differential equations. (6)

Chebyshev polynomial : Definition, Series representation, Recurrence relations, Deduction of Chebyshev differential equation, Orthogonal property. (2)

Bessel's functions : Generating relation for integral index, Recurrence relations, Representations for the indices $\frac{1}{2}$ and $-\frac{1}{2}$, Bessel's integral Formulae, Bessel's function of second kind. (4)

UNIT – 7

Integral Equations

(Pure and Applied Streams)

Marks : 20

Definitions of integral equations and their classification. Volterra integral equations of second kind : Solution by successive approximations. Resolvent kernel and solutions of Volterra integral equations. Fredholm integral equations of second kind : Resolvent kernel, solution in terms of resolvent kernel, solution with separable kernels, Method of successive approximations, iterative scheme for Fredholm integral equations. (8)

Classical Fredholm theory : Fredholm theorems, Fredholm Alternative Principles. (4)

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Hilbert-Schmidt theory : Symmetric kernels, Orthogonal system of functions, Fundamental properties of eigenvalues and eigenfunctions for symmetric kernels, Hilbert-Schmidt theorem. (8)

References :

1. E. T. Copson : An Introduction to the Theory of Functions of a Complex Variable.
2. N. N. Lebedev : Special Functions and their Applications.
3. I. N. Sneddon : Special Functions of Mathematical Physics and Chemistry.
4. E. D. Rainville : Special Function.
5. S. G. Michelins : Linear Integral Equations.
6. I. G. Petrovsky : Lectures on the Theory of Integral Equations.
7. R. P. Kanwal : Linear Integral Equations.

UNIT – 7

**Integral Transforms
(Pure and Applied Streams)**

Marks : 20

Laplace Transform : Definition and basic properties. Laplace integral. Lerch's theorem (statement only). Laplace transforms of elementary functions, of derivatives and Dirac-delta function. Differentiation and integration. Convolution. Inverse transform. Applications to solve ordinary differential equations. (7)

Fourier Transform : Definition and basic properties. Fourier transform of some elementary functions, of derivatives. Inverse Fourier transform. Convolution theorem and Parseval's relation. Applications of Fourier inversion and convolution theorems. Fourier sine and cosine transforms. (7)

Hankel Transform : Definition and inversion formula. Hankel transform of derivatives. Finite Hankel transform. (3)

Applications : Applications of integral transforms to solve two-dimensional Laplace and one-dimensional diffusion and wave equations. (3)

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References :

1. D. V. Widder : The Laplace Transforms.
2. H. S. Carslaw and J. C. Jaeger : Operational Methods in Applied Mathematics.
3. N. V. Mclachlan : Operational Calculus.
4. R. V. Churchill : Operational Mathematics.
5. I. N. Sneddon : The Use of Integral Transforms.

UNIT – 8

**Functional Analysis – II
(Pure and Applied Streams)**

Marks : 30

Linear operators between normed linear spaces, continuity, bounded linear operators, norm of an operator, various expressions for the norm. Spaces of bounded linear operators. Inverse of an operator. Linear functionals. Hahn-Banach theorem (without proof), simple applications. Normed conjugate space and separability of the space. Uniform boundedness principle, simple application. (17)

Inner product spaces, Schwarz's inequality, the induced norm. Hilbert spaces, orthogonality, orthonormality, orthogonal complement. The Riesz representation theorem. Bessel's inequality and its generalisation. Convergence of series corresponding to orthogonal sequence, Fourier coefficient, Parseval identity. (13)

References :

1. E. Kreyszig : Introductory Functional Analysis with Applications.
2. G. Bachman and L. Narici : Functional Analysis.
3. W. Rudin : Functional Analysis.
4. N. Dunford and L. Schwartz : Linear Operators (Part I).
5. A. E. Taylor : Introduction to Functional Analysis.
6. B. V. Limaye : Functional Analysis.
7. K. Yoshida : Functional Analysis.
8. B. K. Lahiri : Elements of Functional Analysis.

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UNIT – 8

Operations Research – II

(Pure and Applied Streams)

Marks : 30

Sensitivity Analysis : Changes in price vector of objective function, changes in resource requirement vector, addition of decision variable, addition of a constraint. (6)

Parametric Programming : Variation in price vector, Variation in requirement vector. (4)

Replacement and Maintenance Models : Failure mechanism of items, General replacement policies for gradual failure of items with constant money value and change of money value at a constant rate over the time period, Selection of best item (6)

Non-Linear Programming (NLP) : Lagrange Function and Multipliers, Lagrange Multipliers methods for nonlinear programs with equality and inequality constraints. (6)
Separable programming, Piecewise linear approximation solution approach, Linear fractional programming. (4)

Bi-criterion Transportation Models : Modelling aspects of cost and time minimizing transportation problems, Trade-off ratio technique in Bi-criterion transportation method. (4)

References :

1. Linear Programming – G. Hadley.
2. Mathematical Programming Techniques – N. S. Kambo.
3. Nonlinear and Dynamic Programming – G. Hadley.
4. Operations Research – K. Swarup, P. K. Gupta and Man Mohan.
5. Operations Research – H. A. Taha.
6. Introduction to Operations Research – A. Frederick, F. S. Hillier and G. J. Lieberman.
7. Engineering Optimization : Theory and Practice – S. S. Rao.
8. Principles of Operations Research – Harvey M. Wagner.
9. Operations Research – P. K. Gupta and D. S. Hira.
10. Nonlinear and Mixed-Integer Optimization – Christodoulos A. Floudas.
11. Operations Research : Theory and Applications – J. K. Sharma.

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UNIT – 9

Mechanics – II (Dynamics of Particles)

(Pure and Applied Streams)

Marks : 30

Lagrangian Formulation : Generalised coordinates. Holonomic and nonholonomic systems. Scleronomic and rheonomic systems. D’Alembert’s principle. Lagrange’s equations. Energy equation for conservative fields. Cyclic (ignorable) coordinates. Generalised potential. (8)

Moving Coordinate System : Coordinate systems with relative translational motions. Rotating coordinate systems. The Coriolis force. Motion on the earth. Effect of Coriolis force on a freely falling particle. Euler’s theorem. Euler’s equations of motion for a rigid body. Eulerian angles. (7)

Variational Principle : Calculus of variations and its applications in shortest distance, minimum surface of revolution, Brachistochrone problem, geodesic. Hamilton’s principle. Lagrange’s undetermined multipliers. Hamilton’s equations of motion. (5)

Canonical Transformations : Canonical coordinates and canonical transformations. Poincaré theorem. Lagrange’s and Poisson’s brackets and their variance under canonical transformations, Hamilton’s equations of motion in Poisson’s bracket. Jacobi’s identity. Hamilton-Jacobi equation. (6)

Small Oscillations : General case of coupled oscillations. Eigen vectors and Eigen frequencies. Orthogonality of Eigen vectors. Normal coordinates. Two-body problem. (4)

References :

1. E. T. Whittaker : A Treatise of Analytical Dynamics of Particles and Rigid Dynamics.
2. Greenwood : Dynamics.
3. F. Chorlton : Dynamics.
4. Routh : Dynamics.
5. H. Lamb : Dynamics.
6. R. G. Takwale and P. S. Puranik : Introduction to Classical Mechanics.
7. H. Goldstein : Classical Mechanics.

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UNIT – 9

Abstract Algebra – II

(Pure and Applied Streams)

Marks : 30

Homomorphism and Isomorphism of Rings, Maximal Ideals, Prime Ideals, Primary Ideals, Jacobson Radicals, Prime Fields, Extension and Embedding of Ring, Quotient Field of an Integral domain, Euclidean Ring, Euclidean Domain, Noetherian and Artinian Rings. (8)

Polynomial Rings, Division Algorithm, Irreducible Polynomials, Eisenstein's Criterion for Irreducibility (5)

Principal Ideal Domain, Unique Factorization Domain, Fundamental Theorem of Arithmetic, Uniqueness of Factorization in $K[x]$, where K is a field. (5)

Extension of Fields, Degrees of Freedom, Algebraic and Transcendental Elements, Algebraic Extension, Algebraic Closed Field, Fundamental Theorem of Algebra, Simple Extension, Normal Extension, Roots of a Polynomial, Splitting Field, Automorphism, Group of Automorphisms, Fixed Field, Elements of Galois Theory, Solvability by Radicals. (12)

References :

1. I. N. Herstein – Topics in Algebra.
2. Malik, Mordeson and Sen – Fundamentals of Abstract Algebra.
3. M. R. Adhikari and Abhishek Adhikari – Groups, Rings and Modules with Applications.
4. S. Lang – Algebra.
5. J. B. Fraleigh – A First Course in Abstract Algebra.
6. N. Jacobson – Lecturers in Abstract Algebra.
7. B. C. Chatterjee – Abstract Algebra (Vol. 1).
8. J. A. Gallian – Contemporary Abstract Algebra.
9. T. W. Hungerford – Algebra.
10. Luthar and Passi – Algebra (Vol. 1).

*** Unit 6 – Unit 9 (240 marks) are common to both the pure and applied streams.**

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UNIT – 10

(Applied Stream and Pure Stream separately)

UNIT – 10

APPLIED STREAM

UNIT – 10

Mechanics of Fluids

(Applied Stream)

Marks : 60

Kinematics : Real and ideal fluids. Streamlines and paths of particles. Steady and unsteady flows. Lagrange's and Euler's methods of description of fluid motion. Accelerations. Boundary surface. Irrotational and rotational motions. Equation of continuity. (10)

Equations of Motion : Lagrange's and Euler's equations of motion. Bernoulli's theorem. Cauchy's integrals. Impulsive action. (8)

Motion in Two Dimensions : Stream function. Sources, sinks and doublets. Images. Image of a source (sink) with regard to a plane and a sphere. Image of a doublet with regard to a sphere, Images in two dimensions. Milne-Thomson circle theorem. Blasius theorem. (8)

General Theory of Irrotational Motion : Flow and circulation. Cyclic and acyclic motions. Impulsive motion. Properties of irrotational motion. Kelvin's theorem of minimum kinetic energy. (6)

Irrotational Motion in Two-dimensions : Motion of translation and rotation of circular and elliptic cylinders in infinite liquid. Streaming motion past cylinders. (6)

Irrotational Motion in Three-dimensions : Motion of a sphere. Liquid streaming past a fixed sphere. Equations of motion of a sphere. Stokes' stream function. (4)

Vortex Motion : Vortex motion and its simple properties. Motion due to circular and rectilinear vortices. Vortex pair and doublet. Karman vortex street. (6)

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Viscous Liquid Motion : Stress components in real fluid. Rate of strain quadric. Stress analysis in fluid motion. Relation between stress and rate of strain. Navier-Stokes' equations. Plane Poiseuille and Couette flow between two parallel plates. Flow through tubes of uniform cross-sections in the form of circle, annulus, ellipse, equilateral triangle and rectangle under constant pressure gradient. (12)

References :

1. W. W. Besant and A. S. Ramsey : A Treatise
2. on Hydrodynamics.
3. G. K. Batchelor : An Introduction to Fluid Mechanics.
4. F. Chorlton : Text Book of Fluid Dynamics.
5. L. D. Landau and E. M. Lipschitz : Fluid Mechanics.
6. R. K. Rathy : An Introduction to Fluid Dynamics.
7. H. Lamb : Hydrodynamics.

UNIT – 10
PURE STREAM

UNIT – 10
Differential Geometry–II

(Pure Stream)

Marks : 30

Intrinsic Geometry of a surface : Nature of surface coordinates, First Fundamental Form, Serret-Frenet Formulae for a surface curve, Geodesics, Isometric surfaces, The Gaussian curvature or Total curvature, Developable surface (10)

Surfaces in Space : The normal line to the surface, Tensor derivative, second Fundamental Form, Weingarten Formulae, The integrability conditions, Equations of Gauss and Codazzi, Mean curvature, Third Fundamental Form. (10)

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Curves on a surface : Meusnier's Theorem, Principal curvature, Lines of curvature, Conjugate direction and Asymptotic Lines, Enneper's Formula, Surfaces of positive and Negative curvature. (10)

References :

1. I. S. Sokolnikoff : Tensor Analysis, Theory and Applications to Geometry and Mechanics of Continua.
2. L. P. Eisenhart : An Introduction to Differential Geometry (with the use of Tensor Calculus).
3. T. Y. Thomas : Concepts from Tensor Analysis and Differential Geometry.
4. U. C. De : Differential Geometry of Curves and Surfaces in E^3 (Tensor Approach).

UNIT – 10

Topology–II

(Pure Stream)

Marks : 30

Separation axioms : T_0 , T_1 , T_2 , T_3 , $T_{3\frac{1}{2}}$, T_4 and T_5 . Their relations, characterizations and basic properties. Urysohn lemma and Tietze's extension theorem (Statement only) and some of their applications. (8)

Compactness : Characterizations and examples. Relation of compactness with separation axioms, basic properties of compactness. Compactness and continuous functions. Sequential compactness, BW Compactness and countable compactness. (6)

Connectedness : Examples, various characterizations and basic properties. Connectedness on the real line. Components and quasi components. Applications of connectedness. (6)

Cartesian product topology, Continuity of maps on product spaces, projections, separation axioms and product spaces. Connectedness in product spaces. Tychonoff product theorem.

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Countability axioms (first and second) and separability in product spaces. Quotient spaces and some basic properties. (10)

References :

1. J. Dugundji : Topology.
2. S. Willard : General Topology.
3. J. L. Kelley : General Topology.
4. B. C. Chatterjee, S. Ganguly and M. R. Adhikari : General Topology and Elements of Set Theory.
5. K. D. Joshi : General Topology.
6. W. J. Pervin : Foundation of General Topology.
7. T. D. Moore : Elementary General Topology.
8. P. E. Long : An Introduction to General Topology.
9. G. McCarty : Topology.
10. E. T. Copson : Metric Spaces.
11. N. Bourbaki : General Topology (Part – I & Part – II).
12. C. Kuratowski : Topology (Vol. I and Vol. II).
13. J. H. Manheim : The Genesis of Point Set Topology.
14. J. Munkres : Topology.
15. I. M. Singer and J. A. Thrope : Lecture Notes on Elementary Topology and Geometry.

(B. B. PAL)

The Head of the Department of Mathematics

(*Contd. to 3rd and 4th Semesters)

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M. Sc. Course in Mathematics (Pure and Applied Streams)

(Total Marks = 1200)

Semester System Course Structure

(Total Four Semesters and 300 marks in each semester)

The Third and Fourth Semesters

Semester-Wise Distribution of Subjects with Marks

III. Third Semester :

<u>Course Name</u>	<u>Subject</u>	<u>Total Marks</u>
Unit 11 (Part-I & Part-II) :	Computer Programming in 'C'	60
Part-I – Computer Programming in 'C' :	Theory	30
Part- II – Computer Programming in 'C' :	Practical	30

*** Unit 11 is common to both the Applied and Pure Streams**

APPLIED STREAM

Unit 12:	Numerical Analysis : Theory	50
Unit 13 :	Numerical Analysis : Practical(in 'C')	40
Unit 14 :	Electromagnetic Theory	50
Unit 15 :	Mathematical Biology	50
Unit 16 :	Dynamical Systems	50

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PURE STREAM

<u>Course Name</u>	<u>Subject</u>	<u>Total Marks</u>
Unit 12:	Linear Algebra	50
Unit 13 :	Calculus of \mathcal{R}^n	40
Unit 14 :	Topological Groups	50
Unit 15 :	Algebraic Topology	50
Unit 16 :	Operator Theory	50

IV. Fourth Semester :

<u>Course Name</u>	<u>Subject</u>	<u>Total Marks</u>
Unit 17 :	Discrete Mathematics	50

*** Unit 17 is common to both the Pure and Applied Streams.**

***Unit 18 and Unit 19 : Two Separate Optional Subjects with 100 Marks under
Each of the Units as Special Fields of Study.**

(The Optional Subjects are Listed in a Separate Sheet)

- The Optional Subjects be offered to the Students of both the Streams (Pure and Applied) on the basis of availability of Teachers as Resource Persons and within the Framed Syllabi of the Optional Subjects.**

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No

<u>Course Name</u>	<u>Subject</u>	<u>Total Marks</u>
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Unit 20 : Advanced - Study Assignment : 25, and Viva-Voce : 25	50
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***Unit 20 is Compulsory to Both the Pure and Applied Streams Students.**

Examination Related Course Criteria (Unit 20) :

- (i) Advanced-Study Works be made by the Students under the Guidance of the Teacher(s) of the Department, and on the basis of Subject–interest of the Students in advanced field of Study in different areas of the **Discipline of Mathematics**.
- (ii) Dissertation of the Advanced-Study Work be prepared by individual student and the same be submitted to the H. O. D. after countersigned by the concerned Teacher(s) and prior to commencement of Viva-Voce.
- (iii) Evaluation of Advanced - Study Work of each of the Students be made by the concerned Teacher of the Department.
- (iv) **Advanced – Study Work Record** be maintained by the Department.
- (v) Viva–Voce be conducted by the Department.
- (vi) At least one External Examiner for each of the Two Streams (Applied and Pure Streams) be appointed for Viva-Voce.

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Optional Subjects with Covering of the Unit 18 & Unit 19 : 100 marks each

I. For both the Applied and Pure Streams

- | |
|--|
| <ol style="list-style-type: none"> 1. Advanced Operations Research – I 2. Advanced Operations Research – II 3. Fuzzy Sets and Systems |
|--|

II. For the Applied and Pure Streams Separately

Applied Stream	Pure Stream
1. Advanced Solid Mechanics	1. Advanced Real Analysis
2. Advanced Fluid Mechanics	2. Measure and Integration
3. Computational Fluid Mechanics	3. Advanced Complex Analysis – I
4. Magneto-Fluid Mechanics	4. Advanced Complex Analysis – II
5. Plasma Physics	5. Advanced Functional Analysis
6. Mathematics of Finance & Insurance	6. Set-Valued Analysis
7. Seismology	7. Abstract Harmonic Analysis
8. Computational Biology	8. Advanced General Topology
9. Mathematical Biology	9. Advanced Algebraic Topology
10. Dynamical Oceanography	10. Advanced Algebra – I
11. Applied Functional Analysis	11. Advanced Algebra – II
12. Advanced Numerical Analysis	12. Advanced Geometry – I
(Part I and Part II) --	13. Advanced Geometry – II
Part- I : Advanced Numerical Analysis :	
Theory – 60 marks	
Part- II : Advanced Numerical Analysis :	
Practical (in ‘C’) – 40 marks	

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Detailed Syllabi for the Third Semester and Fourth Semester of the Semester

System : M. Sc. Course in Mathematics (Pure and Applied Streams)

III. The Third Semester

(The General Subjects)

Unit – 11 (Part – I & Part – II)

Computer Programming in ‘C’

Total Marks : 60

Unit – 11 (Part – I)

Computer Programming : Theory

(Programming in ‘C’)

(Pure and Applied Streams)

Marks : 30

Introduction and a Brief History of ‘C’ Language. (1)

Fundamentals of ‘C’ Language : Basic structure of a ‘C’ program, Basic Data type, Constants and Variables, Identifier, Keywords, Constants, Basic data type, Variables, Declaration and Initialization, Statements and Symbolic constants. Compilation and Execution of a ‘C’ program. (3)

Operators and Expressions : Arithmetic, Relational, Logical operators. Increment, Decrement, Control, Assignment, Bitwise, and Special operators. Precedence rules of operators, Type Conversion (casting), Modes of arithmetic expressions, Conditional expressions. (4)

Input / Output Operations : Formatted I/O - Single character I/O (getchar(), putchar()), Data I/O (scanf(), printf()), String I/O (gets(), puts()). Programming problems. (2)

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Decision Making Statements : Branching – *if* Statement, *ifelse* Statement, Nested *if.... else* Statement. *elseif* and *switch* Statements.

Loop Control : *for* Statement, *while* Statement, *do while* Statement. *break*, *continue* and *exit* Statements. Programming problems. (4)

Functions : Function declaration, Library functions, User defined function, Passing argument to a function, Recursion. Programming problems. (4)

Arrays : Array declaration and static memory allocation. One dimensional, two dimensional and multidimensional arrays. Passing arrays to functions. Sparse matrix. (3)

Pointers : Basic concepts of pointer, Functions and Pointers. Pointers and Arrays, Memory allocation, Passing arrays to functions, Pointer type casting. Programming problems. (3)

Structures and Unions : Declaring a Structure, Accessing a structure element, Storing methods of structure elements, Array of structures, Nested structure, Self – referential structure, Dynamic memory allocation, Passing arrays to function. Union and rules of Union. Programming problems. (4)

File Operations : File Input / Output operations – Opening and Closing a file, Reading and Writing a file. Character counting, Tab space counting, File-Copy program, Text and Binary files. (2)

References :

1. Programming in ANSI C : E. Balaguruswamy.
2. Let Us C : Y. Kanetkar.
3. Programming in C Language : B. S. Gottfred.
4. Mastering Algorithm in C : K. Loudon.
5. The C Programming Language : B.W. Kernighan and D. Ritchie.

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Unit – 11 (Part – II)

Computer Programming : Practical

(Programming in ‘C’)

(Pure and Applied Streams)

Marks : 30*

(*Laboratory Assignment = 5 marks + Viva-Voce = 5 marks
+ Compilation and Execution of Two Problems** = 20 marks).

1. Basic Computation :

- i) Summation of natural numbers up to a given number.
- ii) Summation of odd / even numbers up to a given number.
- iii) Evaluation of the factorial of a given number.
- iv) Summation of all the digits of a number.
- v) Determination of the mean, variance and standard deviation from a list of numbers.

(6)

2. Number Testing [Hints are provided] :

- i) Generation of all the terms of Fibonacci Series up to a certain number.

(Hints : General term in Fibonacci Series is as follows :

$$F[i] = i, \quad \text{if } i < 2$$
$$= F[i - 1] + F[i - 2], \text{ if } i \geq 2$$

(The resultant series is : 0,1,1,2,3,5,8,13,21,34,55 etc.)

- ii) Testing of whether a number is prime or not.
- iii) Checking whether a number is Armstrong number or not (Hints : A number is Armstrong if sum of the cubes of its digits, matches with the number – e.g., $153 = 1^3 + 5^3 + 3^3$).
- iv) Checking whether a number is Peterson number or not (Hints : A number is Peterson if sum of the factorials of its digits, matches with the number – e.g., $145 = 1! + 4! + 5!$).

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v) Checking whether a number is Perfect number or not (Hints : a number is Perfect if sum of the factors (except itself), matches with the number- e.g. $28=1+2+4+7+14$).

(8)

3. Series Computation :

i) The Exponential Series : $e^x (= 1 + x + x^2/ 2! + x^3/ 3! \dots$ up to n terms).

ii) The base of a Natural Log : $e (= 1 + 1/ 1! + 1/ 2! + 1/ 3! \dots$ up to n terms).

iii) The Sine Series : $\sin(x) (= x - x^3/ 3! + x^5/ 5! - x^7/ 7!+ \dots$ up to n terms).

iv) The roots of a quadratic equation : $ax^2+bx +c =0$ for any input a ,b, c.

(8)

4. Matrix Operation :

i) Matrix Addition and Matrix Multiplication using 2D Array.

ii) Matrix Inversion using 2D Array.

iii) Sorting of a list of numbers.

iv) Finding of the Amplitude, Modulus, Addition and Subtraction of Complex numbers using Structure.

(8)

****Applications of Branches, Loops, Arrays and Structures mainly be taken into account in Lab. Assignment.**

Practical Examination Related Criteria :

(i) Laboratory clearance be taken by the students prior to commencement of Practical Examination.

(ii) The Lab. Assignment Note Books of the students be submitted prior to commencement of Practical Examination.

(iii) Duration of practical examination will be 3 (Three) hours.

(iv) One External Examiner be appointed for Practical Examination.

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3. Programming in C Language : B. S. Gottfred.
4. Mastering Algorithm in C : K. Loudon.
5. The C Programming Language : B.W. Kernighan and D. Ritchie.
6. C by Example : N. Kalicharan.

APPLIED STREAM

Unit – 12

Numerical Analysis : Theory

(Applied Stream)

Marks : 50

Interpolation : Confluent divided differences . Hermite's interpolation. Interpolation by iteration – Aitken's and Neville's schemes. Cubic spline interpolation, minimizing property of cubic spline, and error estimation. (6)

Approximation of Function : Least square approximation. Weighted least square approximation. Orthogonal polynomials, Gram – Schmidt orthogonalisation process, Chebysev polynomials, Mini- max polynomial approximation. (6)

Numerical Integration : Gaussian quadrature formula and its existence. Bernoulli polynomials and Bernoulli numbers. Euler- MacLaurin formula. Gregory-Newton quadrature formula. Romberg integration. (8)

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Systems of Linear Algebraic Equations : Direct methods –Factorization method.(4)

Eigen value and Eigenvector Problems : Direct methods – Jacobi’s method.
Iterative method – Power method . (4)

Nonlinear Equations : Fixed point iteration method, convergence and error estimation. Modified Newton-Raphson method, Muller’s method, Inverse interpolation method, error estimations and convergence analysis. (10)

Ordinary Differential Equations : Initial value problems – Semi-analytic methods: Picard’s successive approximation method, error estimation. Single-step methods – Euler’s method and Runge-Kutta method, error estimations and convergence analysis. Multi-step method – Milne’s predictor - corrector method, error estimation and convergence analysis. (10)

Boundary Value Problems : Shooting method, error estimation and convergence analysis. (2)

References :

1. Froberg, C. E. – Introduction to Numerical Analysis.
2. Hildebrand, F.B. – Introduction to Numerical Analysis.
3. Ralston, A. and Rabinowits, P. – A First Course in Numerical Analysis.
4. Atkinson, K. and Cheney, W. – Numerical Analysis.
5. David, K. and Cheney, W. – Numerical Analysis.
6. Jain, M. F., Iyenger, S. R. K. and Jain, R.K. – Numerical Methods for Scientific and Engineering Computation.
7. Scheid, F. – Numerical Analysis.
8. Powell, M. – Approximation Theory and Methods.
9. Conte, S. D. and Boor, C. D. – Elementary Numerical Analysis : *An Algorithmic Approach.*

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10. Dalton, B. – Numerical Analysis : *An Intelligence Approach to Numerical Computation.*
11. Press, W. H., Flannery, D. P. , Tenkolsky S. K., and Venner Link W. T.– Numerical Recipes.
12. Sanyal, D. C. and Das, K. - A Text Book of Numerical Analysis.
13. Rajaraman, V. – Computer Oriented Numerical Methods.
14. Balagurusamy, E. – Computer Oriented Numerical Methods.
15. Reddy, J. N. – An Introduction to Finite Element Methods.
16. Sastry, S. S. – Introductory Methods of Numerical Analysis.

Unit – 13

Numerical Analysis : Practical

(Programming in ‘C’)

(Applied Stream)

Marks : 40*

(*Laboratory Assignment = 5 marks + Viva-Voce = 5 marks
+ Compilation and Execution of Two Problems = 30 marks).

Numerical Computation :

1. Interpolation and Approximation :
 - (i) Hermite and cubic spline interpolations,
 - (ii) Least square approximation.
2. Numerical Integration : (i) Gaussian quadrature, (ii) Romberg formula.
3. Solutions of a System of Linear Algebraic Equations : Factorization method.
4. Eigen value and Eigenvector Problems : (i) Power method.
5. Solutions of Non-linear Equations : Newton-Raphson method.

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6. Numerical Solutions of Ordinary Differential Equations for Initial Value Problems : (i) Euler's method, (ii) Runge-Kutta method, (iii) Milne's predictor-corrector method.

Practical Examination Related Criteria :

- (i) Laboratory Clearance be taken by the students prior to commencement of Practical Examination.
- (ii) The Lab. Assignment Note Books of the students be submitted prior to commencement of Practical Examination.
- (iii) Duration of Practical Examination will be 3 (Three) hours.
- (iv) One External Examiner be appointed for Practical Examination.

References :

- 1. Scheid, F. – Theory and Problems of Numerical Analysis.
- 2. Rajaraman, V. – Computer Oriented Numerical Methods.
- 3. Xavier, C. – C Language and Numerical Methods.
- 4. Salaria, R. S. – Numerical Methods : A Computer Approach.
- 5. Balagurusamy, E. – Computer Oriented Statistical and Numerical Methods.
- 6. Sanyal, D. C. and Das, K – A Text Book of Numerical Analysis.
- 7. Mukhopadhyay, A. K. – Introduction to Numerical Methods with Computer Programming.
- 8. Kahaner, D., Moler C., and Nash S. – Numerical Methods and Software.
- 9. Rice, J. R. – Numerical Methods, Software and Analysis.
- 10. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. – Numerical Methods for Scientific and Engineering Computation.
- 11. Conte, S. D. and Boor, C. D. – Elementary Numerical Analysis : *An Algorithmic Approach*.
- 12. Dalton, B. – Numerical Analysis : *An Intelligence Approach to Numerical Computation*.

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Unit – 14

Electromagnetic Theory

(Applied Stream)

Marks : 50

Electrostatics : Law of force, Electrostatic potential, Gauss' Law. Conductors and dielectrics. Energy of the electrostatic field. Electric dipoles. Double layers. Capacitors, Polarization, Electric displacements and energy. (8)

Steady currents: Current vector, ohm's law, Differential equations of the field and flow. (3)

Magnetostatics: Lorentz force, Magnetic induction. Biot-Savart law. Laws of magnetostatics. Ampere's law. Magnetic potentials. Magnetic dipole. Magnetic media. Magnetization current, Equations of the magnetic field. Boundary conditions. (10)

Maxwell's equations: Equations of continuity for time – varying fields, Maxwell equations. Boundary conditions. Maxwell's stress. (6)

Electromagnetic waves : Wave equation. Plane waves in a uniform non- conducting medium, Polarization. Electromagnetic energy and Poynting's theorem. Energy flux in a plane wave. Plane waves in a conducting medium. Reflection and refraction at a dielectric boundary, Fresnel relations. Reflection from a conductor- normal incidence. (15)

Relativistic electrodynamics: The principle of relativity. Lorentz transformation, Transformation of electrodynamics variables. Theory of special relativity (statement of the principles only). Transform relations for systems in relative motion, Derivation of electromagnetic relations. (8)

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References :

1. Jackson, J, D – Classical Electrodynamics.
2. Hallen, E. – Electromagnetic Theory.
3. Jaens, J, H – Mathematical Theory of Electricity and Magnetism.
4. Jones, D. S – The Theory of Electromagnetism.
5. Sommerfield, A. – Electrodynamics
6. Landan, L. D and Lifshitz, E. M – The classical Theory of Fields.
7. Coulson, C. A and Boyd, T. J. M. – Electricity.
8. Cullwick, E. G. – Electromagnetism and Relativity.
9. Smith, J, H. – Introduction to Special Relativity.
10. Barut, A. O. – Electrodynamics and classical Theory of Fields and Particles.

Unit – 15

Mathematical Biology

(Applied Stream)

Marks : 50

A brief introduction to mathematical aspects in Biological System.

Microbial population model : Microbial growth in a chemostat. Stability of steady states. Growth of microbial population. Product formation due to microbial action. Competition for a growth- rate limiting substrate in a chemostat. (10)

Mathematical models in ecology : Discrete and Continuous population models for single species. Logistic models and their stability analysis. Lag factor and stability of population steady states. Random perturbations on population stability. Average life time of a population. (15)

Continuous models for two interacting populations: Lotka-Volterra model of predator -prey system, Kolmogorov model. Trophic function. Analysis of predator-

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prey model with in limit cycle behaviour. Nonlinear oscillations in predator-prey system. (10)

Continuous models for three or more interacting populations: Food chain models. Stability of food chains. (5)

Species harvesting in competitive environment, Economic aspects of harvesting in predator-prey systems. (6)

Optimal pollution control models : Basic concepts and formulations of water pollution, air pollution, disposal of waste products, noise and environment pollution models. (4)

References :

1. K. E. Watt : Ecology and Resource Management-A Quantitative Approach.
2. S. J. Maynard : Models in Ecology.
3. R. M. May : Stability and Complexity in Model Ecosystem.
4. M. Williamson : The Analysis of Biological populations.
5. Y. M. Svirezhev and D. O. Logofet : Stability of Biological Communities.
6. A. Segel : Modelling Dynamic Phenomena in Molecular Biology.
7. J. D. Murray : Mathematical Biology.
8. A. S. Ghosh : Management and Analysis of Biological populations.
9. N. T. J. Bailey : The Mathematical Approach to Biology and Medicine.
10. J. Lolka : Elements of Mathematical Biology.
11. J. N. Kapur : Mathematical Models in Biology and Medicine.
12. N. Rashevsky : Mathematical principles in Biology.

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Unit – 16
Dynamical Systems
(Applied Stream)
Marks : 50

Autonomous and non-autonomous systems : Orbit of a map, fixed point, equilibrium point, periodic point, circular map, configuration space and phase space. (10)

Nonlinear oscillators-conservative system. Hamiltonian system. Various types of oscillators in nonlinear system viz. simple pendulum, and rotating pendulum. (7)

Limit cycles : Poincaré-Bendixon theorem (statement only). Criterion for the existence of limit cycle for Liénard's equation. (5)

Stability : Definition in Liapunov sense. Routh-Hurwitz criterion for nonlinear systems. Liapunov's criterion for stability. Stability of periodic solutions. Floquet's theorem. (12)

Solutions of nonlinear differential equations by perturbation method : Secular term. Nonlinear damping. Solutions for the equations of motion of a simple pendulum, Duffing and Vander Pol oscillators. (6)

Bifurcation Theory : Origin of Bifurcation, Bifurcation Value, Normalisation, Resonance, Stability of a fixed point. Bifurcation of equilibrium solutions – the saddle node bifurcation, the pitch-fork bifurcation, Hopf-bifurcation. (6)

Randomness of orbits of a dynamical system : The Lorentz equations, Chaos, Strange attractors. (4)

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References :

1. D. W. Jordan and P. Smith : Nonlinear Ordinary Differential Equations.
 2. F. Verhulst : Nonlinear Differential Equations and Dynamic Systems.
 3. R. L. Davaney : An Introduction to Chaotic Dynamical Systems.
 4. P. G. Drazin : Non-linear Systems.
 5. K. Arrowsmith : Introduction to Dynamical Systems.
 6. C. Havyski : Nonlinear Oscillations in Physical Systems.
 7. A. H. Nayfeh and D. T. Mook : Nonlinear Oscillations.
 8. V. I. Arnold : Dynamical Systems V-Bifurcation Theory and Catastrophy Theory.
 9. V. I. Arnold : Dynamical Systems III – Mathematical Aspects of Classical and Celestial Mechanics.
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No

PURE STREAM

Unit – 12

Linear Algebra

(Pure Stream)

Marks : 50

Matrices over a field: Matric polynomial, Characteristic polynomial, Minimal polynomial, Eigen values and eigen vectors. (4)

Linear Transformation (L.T.): Definition and the algebra of L.T., Rank and Nullity of L.T., Dual space, dual basis, Representation of L.T. by matrices, Change of basis. (5)

Normal forms of matrices: Smith's normal form, Invariant factors and elementary divisors, Unitary Similarity, Unitary and Normal Operators on inner product spaces. (8)

Some other canonical forms: Triangular form. Jordan form, Rational (or Natural Normal) form. (5)

Bilinear forms: Equivalence of bilinear forms, Symmetric and skew-symmetric bilinear forms, Sylvester law of inertia for quadratic forms, Hermitian Form. (8)

Module Theory: Definition of modules, examples. Submodules, intersections and sums of submodules. Generated submodule, generators of a submodule. Homomorphisms of modules, Exact sequence. Quotient module. Correspondence theorem. Isomorphism Theorems on Modules. Modules with chain conditions. Simple modules. Free modules. (20)

References :

1. A.I. Malcev : Foundation of Linear Algebra.
2. I. N. Herstein : Topics in Algebra.

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3. K.Hoffman and R. Kunze : Linear Algebra.
4. B.C. Chatterjee : Linear Algebra.
5. J. H. Kwak and S. Hong : Linear Algebra.
6. E. D. Nering : Linear Algebra and Matrix Theory.
7. T. S. Blyth : Module Theory.
8. I. S. Luthar and I. B. S. Passi : Modules.
9. L. A. Kurdachenko, J. Otal and I. Y. Subbotin : Artinian Modules over Group, Rings.
10. M. R. Adhikari : Groups, Rings and Modules with Applications.

Unit – 13

Calculus of \mathfrak{R}^n

(Pure Stream)

Marks : 40

Differentiation on \mathfrak{R}^n : Directional derivatives and continuity, the total derivative and continuity, total derivative in terms of partial derivatives, the matrix transformation of $T : \mathfrak{R}^n \rightarrow \mathfrak{R}^n$. The Jacobian matrix. (5)

The chain rule and its matrix form. Mean value theorem for vector valued function. Mean value inequality. (3)

A sufficient condition for differentiability. A sufficient condition for mixed partial derivatives. (2)

Functions with non-zero Jacobian determinant, the inverse function theorem, the implicit function theorem as an application of Inverse function theorem. Extremum problems with side conditions – Lagrange's necessary conditions as an application of Inverse function theorem. (15)

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Integration on \mathfrak{R}^n : Integral of $f : A \rightarrow \mathfrak{R}$ when $A \subset \mathfrak{R}^n$ is a closed rectangle.
Conditions of integrability.

Integrals of $f : C \rightarrow \mathfrak{R}$, $C \subset \mathfrak{R}^n$ is not a rectangle, concept of Jordan measurability of a set in \mathfrak{R}^n .

Fubini's theorem for integral of $f : A \times B \rightarrow \mathfrak{R}$, $A \subset \mathfrak{R}^n$, $B \subset \mathfrak{R}^n$, are closed rectangles.

Fubini's theorem for $f : C \rightarrow \mathfrak{R}$, $C \subset A \times B$.

Formula for change of variables in an integral in \mathfrak{R}^n . (15)

References :

1. T. M. Apostol : Mathematical Analysis.
2. M. Spivak : Calculus on Manifolds.

Unit – 14

Topological Groups

(Pure Stream)

Marks : 50

Definition of topological group and examples. Right and left translations. Homogeneity property in a topological group. Fundamental neighbourhood system of the identity element. Separation axioms in topological groups. (15)

Subgroups. Criteria to be Hausdorff subgroups. Invariant subgroups and open and closed subgroups. Compactly generated subgroups. Coset space and Quotient space. Natural mapping. Isomorphism theorems. (15)

Uniform structure of a topological group. Locally compact topological group and its basic properties. Properties of topological groups involving connectedness. Invariant pseudo-metrics. Character groups. (20)

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References :

1. T. Husain : Introduction to Topological Groups.
 2. D. Montgomery and L. Zippin : Topological Transformation Groups.
 3. E. Hewitt and K. A. Ross : Abstract Harmonic Analysis (Vol. I).
 4. L. Pontryagin : Topological Groups.
 5. F. J. Higgins : An Introduction to Topological Groups.
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Unit – 15

Algebraic Topology

(Pure Stream)

Marks : 50

Introduction : Geometric complexes and polyhedra. Orientation of geometric complexes. Triangulation. Examples. (2)

Category : Definition and examples. Morphism, uniqueness of identity morphisms, inverses of morphisms, equivalence morphisms. Equivalence of object in a category. Covariant and contravariant functions. Examples. (7)

Homotopy : Definition of homotopy. Homotopy classes. Homotopy equivalences. Null homotopy. Relative homotopy, contractible spaces, Composite of homotopic maps, contractibility, deformation, strong retraction and weak deformation retraction, topological pair, extendibility, retracts of contractibility spaces. (16)

Paths : Definition, Path-connected spaces, their union, intersection and continuous images. Product and inverse of paths. Homotopy of paths, Homotopy between $(f * g) * h$ and $f * (g * h)$. Products of homotopic paths. (5)

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Fundamental group : Definition and verification. Homomorphism and isomorphism of fundamental groups. Fundamental groups of Circle. Torus. The homotopy category of pointed topological spaces. Category of groups and homomorphisms, covariant function between them. (10)

Simplexes and Simplicial homology : Simplexes, Orientation of Simplexes, Complexes, Chains, Boundaries, Cycles, Homology Groups. (10)

References :

1. E. H. Spanier : Algebraic Topology.
 2. A. Dold : Lectures on Algebraic Topology.
 3. W. Massey : Algebraic Topology.
 4. J. Dugundaji : Topology.
 5. S. Williard : General Topology.
 6. C. R. F. Maunder : Algebraic Topology.
 7. B. K. Lahiri : A First Course in Algebraic Topology.
 8. J. R. F. Munkers : Algebraic Topology.
 9. F. H. Croom : Basic Concepts of Algebraic Topology.
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Unit – 16

Operator Theory

(Pure Stream)

Marks : 50

Conjugate (or dual) spaces, determination of conjugate spaces of \mathbb{R}^n , ℓ_p for $1 \leq p < \infty$. Representation theorem for bounded linear functionals on $C[a, b]$ (Statement only), Conjugate spaces of $C[a, b]$ and some other spaces (results only). (10)

Weak convergence and weak* convergence, characterization of weak convergence, sufficient condition for the equivalence of weak* convergence and weak convergence in the dual space. (5)

Canonical imbedding, reflexive spaces, connection between reflexivity and separability, embedding of n. ℓ . spaces into a Banach space, some consequences of reflexivity. (5)

Bounded linear operator, uniqueness theorem, adjoint of an operator and some properties. (2)

Self adjoint, compact, normal, unitary, projection, positive operators, square roots of positive operators : Characterizations and some of their basic properties. Conditions under which the sum of projections is also a projection, expression of the norm of self adjoint operator, invariant subspaces. Closed linear transformation, closed graph theorem and open mapping theorem.

Finite dimensional spectral theorem for normal / self adjoint operators. Spectral theorem for compact self adjoint operators (statement only). (13)

The spectrum of a bounded linear operator, spectral properties of bounded linear operators. Existence and representation of the inverse of I-T, closedness of the

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spectrum, representation of the resolvent operator $R(T)$, non-emptiness of the resolvent set $\sigma(T)$, expression of spectral radius. (13)

Spectral mapping theorem for polynomials. (2)

References :

1. C. Bachman and L. Narici : Functional Analysis.
 2. E. Kreyszing : Introductory Functional Analysis with Applications.
 3. W. Rudin : Functional Analysis.
 4. B. V. Limaye : Functional Analysis.

 5. B. K. Lahiri : Elements of Functional Analysis.
 6. P. K. Jain : Functional Analysis.
 7. G. F. Simons : Introduction to Topology and Analysis.
 8. A. E. Taylor : Introduction to Functional Analysis
 9. S. K. Berbarian : Introduction to Hilbert Spaces.
 10. A. N. Kolmogorov and S. V. Fomin : Elements of the Theory of Functions and Functional Analysis.
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IV. The Fourth Semester
(The General and Optional Subjects)

Unit – 17 (General)

Discrete Mathematics

(Applied and Pure Streams)

Marks : 50

Graph Theory : Definition of (undirected) graphs, circuits, cycles, sub-graphs, induced sub-graphs. Degree of vertex. Connectivity. Planar graphs and their properties. Trees, Euler's formula for connected graphs. Complete and complete bipartite graphs. spanning trees. Fundamental cut set and cycles. Matrix representation of graphs, Kuratowski's theorem (statement only) and its use. Chromatic index ,chromatic numbers and stability numbers. (15)

Lattices : Lattices as partial ordered sets. Their properties. Lattices as algebraic system. Sublattices. Direct products and Homomorphism. Some special Lattices e.g. complete complemented and distributed lattices. (5)

Boolean Algebra : Basic Definitions, Duality, Basic theorems, Boolean algebra as lattices, Sum and Product of Boolean algebra Minimal Boolean Expressions, Prime implicants, Logic gates and circuits. Truth tables, Boolean functions. Applications of Boolean Algebra to Switching theory (using AND,OR & NOT gates). Karnaugh Map method. (12)

Combinatorics : Introduction, Basic counting principles, permutation and combination, pigeonhole principles, Recurrence relations and generating functions. (8)

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Grammar and Language : Introduction, Alphabets, Words, Free semi group, Languages, Regular expression and regular languages. Finite Automata (FA). Grammars. Finite State Machine. Non-deterministic and deterministic FA.

Push Down Automation (PDA). Equivalence of PDAs and Context Free Languages (CFLs), Computable Functions. (10)

References :

1. J. P Tremblay and R. Manohar : Discrete Mathematical Structures with Applications to Computers.
2. J. L. Gersting : Mathematical Structures for Computer Sciences.
3. S. Lepschutz : Finite Mathematics.
4. S. Wiitala : Discrete Mathematics – A Unified Approach.
5. J. E. Hopcroft and J. D. Ullman : Introduction to Automata Theory, Languages and Computation.
6. C. L. Liu : Elements of Discrete Mathematics.
7. F. Harary : Graph Theory.
8. C. Berge : The Theory of Graphs and its Applications.
9. N. Deo : Graph Theory with Applications to Engineering and Computer Science.
10. K. D. Joshi : Foundation of Discrete Mathematics.
11. S. Sahani : Concept of Discrete Mathematics.
12. L. S. Levy : Discrete Structure in computer Science.
13. J. H. Varlist and R. M. Wilson : A course in Combinatorics.
14. J. E. Whitesitt : Boolean Algebra and its Applications.
15. G. E. Revesz : Introduction to Formal Languages.
16. G. Birkhoff and T. C. Bartee : Modern Applied Algebra.
17. K. L. P. Mishra and N. Chandrasekaran : Automata, Languages, and Computation.

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Detailed Syllabi for the Optional Subjects with Covering of

Unit 18 and Unit 19 : 100 Marks Each

(APPLIED and PURE STREAMS)

Advanced Operations Research–I

Optional Subject (Applied and Pure Streams)

Marks : 100

Network Analysis– Project management by PERT and CPM : A brief introduction to PERT and CPM, Components of PERT/CPM Network and precedence relationships, Critical path analysis, PERT analysis in controlling project. (6)

Theory of Inventory Control : A brief introduction to Inventory Control, Single-item deterministic models without shortages and with shortages, models with price breaks. Dynamic Demand Inventory Models. (10)

Single-item stochastic models without Set-up cost and with Set-up cost (6)

Multi-item inventory models with the limitations on warehouse capacity, Average inventory capacity, Capital investment. (4)

Queueing Theory : Basic features of Queueing Systems, Operating characteristics of a Queueing System, Arrival and Departure (birth and death) distributions, Inter-arrival and service times distributions, Transient steady-state conditions in queueing process.

Poisson queueing models : $(M / M / 1) : (\infty / \text{FIFO} / \infty)$; $(M / M / 1) : (N / \text{FIFO} / \infty)$;

$(M / M / C) : (\infty / \text{FIFO} / \infty)$; $(M / M / C) : (N / \text{FIFO} / \infty)$, $C \leq N$;

$(M / M / R) : (K / \text{GD} / K)$, $R < K$ – machine servicing model ; Non-Poisson Queueing

Model : $(M / G / 1) : (\infty / \text{GD} / \infty)$ – (P-K) formula. (12)

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Simulation : A brief introduction to simulation, Advantages of simulations over traditional search methods, Limitations of simulation techniques, Computational aspects of simulating a system, random number generation in stochastic simulation, Monte-Carlo simulation and modelling aspects of a system, Simulation approaches to inventory and queueing systems, Project scheduling by PERT, Investment and budgeting. (6)

Linear Multi-Objective Programming (LMOP) : Conversion of LMOP to linear programming, *Minsum* and *Priority based* Goal Programming (GP) approaches to LMOP problems, Fuzzy Set -Theoretic approaches to GP Problems. (6)

Hierarchical Decision Analysis : Introduction to Bilevel Programming (BLP) and Multilevel Programming (MLP), Crisps and Fuzzy Programming approaches to BLP and MLP problems. (6)

Genetic Algorithms (GAs) : Introduction to GAs, Robustness of GAs over traditional search methods. Binary encodings of candidate solutions, Schema Theorem and Building Block Hypothesis, Genetic operators – crossover and mutation, parameters for GAs, Reproduction mechanism for producing Offspring, Darwinian Principle in evaluating objective function, Simple GA schemes, GA approaches to optimization problems. (8)

Reference :

1. Operations Research – K. Swarup, P. K. Gupta and Man Mohan.
2. Operations Research – H. A. Taha.
3. Operations Research – S. D. Sharma.
4. Introduction to Operations Research – A. Frederick, F. S. Hillier and G. J. Lieberman.
5. Optimization Theory and Applications – S. S. Rao.
6. Engineering Optimization : Theory and Practice – S. S. Rao

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7. Mathematical Programming Methods – G. Zoutendijk.
8. Optimization Methods in Operation Research – K. V. Mital.
9. Inventory Control – J. Jonson and D. Montogomer.
10. Analysis of Inventory Systems – G. Haddly and T. M. Within.
11. Queuing Theory – J. A. Panico.
12. Introduction to Theory of Queues – L. Takacs.
13. Linear Programming in Single and Multiple Objective System – J. P. Ignizio.
14. Decisions with Multiple Objectives – R. L. Keeney and H. Raiffs.
15. Linear Goal Programming – M. J. Schniederjans.
16. Linear Multiobjective Programming – M. Zeleny.
17. Multi-objective Programming and Goal Programming : *Theory and Applications* – T. Tanino, T. Tanaka and M. Inuiguchi.
18. Mult-objective Programming and Goal Programming : *Theory and Applications* – M. Tamiz.
19. Goal Programming and Extensions – J. P. Ignizio.
20. Handbook of Critical Issues in Goal Programming – C. Romero.
21. Fuzzy Multiple Objective Decision Making – Y. J. Lai and C. L. Hwang.
22. Fuzzy Systems Theory and its Applications – T. Terano, K. Asai and M. Sugeno.
23. Fuzzy Set Theory and its Applications – H. J. Zimmermann.
24. Genetic Algorithms in Search, Optimization and Machine Learning – D. E. Goldberg.
25. An Introduction to Genetic Algorithms – M. Mitchell.
26. Genetic Algorithms – K. F. Man, K. S. Tang and S. Kwong.
27. Genetic Algorithms + Data Structures = Evolution Programs – Z. Michalewicz.
28. Adaptation in Natural and Artificial Systems - J. H. Holland.

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No

Advanced Operations Research–II
Optional Subject (Applied and Pure Streams)

Marks : 100

Reliability : Elements of Reliability theory, failure rate, extreme value distribution, analysis of stochastically failing equipments including the reliability function, reliability and growth model. (8)

Network Flow : Max-flow Min-cut theorem, Generalized Max-flow Min-cut theorem, linear programming interpretation of Max-flow Min-cut theorem, minimum cost flows. (12)

Information Theory : Information concept, expected information, bivariate information theory, economic relations involving conditional probabilities, Entropy and properties of entropy function. (13)

Coding theory : Communication system, encoding and decoding, Shannon-Fano encoding procedure, Haffman encoding, noiseless coding theory, noisy coding, error detection and correction, minimum distance decoding, family of codes, Hamming code, Golay code, BCH codes, Reed-Muller code, perfect code, codes and design, Linear codes and their dual, weight distribution. (15)

Stochastic Process : Stochastic Linear Programming. (4)

Decision Analysis : Introduction to Decision analysis, Types of decision environment, expected monetary value, perfect information, opportunity loss, decision making under uncertainty, conflict resolution, decision tree analysis, decision making under utilities, utility function, utility curve, Bayesian analysis (10)

Markovian Decision Process : Ergodic matrices, regular matrices, imbedded Markov Chain method for Steady State solution. (8)

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References :

1. An Introduction to Information Theory – F. M. Reza.
2. Operations Research : *An Introduction* – P. K. Gupta and D.S. Hira.
3. Graph Theory with Applications to Engineering and Computer Science – N. Deo.
4. Operations Research –K. Swarup, P. K. Gupta and Man Mohan.
5. Coding and Information Theory – Steven Roman.
6. Coding Theory, A First Course – San Ling r choaping Xing.
7. Introduction to Coding Theory – J. H. Van Lint
8. The Theory of Error Correcting Codes – Mac William and Sloane.
9. Information and Coding Theory – Grenth A. Jones and J. Marry Jones.
10. Information Theory, Coding and Cryptography – Ranjan Bose.

Fuzzy Sets and Systems

Optional Subject (Applied and Pure Streams)

Marks : 100

Basis of Fuzzy Sets : A brief review of Classical sets. Basic concepts of *fuzzy sets*. Philosophical issues of Vagueness and Quantification of ambiguity in *Fuzzy Set Theory*. Characterization of Membership Functions in *fuzzy sets* representation. Basic definitions of *fuzzy sets* , Basis of *fuzzy sets* – Complement, Support, α -cuts and Resolution principle, Convexity, Normality, Cardinality, m^{th} power of *fuzzy sets*, Concept of Zadeh's *fuzzy functions*. Set-theoretic operations on *fuzzy sets*. t-norms and t-conorms. (10)

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Extension Principle and Fuzzy Arithmetic : Zadeh's *extension principle* and other *extension principles*. The concept of image and inverse image of *fuzzy sets*. Cartesian product, and *extension principle* in Cartesian Space.

Fuzzy numbers and basic operations on *fuzzy numbers*, *Extension principle* for extended operations on *fuzzy numbers*, Operations on L–R *fuzzy numbers*. (8)

Fuzzy Relations : Crisp versus *fuzzy relations*, Composition of *fuzzy relations*. Fuzzy equivalence relations and Compatibility relations, Fuzzy ordering relations. Operations on *fuzzy relations*, Fuzzy matrices and Fuzzy graphs in Fuzzy relation equations. (8)

Possibility Theory : Introduction to Probability measures and Plausibility measures, Belief functions. Possibility and Fuzzy Sets : Possibility distributions, Possibility and Necessity measures, Sugeno's Fuzzy Integral and conditional Fuzzy measure. (8)

Fuzzy Logic : A brief review of Classical logic, Basic concepts of *fuzzy logic* : Linguistic variables, Linguistic hedges, Detection of hazards. Fuzzy expressions, Monotonicity of Fuzzy expressions, Canonical disjunctive form of a Fuzzy expression. Basic principles of *fuzzy logic*, Fuzzy propositions, Fuzzy quantifications, Fuzzy Inference rules. Fuzzy extension theorems. (10)

Approximate Reasoning : *Approximate reasoning* in Experts Systems, Propositional Calculus in *approximate reasoning*, *Fuzzy sets* in *approximate reasoning*, Fuzzy propositions in *approximate reasoning*. Transition Modifier rules. Basic principles and rules of inference. Fuzzy Multi-conditional *approximate reasoning*, Rules of inter-valued *fuzzy sets* and Fuzzy relation equations in *approximate reasoning*. (8)

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Fuzzy Logic Control : Introduction to Knowledge- Engineering in Expert Systems, Expert-Knowledge representation techniques, Linguistic description of human judgments. Basic concepts of *fuzzy logic control* . Fuzzy state, Input and Output variables, Fuzzy state space. Basis of *fuzzy logic control* : Fuzzy controller, Inference engine (rule-firing), Fuzzification and defuzzification. The basic *fuzzy logic control* methodology. Takagi-Sugeno *fuzzy logic control* Scheme. (8)

Fuzzy Decision Making : Introduction to decision- making in Fuzzy environment. *Fuzzy sets* representation of objectives and constants. Concept of *Fuzzy set 'decision'*. The use of α -cuts for Fuzzy feasible set representation of a decision- making problem. Modelling aspects of Fuzzy Mathematical Programming problems.

Fuzzy Linear Programming : Fuzzification of Linear Programming problems, *Fuzzy set 'decision'* models of different Fuzzy Linear Programming problems. *Fuzzy set 'decisions'* of Fuzzy Linear Programming problems with fuzzified resource constraints.

Fuzzy Multiobjective Decision- Making : Modelling aspects of Linear fuzzy multiobjective decision-making. Fuzzy programming approaches to linear fuzzy multiobjective programming problems. (10)

References :

1. The Importance of Being Fuzzy – A. Sangalli.
2. Fuzzy Sets and Systems – D. Dubois and H. Prade.
3. Artificial Intelligence Techniques – A. Bundy.
4. Fuzzy Set Theory – R. Lowen.
5. A First Course in Fuzzy Logic – H. T. Nguyen and E. A. Walker.
6. Fuzzy Logic – J. E. Baldwin.
7. Fuzzy Set Theory and Its Applications – H. J. Zimmermann.
8. Fuzzy Sets, Decision making, and Expert System. – H. J. Zimmermann.

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9. Classical and Fuzzy Concepts in Mathematical Logic and Application – M. Reghis and E. Roventa.
10. Fuzzy Sets and Fuzzy Logic *Theory and Applications* – G. J. Klir and B. Yuan.
11. Fuzzy Systems Theory and Its Applications – T. Terano, K. Asai, and M. Sugeno.
12. Introduction to Fuzzy Arithmetic *Theory and Applications* – A. Kaufmann and M. M. Gupta.
13. An Introduction to Fuzzy Control – D. Driankov, H. Hollendoorn and M. Reinfrank.
14. Model Based Fuzzy Control – R. Palm, D. Driankov, and H. Hollendoorn.
15. Theoretical Aspects of Fuzzy Control – H. T. Ngvyen, M. Sugeno, R. Tong, and R. Yager.
16. Fuzzy Control – S. S. Farinwata, D. Filev, and R. Langari.
17. Fuzzy Logic for Planning and Decision Making – F. A. Lootsma.
18. Fuzzy Preference Modelling and Multicriteria Decision Support – J. Fodor and M. Roubens.
19. Fuzzy Multiple Attribute Decision Making *Methods and Applications* – S. J. Chen and C. L. Hwang.
20. Fuzzy Multiple Objective Decision Making – Y. J. Lai and C. L. Hwang.
21. Fuzzy Sets and Interactive Multiobjective Optimization – M. Sakawa.

(**B. B. Pal**)

The Head of the Department of Mathematics

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Detailed Syllabi for the Optional Subjects with Covering of
Unit 18 and Unit 19 : 100 marks each
(APPLIED STREAM)

Advanced Solid Mechanics
Optional Subject (Applied Stream)

Marks : 100

Elastostatics : Orthogonal curvilinear coordinates. Strain and rotation components, dilatation. Equations of motion in terms of dilatation and rotation. Stress equations of motion. Radial displacement. Spherical shell under internal and external pressures, gravitating sphere. Displacement symmetrical about an axis. Cylindrical tube under pressure, rotating cylinder. (15)

Problems of semi-infinite solids with displacements or stresses prescribed on the plane boundary. (4)

Variational methods. Theorems of minimum potential energy. Betti-Rayleigh reciprocal theorem. Use of minimum principle in the case of deflection of elastic string of central line of a beam. (6)

Equilibrium of thin plates. Boundary conditions. Approximate theory of thin plates. Application to thin circular plates. (6)

Elastodynamics: Waves in isotropic elastic solid medium. Surface waves, e.g. Rayleigh and Love waves. Kinematical and dynamical conditions in relation to the motion of a surface of discontinuity. Poisson's and Kirchoff's solutions of the characteristic wave equation. (8)

Radial and rotatory vibration of a solid and hollow sphere. Radial and torsional vibration of a circular cylinder. (6)

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Transverse vibration of plates, Basic differential equations. Vibration of a rectangular plate with simply supported edges. Free vibration of a circular plate. (5)

Plasticity: Basic concepts and yield criteria. Prandtl-Reyss theory, Stress-strain relations of Von-Mises. Hencky's theory of small deformation. (5)

Torsion of cylindrical bars of circular and oval sections. Bending of a prismatic bar of narrow rectangular cross-section by terminal couple. Spherical and cylindrical shell under internal pressure. Plastic deformation of flat rings. (8)

Slip lines and plastic flow. Plastic mass pressed between two parallel planes. (4)

References :

1. Sokolnikoff I. S. : Mathematical Theory of Elasticity.
2. Love A.E. H. : A Treatise on the Mathematical Theory of Elasticity.
3. Fung Y.C. : Foundations of Solid Mechanics.
4. Timoshenko S. and Goodier N : Theory of Elasticity.
5. Ghosh. P.K. : Waves and Vibrations.
6. Prager, N and Hodge , P.G. : Theory of Perfectly Plastic Solids.
7. Southwell, R. V. : Theory of Elasticity.

Advanced Fluid Mechanics

Optional Subject (Applied Stream)

Marks : 100

Incompressible fluid: Elementary theory of aerofoils: Kutta - Joukowski's theorem. Joukowski's hypothesis. Joukowski's, Karmann-Trefftz and Mises family of profiles. Theory of discontinuous potential motion. Kirchhof's method of solving problems of two-dimensional motion with free streamlines. Levi - Cevita's method. Concept of a

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vortex sheet. Karmann's vortex sheet and its stability. Karmann's formula for resistance due to a vortex wake. (15)

Prandtl boundary layer. Boundary layer equations. Blasius solution. Boundary layer parameters. (5)

Compressible fluid: Polytropic gas and its entropy. Adiabatic and isentropic flow. Propagation of small disturbance. Bernoulli's integral. Isentropic flow of a perfect gas. Subsonic and supersonic flow. Mach numbers and critical speeds. Mach lines. Normal and oblique shock waves. Steady isentropic irrotational flow. Prandtl - Maye flow. Hodograph equations, characteristic of steady flow in the real and hodograph plane. (15)

Viscous flow: Navier-Stokes equations in orthogonal curvilinear coordinates. Dissipation of energy. Hydrodynamical theory of lubrication. Principle of similitude. Two – dimensional motion of viscous liquid (equation satisfied by the stream function). Hamel's equation and its solution. Diffusion of vorticity from a line vortex. Stokes and Lambosen's solutions. Prandtl equation of boundary layer. Steady plane and circular jets. (15)

Turbulent flow: Mean values. Reynolds theory. Mixing length theories. Momentum transfer theory. Taylor's vorticity transfer theory. Karmann's similarity hypothesis. Applications to the solutions of (i) mixing zone between two parallel flows, (ii) motion in a plane jet. Prandtl 1/7power law and its application to turbulent boundary layer over a flat- plate. (15)

References :

1. Goldstein, A : Modern Development in Fluid Mechanics (Vol. I & II).
2. Lamb, H. : Hydrodynamics.
3. Milne-Thomson, L. M . : Theoretical Hydrodynamics.
4. Pai, S. I. : Viscous Flow Theory (Vol. I & II).

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5. Landau L. D. and Lifshitz E. M. : Fluid Mechanics.
6. Schlichting H. : Boundary Layer Theory.
7. Young , A. D. : Boundary Layers.
8. Batchelor, G. K. : An Introduction to Fluid Mechanics.
9. Pai, S. I. : Theory of Jets, Turbulent Flow.

Computational Fluid Mechanics

Optional Subject (Applied Stream)

Marks : 100

A brief Introduction to Computational Fluid Mechanics.

Stationary convection : Diffusion equation (finite volume discretization schemes of positive type, upwind discretization). (5)

Nonstationary convection : Diffusion equation: Stability. Discrete maximum principle. (5)

Incompressible Navier-Stokes (NS) equations : Boundary conditions. Spatial and temporal discretization on collocated and on staggered grids. (5)

Iterative method : Stationary methods. Krylov subspace methods. Multigrid methods. Fast position solvers. Iterative methods for incompressible NS equations. (15)

Shallow water equations : One - and two-dimensional cases. (5)

Scalar conservation laws : Godunov's order Barrier Theorem. Linear Schemes. (5)

Euler equation in one space dimension : Analytic aspects. Approximate Riemann solver. Osher scheme. Flux splitting schemes. Stability. James-Schmidt-Turkel scheme. Higher order scheme. (13)

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Discretization in general domains : Boundary fitted grids. Equations of motion in general coordinates. Numerical solution of Euler equation in general coordinates. Numerical solution of NS equations in general domains. (10)

Unified methods : computation of compressible and incompressible flow. (5)

References:

1. Wesseling, P. : Principle of Computational Fluid Dynamics.
2. Anderson, J. D. : Principle of Computational Fluid Dynamics; The Basics with Applications.
3. Wendt, J. F., Anderson J. D., Degrez G. and Dick E. : Principle of Computational Fluid Dynamics.
4. Ferziger, J. H. and Peric, M. : Computational Methods for Fluid Dynamics.

Magneto-Fluid Mechanics
Optional Subject (Applied Stream)

Marks : 100

Fundamental equations: Maxwell's electromagnetic field equations. Basic Magneto-Fluid Dynamics (MFD) equations. Energy conservation equation. Equations for infinitely conducting medium. Lundquist equations. Properties of MFD equations, Magnetic Reynolds number.

Boundary conditions. Alfvén's wave. Magnetic body force. Ferraro's law of isorotation. (16)

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Incompressible magneto-hydrodynamic flow : Parallel steady flow. One-dimensional steady viscous flow. Isentropic and homentropic flows. Hartmann and Couette flows. (12)

Characteristics of MFD waves : Characteristic equation. Characteristic determinant. Magneto hydrodynamic waves. Fast, slow, transverse and entropy waves. (15)

MFD shock waves, and Jump relation: The generalized Hugoniot condition. The compressive nature of magneto hydrodynamic shocks. Mach number, Subsonic and supersonic flows. Sub and super Alfvénic waves. (12)

MFD Stability: Normal mode analysis of stability for infinitely conducting, inviscid and incompressible medium. Rayleigh-Taylor and Kelvin -Helmholtz instabilities in presence of horizontal magnetic field. Capillary instability of a jet in presence of axial magnetic field. Stability of pinch. Principle of exchange instability – marginal stability analysis of a layer of fluid heated from below in presence of uniform magnetic field and gravity perpendicular to the boundary. (15)

References

1. Jeffrey, A.: Magneto Hydrodynamics.
2. Cowling, T. G. : Magneto Hydrodynamics.
3. Ferraro, V. C. A. and Plumpton. C. : An Introduction to Magnetofluid Mechanics.
4. Pai, S. I. : Magnetogas Dynamics and Plasma Dynamics.
5. Cramer, K. R. and Pai S. I. : Magnetofluid Dynamics for Engineers and Physicists.
6. Shercliff, J. A. : Magnetohydrodynamics.
7. Bansal, J. L. : Magnetofluid Dynamics of Viscous Fluids.

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Plasma Physics

Optional Subject (Applied Stream)

Marks : 100

Field of a moving point charge: Radiation from an accelerated charge. Radiation power. Damping force of radiation. Lagrangian and Hamiltonian for the motion of a charge particle in electromagnetic field. (10)

Non-relativistic motion: Non-relativistic motion of charged particles in electric and magnetic fields. Gradient and curvature drifts. (6)

Basic Plasma properties : Waves in unmagnetized and cold magnetized Plasmas. Radiation from plasma-the Bremsstrahlung and Synchrotron radiation. Stream instabilities in cold plasma. (15)

Collision processes in plasmas : Two-body elastic collisions. Two-particle Coulomb interaction. Thomson and Rayleigh scattering. Compton radiation. (8)

Small amplitude waves in plasmas: Linearized equations. Anisotropy of magnetized plasmas. Appleton-Hartree equation. Dielectric and conductivity tensors. Electromagnetic field in dissipative plasmas. (10)

Kinetic approach-Linearized Vlasov equations: Small amplitude Oscillations-Landau damping. (7)

Derivation of MHD equations : General properties, e.g. generalization of Bernoulli's and Kelvin's theorems, diamagnetic drifts and currents. Double-adiabatic theory for collisionless plasma- the Chew-Goldberger-low (CGL) equations. (7)

Space and astrophysical plasmas : Structuring of plasmas in solar system and magnetospheres. Magnetic reconnections. Double layers and particle acceleration.

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Solar wind-magnetosphere-Ionosphere intersection. Solar wind intersection with smaller bodies. (4)

Dusty plasmas : Dusty plasmas and the role of dust in stellar environment, galactic and planetary systems. (3)

References :

1. Jackson, J. D. : Classical Electrodynamics.
 2. Jones, D. S. : Theory of Electromagnetism.
 3. Landau, L. D. and Lifshitz E. M. : Classical Theory of Fields.
 4. Panofsky, W. K. H. and Philips M. : Classical Theory of Fields.
 5. Kompanoyets, A.S. : Theoretical Physics.
 6. Alfven, H. and Falthamman, C. A. : Cosmical Electrodynamics.
 7. Chandrasekher, S. : Plasma Physics.
 8. Thomson, W.B. : An Introduction to Plasma Physics.
 9. Clemmow, P.C. and Dougherty J. P. : Electrodynamics of Particles and Plasma.
 10. Chakraborty, B. : Principles of Plasma Mechanics.
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Mathematics of Finance and Insurance

Optional Subject (Applied Stream)

Marks : 100

Mathematics of Finance (60 marks) :

Financial derivatives : An introduction. Types of financial derivatives – forwards and futures. Option and its kinds; and SWAPS.

The Arbitrage Theorem and Introduction to Portfolio selection and capital Market Theory : Static and Continuous – Time model. (10)

Pricing by Arbitrage : A single –period option pricing model; Multi – period pricing model – Cox – Ross – Rubinstein model; Bounds on option prices.

The Ito's lemma and the Ito's integral. (6)

Dynamics of derivative prices : Stochastic differential equations (SDEs) –Major models of SDEs, Linear constant coefficient SDEs, Geometric SDEs, Square root process, Mean reverting process and Ornstein- Uhlenbeck process. (6)

Martingale measures and risk-neutral probabilities : Pricing of binomial options with equivalent martingale measures. (6)

The Black-Scholes option pricing : Model with no arbitrage approach, limiting case of binomial option pricing and risk –neutral probabilities. (6)

The American Option pricing : Extended trading strategies. Analysis of American put options; early exercise premium and relation of free boundary problem. (6)

Mathematics of Insurance (40 marks):

Concepts from insurance : Introduction. The claim number process. The claim size process. Solvability of the portfolio. Reinsurance and ruin problem. (6)

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Premium and ordering of risks : Premium calculation principles and ordering distributions. (5)

Distribution of aggregate claim amount : Individual and collective model. Compound distribution. Claim number of distribution. Recursive computation methods. Lundberg bounds and approximation by compound distributions. (8)

Risk processes: Time-dependent risk models. Poisson arrival processes. Ruin probabilities and bounds asymptotic and approximation. (5)

Time dependent risk models: Ruin problems and computations of ruin functions. Dual queuing models in continuous time and numerical evaluation of ruin functions. (6)

References :

1. Hull, J. C. – Options, Futures and other Derivatives.
2. Ross, S. M. – An Introduction to Mathematical Finance.
3. Neftci, S. N. – An Introduction to Mathematical Financial Derivatives.
4. Elliott, R. J. and Kopp, P. E. – Mathematics of Financial Markets.
5. Merton, R. C. Continuous – Time Finance.
6. Daykin, C. D., Pentikainen, T. and Pesonen, M. – Practical Risk Theory for Actuaries.
7. Rolski, T., Schmidli, H., Schmidt, V. and Teugels, J. – Stochastic Processes for Insurance and Finance.

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Seismology

Optional Subject (Applied Stream)

Marks : 100

Vibrations and Waves : Theory of elastic waves in perfectly elastic media. Vibration and waves. Seismological considerations. Plane waves Standing waves. Dispersion of waves. Energy in plane wave motion. General solution of wave equation. (10)

Bodily elastic waves: P wave (P-Wave) and Secondary wave (S- waves). The effect of gravity fluctuations. Effect of deviation from perfect elasticity. The Jeffereys–Lomnitz Law. (5)

Surface elastic waves: Surface waves along the plane boundary between two homogeneous perfectly elastic media. Rayleigh waves. Love waves. Dispersion curves. Rayleigh waves in presence of a surface layer. Seismic surface waves. (7)

Reflection and refraction of elastic waves: Laws of reflection and refraction. General equations for the two media. Case of incident Surface Horizontal (SH-wave), P-wave and Surface Vertical (SV-wave) incident against free plane boundary. Reflection and refraction of seismic waves. Lamb’s problem-line load suddenly applied on elastic half-space. Refraction of dispersed waves. (10)

Seismic rays in a spherically stratified earth model: The parameter p of a seismic ray. Relation between p , Δ , T for a given family of rays. Features of the relations between Δ and T corresponding to certain assigned types of variation with r . Derivation of the P-and S-velocity distributions from the (T, Δ) relations. Special velocity distributions, e.g. curvature of a seismic ray, rays in a homogeneous medium, circular rays. (10)

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Amplitude of the surface motion due to seismic waves: Energy per unit area of wave front in an emerging wave. Relation between energy and amplitude Movements of the outer surface arising from an incident wave of given amplitude. Amplitude as a function of Δ . Loss of energy. (10)

Travel-time analysis: Parameters of earthquakes. Epicentral distance and azimuth of an observing station from an epicentre. Theory of the evolution of the main P travel-time table. (7)

Seismology and the earth's upper layers and interior Positions : Theory of travel-times near earthquakes. Physical properties of earth's upper layers. Discontinuities within the earth. (7)

References :

1. Byerlg, P. : Seismology.
2. Richter, C. F. : Elementary Seismology
3. Love, A. E. H. : Some Problems of Geodynamics.
4. Bullen, K. E. : An Introduction to the Theory of Seismology.
5. Bath, M. : Theory of Seismology.

Computational Biology

Optional Subject (Applied Stream)

Marks : 100

A brief review of computational aspects molecular biology.

Basic concepts of molecular biology: DNA and proteins. The central dogma. Gene and Genome sequences. (10)

Restriction maps : Graphs. Interval graphs. Measuring fragment sizes. (10)

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Algorithms for double digest problem (DDP) : Algorithms, and complexity Analysis. Mathematical programming approaches to DDP : Integer programming. Partition problems. Travelling Salesman Problem (TSP). Simulated Annealing (SA). (15)

Sequence assembly: Sequencing strategies. Assembly in practices, fragment overlap statistics, fragment alignment, sequence accuracy. (13)

Sequence comparisons methods: Local and global alignment. Dynamic programming solution method. Multiple sequence alignment. (12)

Stochastic Approach to sequence alignment and sequence pattern-Hidden: Markov chain method for biological sequences. (10)

References :

1. Waterman, M. S. : Introduction to Computational Biology.
 2. Baxevanis, A. and Ouelette, B. : Bioinformatics-A Practical Guide to the Analysis of Genes and Proteins.
 3. Floudas, C. A. : Nonlinear and Mixed -Integer Optimization.
 4. Bellman, R. and Krush, R. : Dynamic Programming – Bibliography of Theory and Applications.
 5. Bellman, R. and Dreyfus, S. E. : Applied Dynamic Programming.
 6. Rao, S. S. : Engineering Optimization.
 7. Devis, L. : Genetic Algorithms and Simulated Annealing.
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Mathematical Biology
Optional Subject (Applied Stream)

Marks : 100

A brief review of mathematical aspects in biological systems.

Epidemic models: Deterministic and stochastic models without and with removal, with removal and immigration, Control of epidemic. (10)

Genetic models: Genetic matrices. Hardy – Weinberg law. Correlation between genetic composition of siblings. Bayesian model. Phenotype ratios. Selection and mutation. Genetic in breeding. (15)

Models in Pharmacokinetics: Compartments. Basic equations. single and two – compartment models. Transfer coefficients and compartment volumes. (10)

Blood flow Models : Basic concepts of blood, special characteristics of blood flow, application of Poiseuille’s law to the study bifurcation in an artery. Pulsatile flow of blood in rigid and elastic tubes. Aortic diastolic - systolic pressure waveforms. Pulse wave propagation in inviscid fluid through artery, Moen-Korteweg expression for pulse wave velocity in elastic tube. Determination of arterial pressure from arterial wall stress and analysis of pressure pulse propagation. Pulse wave propagation in viscous fluid and its application to determine cardiac output. Blood flow through artery with mild stenosis. (20)

Models for other fluids: Peristaltic motion in a channel and in a tube. Two-dimensional flow in renal tubule. Lubrication of human joints. (10)

Biomechanics of bone: Bone as a material of construction. Functional construction and adaptation of bone. (5)

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References:

1. Fung, Y. C. : Biomechanics.
2. Mazumdar, J. : An Introduction to Mathematical Physiology and Biology.
3. Haken, H. : Synergetics of the Brain.
4. Kapur, J. N. : Mathematical Model in Biology and Medicine.
5. Rashevsky, N. : Mathematical Biophysics.
6. Biswas, D. : Blood Flow Models : A Comparative Study.

Dynamical Oceanography
Optional Subject (Applied Stream)

Marks : 100

Hydrothermic equations of seawater. Gibbs relation, Gibbs-Duhem relation, heat capacities, Vaisala frequency, Determination of the thermodynamic properties of seawater. (6)

Equations of motion of seawater. Conservation of mass and diffusion of salt. Kinematic free surface condition taking mass exchange into account. Equation of motion of seawater considered a viscous compressible fluid referred to a frame rotating with the earth. Energy transport equation. Thermodynamic energy equation. Entropy transfer equation. The closure problem and relation between thermodynamic fluxes and gradients of t , p , s . Properties and consequences of the adiabatic equations. Ertel's formula, potential vorticity and Rossby principle. Approximation of the basic equations - Boussinesq and linear approximations, β -approximation, Quasi-geostrophic equations. (18)

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No

Wave motions in the ocean. General properties of plane and nearly plane waves. Linearised small-amplitude waves under gravity in rotating stratified ocean-simple gyroscopic and internal waves, internal gravity waves, plane waves, the energetic of plane waves. Long wave equation for a continuously stratified fluid. Wave reflection and wave trapping by lateral boundaries. Nonlinear surface waves : the Stokes approximation, finite-amplitude wave in shallow water. The solitary wave. (18)

Turbulence : Basic concept. Time-averaged form of the momentum and continuity equations for incompressible flow. Eddy coefficients and their estimations. Elementary examples of the application of eddy coefficients. Salinity tongue in an ocean at rest. (10)

Currents in the ocean. Quasi-static approximation. Geostrophic motion in a stratified ocean. Helland-Hansen formula. Stationary accelerate currents. Steady wind-driven currents in a homogeneous ocean. Wind-drift. Characterization of horizontal and vertical motion. Equation satisfied by the total flow function. Sverdrup's curl relation. Western boundary current. Munk's formula. Sverdrup's study of wind driven current in a baroclinic ocean. Munk's theory of wind-driven ocean circulation. (14)

Tides and storm surges. Statistical theory of tides. Tidal harmonics channel theory of tides. (4)

References :

1. P. H. Leblond and L. A. Mysak : Waves in the Ocean.
2. J. Pedlosky : Geophysical Fluid Dynamics.
3. V. M. Kamenkovch : Fundamentals of Ocean Dynamics.
4. O. M. Philips : Dynamics of the Upper Ocean.

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Applied Functional Analysis
Optional Subject (Applied Stream)

Marks : 100

Review of basic properties of Hilbert spaces. (5)

Convex programming : Support functional of a convex set. Minkowski functional, Separation theorem. Kuhn-Tucker optimality theorem. Mini-Max theorem. Farkas theorem. (10)

Spectral theory of operators : Spectral theory of compact operators. Operators on a separable Hilbert space. Krein factorization theorem for continuous kernels and its consequences. l_2 spaces over Hilbert spaces. Multilinear forms. Analyticity theorem. Nonlinear Volterra operators. (20)

Semigroups of linear operators : General properties of semigroups. Generation of semigroups. Dissipative semigroups. Compact semigroups. Holomorphic semigroups. Elementary examples of semigroups. Extensions. Differential equations. Cauchy problem. Controllability. State reduction. Observability. Stability and stabilizability. Evaluation equations. (20)

Optional control theory : Linear quadratic regulator problems with finite and infinite time intervals. Concept of hard constraints. Final value control. Time optimal control problems. (15)

References :

1. A. V. Balakrishnan : Applied Functional Analysis.
2. N. Dunford and J. T. Schwartz : Linear Operators, Vols. I & II.
3. S. G. Krein : Linear Differential Equations in a Banach Space.
4. K. Yosida : Functional Analysis.
5. M. Avriel : Nonlinear Programming – *Analysis and Methods*.
6. L. Mangasarian : Nonlinear Programming.

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7. S, S. Rao : Optimization – *Theory and Applications*.
8. E. Kreyszing : Introductory Functional Analysis with Applications.
9. D. H. Grieffel : Applied Functional Analysis.
10. J. Zabczyk : Mathematical Control Theory – *An Introduction*.
11. W. L. Brogan : Modern Control Theory.
12. H. Kwakernaak and R. Sivan : Linear Optimal Control Systems.
13. A. Isidori : Nonlinear Control Systems.
14. S. G. Tzafestas : Methods and Applications of Intelligent Control.

Advanced Numerical Analysis (Part- I and Part- II)

Optional Subject (Applied Stream)

Marks : 100

Advanced Numerical Analysis (Part- I) : Theory

Optional Subject (Applied Stream)

Marks : 60

Interpolation : Newton's bivariate interpolation Triangular interpolation, Bilinear interpolation. Approximation: Rational approximation, Continued fraction approximation, Pade approximation. Solution of polynomial equation : Birge-Vieta method, Bairstaw method. (8)

Solution of linear system of equations : Direct methods : Cholosky method, Partition method, error estimations. Iterative methods : Different iterative schemes, Optimal relaxation parameter for SOR method, Convergence analysis. (16)

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Eigen value problems of real symmetric matrices : Bounds of Eigenvalues, Householder's method, Given's method, Inverse power method. (10)

Solution of nonlinear system of equations : Newton's method, Steepest- Descent method, Convergence analysis. (6)

Numerical solution of boundary value problems of Ordinary differential equations : Finite-difference method, Newton-Raphson method (second order equation), error estimations. (5)

Numerical solution of partial differential equations : Introduction to Elliptic, Parabolic and Hyperbolic equations. Explicit methods : Schmidt method, Dufort-Frankel method, Convergence and stability analysis. Implicit methods : Crank-Nicolson method, convergence and stability analysis, Matrix method. (6)

Numerical solution of integral equations : Finite - difference method, Cubic spline method, Method using Generalized quadrature. (5)

Finite Element Methods : Introduction to Finite Element methods. Weighted residual methods : Least square method, Partition method, Variational method : Ritz method. (5)

Finite elements : Line segment element, Triangular element, Rectangular element, Curved-boundary element. (5)

Finite element methods: Ritz finite element method, Least square finite element method, Convergence, Completeness and Compatibility analysis. Boundary value problems in ordinary differential equations : Mixed boundary conditions - Galerkin method. (10)

References :

1. E. V. Krishnamurthy and S. K. Sen : Numerical Algorithms Computations in Science and Engineering.
2. Hildebrand, F. B. : An Introduction to Numerical Analysis.

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No

3. Atkinson, K. E.: An Introduction to Numerical Analysis.
4. Collatz, L. : Functional Analysis and Numerical Mathematics.
5. Fox, L. : Numerical Solution of Ordinary and Partial Differential Equations.
6. Ames, W. F. : Numerical Methods of Partial Differential Equations.
7. Strang, G., Fix, G. : An Analysis of the Finite Element Methods.
8. Zienkiewicz, O. C. : The Finite Element Methods in Structural and Continuum Mechanics.
9. Jain, M. K., Iyengar, S. R. K., Jain, R. K. : Numerical Methods for Scientific and Engineering Computations.
10. Jain, M. K. : Numerical Solution of Differential Equations.
11. Baker, C. T. H. and Phillips, C. : The Numerical Solution of Non-linear Problems.
12. Row, S. S. : Finite Element Methods in Engineering.

**Advanced Numerical Analysis (Part- II): Practical
(Programming in 'C')**

Optional Subject (Applied Stream)

Marks : 40*

(*Laboratory Assignment = 5 marks + Viva- Voce = 5 marks
+ Compilation and Execution of Two Problems = 30 marks).

1. Newton's method for finding real roots of simultaneous equations.
2. Graeffee's Root-squaring method (up to biquadratic).
3. Bairstow's method (up to biquadratic).
4. Q-D (Quotient-Difference) method.
5. Matrix inversion : Cholesky method.
6. Eigen value problems : Jacobi's method, Inverse Power method.

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7. Numerical Solution of ODEs : Explicit and implicit R–K (Runge–Kutta) methods, Predictor–Corrector methods, Adams’ method.
8. Boundary value problems : Finite- difference method.
9. Numerical solutions of PDEs : Crank – Nicolson method.
10. Cubic Spline interpolation using the General Form.
11. Integral equation : Monte – Carlo method.

Practical Examination Related Criteria :

- (i) Laboratory clearance be taken by the students prior to commencement of practical examination.
- (ii) The Lab. Assignment Note Books of the students be submitted prior to commencement of practical examination.
- (iii) Duration of practical examination will be 4 (Four) hours.
- (iv) One external examiner be appointed for practical examination.

References :

1. Krishnamurthy, E. V. and S. K. Sen : Numerical Algorithms Computations in Science and Engineering.
2. Jayashri, J. : The ‘C’ Language Trainer with C Graphics and C++.
3. Balaguruswamy, E. : Programming in ANSI C.
4. Xavier, C : C and Numerical Methods.

(B. B. Pal)

The Head of the Department of Mathematics

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No

Detailed Syllabi for the Optional Subjects with Covering of

Unit 18 and Unit 19 : 100 marks each

(PURE STREAM)

Advanced Real Analysis

Optional Subject (Pure Stream)

Marks : 100

Representation of real numbers by series of radix fractions. Sets of real numbers, Derivatives of a set. Points of condensation of a set. Structure of a bounded closed set. Perfect sets. Perfect kernel of a closed set. Cantor's nondense perfect set. Sets of first and second categories, residual sets. (12)

Baire one functions and their basic properties. One-sided upper and lower limits of a function. Semicontinuous functions. Dini derivatives of a function. Zygmund's monotonicity criterion. (12)

Vitali's covering theorem. Differentiability of monotone functions and of functions of bounded variation. Absolutely continuous functions, Lusin's condition (N), characterization of AC functions in terms of VB functions and Lusin's condition. (6)

Concepts of VB^* , AC^* , VBG^* , ACG^* etc. functions. Characterization of indefinite Lebesgue integral as an absolutely continuous function. (6)

Generalized Integrals : Gauge function. Cousin's lemma. Role of gauge function in elementary real analysis. Definition of the Henstock integral and its fundamental properties. Reconstruction of primitive function. Cauchy criterion for Henstock integrability. Saks-Henstock Lemma. The Absolute Henstock Integral. The McShane integral. Equivalence of the McShane integral, the absolute Henstock integral and the Lebesgue integral. Monotone and Dominated convergence theorems. The Controlled convergence theorem. (16)

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No

Definition and elementary properties of the Perron integral and its equivalence with the Henstock integral. (6)

Definition of the (special) Denjoy integral and its equivalence with the Henstock integral (characterization of indefinite Henstock integral as a continuous ACG^* function). (4)

Density of arbitrary sets. Approximate continuity. Approximate derivative. (4)

References :

1. E. W. Hobson : The Theory of Functions of a Real Variable (Vol. I and II).
 2. I. P. Natanson : Theory of Functions of a Real Variable (Vol. I and II).
 3. R. A. Gordon : The Integrals of Lebesgue, Denjoy, Perron and Henstock, Amer. Math. Soc. Graduate Studies in Math., Vol. 4, 1994.
 4. W. F. Pfeffer : The Riemann Approach to Integration - Local Geometric Theory.
 5. R. Henstock : Lectures on the Theory of Integration.
 6. P. Y Lee : Lanzhou Lectures on Henstock Integration.
 7. S. Schwabik : Generalized Ordinary Differential Equations.
 8. E. J. McShane : Unified Integration.
 9. S. Saks : Theory of the Integral.
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Measure and Integration
Optional Subject (Pure Stream)
Marks : 100

Semi-ring, ring, σ -ring, σ -algebra, monotonic class and monotone ring of subsets of a set. Disjointness Condition. Generated ring, σ -ring, algebra and σ -algebra (4)

Measure on arbitrary non-void class of sets. Basic properties of measures on rings, Continuity from above and below. (3)

Carathédory's outer measure on the power-set of a set, condition of measurability, induced measure, completeness ; regular outer measure and the increasing sets property. Method-I construction of outer measures ; Metric outer measures. (5)

Standard extension theorems for measures, and approximations. (4)

Measurable functions on a measurable space (X, \mathcal{A}) and integration in a measure space (X, \mathcal{A}, μ) , where \mathcal{A} is a σ -algebra of subsets of X . Standard properties of the integral. The Egoroff's theorem. Almost uniform convergence and convergence in measure. (20)

Signed measure on (X, \mathcal{A}) . Hahn decomposition theorem, Jordan decomposition theorem. Complex measure on (X, \mathcal{A}) , its total variation and Jordan decomposition.(6)

Absolute continuity for measures, signed measures and complex measures ; mutual singularity Lebesgue decomposition theorem and Radon-Nikodym theorem. (5)

Product of two measure spaces. Fubini's theorem. (6)

Borel measure and Baire measure in topological spaces. (2)

The Daniell integral. Convergence theorems (5)

References :

1. S. J. Taylor, Introduction to Measure and Integration.
2. E. Hewitt and K. Stromberg, Real and Abstract Analysis.

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No

3. A. J. Weir, General Integration and Measure.
4. S. K. Berberian, Measure and Integration.
5. M. E. Munroe, Measure and Integration.
6. P. R. Halmos, Measure Theory.

Advanced Complex Analysis – I
Optional Subject (Pure Stream)

Marks : 100

The functions- $M(r)$ and $A(r)$. Hadamard theorem on the growth of $\log M(r)$, Schwarz inequality, Borel-Caratheodory inequality, Open mapping theorem. (10)

Dirichlet series, abscissa of convergence and abscissa of absolute convergence, their representations in terms of the coefficients of the Dirichlet series. The Riemann Zeta function, the product development and the zeros of the zeta functions. (10)

Entire functions, growth of an entire function, order and type and their representations in terms of the Taylor coefficients, distribution of zeros. Schottky's theorem (no proof). Picard's first theorem. Weierstrass factor theorem, the exponent of convergence of zeros. Hadamard's factorization theorem, Canonical product, Borel's first theorem. Borel's second theorem (statement only). (16)

Multiple-valued functions, Riemann surface for the functions \sqrt{z} , $\log z$ (3)

Analytic continuation, uniqueness, continuation by the method of power series, natural boundary, existence of singularity on the circle of convergence. Functions element, germ and complete analytic functions. Monodormy theorem. (12)

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No

Conformal transformations, Riemann's theorems for circle, Schwarz principle of symmetry, Schwarz-Christoffel formula (statement only) with applications.

Univalent functions, general theorems, sequence of univalent functions, sufficient conditions for univalence. (8)

References :

1. E. T. Copson : An Introduction to the Theory of Functions of a Complex Variable.
2. E. C. Titchmarsh : The Theory of Functions.
3. A. I. Markushevich : Theory of Functions of a Complex Variable (Vol. I, II & III).
4. L. V. Ahlfors : Complex Analysis.
5. J. B. Conway : Functions of One Complex Variable.
6. A. I. Markushevich : The Theory of Analytic Functions, A Brief Course.
7. G. Valiron : Integral Functions.
8. C. Caratheodory : Theory of Functions of a Complex Variable.
9. R. P. Boas : Entire Functions.

Advanced Complex Analysis – II

Optional Subject (Pure Stream)

Marks : 100

Harmonic functions, Characterisation of Harmonic functions by mean-value property. Poisson's integral formula. Dirichlet problem for a disc. (12)

Doubly periodic functions. Weierstrass Elliptic function, Weierstrass σ -function and their properties. (16)

Entire functions, $M(r, t)$ and its properties (statements only). Meromorphic functions. Expansions. Definition of the functions $m(r, a)$, $N(r, a)$ and $T(r)$.

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No

Nevanlinna's first fundamental theorem. Cartan's identity and convexity theorems. Orders of growth. Order of a meromorphic function. Comparative growth of $\log M(r)$ and $T(r)$. Nevanlinna's second fundamental theorem. Estimation of $S(r)$ (Statement only). Nevanlinna's theorem on deficient functions. Nevanlinna's five-point uniqueness theorem. Milloux theorem. Milloux basic result. Idea of fix points. (25)

Functions of several complex variables. Power series in several complex variables. Region of convergence of power series. Associated radii of convergence. Analytic functions. Cauchy-Riemann equations. Cauchy's integral formula. Taylor's expansion. Cauchy's inequalities. Zeros and Singularities of analytic functions. Maximum modulus theorem. Weierstrass preparation theorem. (15)

References :

1. E. C. Tittmarsh, The Theory of Functions.
2. E. T. Copson, An Introduction to the Theory of Functions of a Complex Variable.
3. A. I. Markushevich, Theory of Functions of a Complex Variable, (Vol. I, II, III).
4. W. Kaplan, An Introduction to Analytic Functions.
5. H. Cartan, Theory of Analytic Functions.
6. W. K. Hayman, Meromorphic Functions.
7. L. Yang, Value Distribution Theory.
8. R. C. Gunning and H. Rossi, Analytic Functions of Several Complex Variables.
9. B. A. Fuks. An Introduction to the Theory of Analytic Functions of Several Complex Variables.
10. Bochner and Martin. Several Complex Variables.

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Advanced Functional Analysis
Optional Subject (Pure Stream)
Marks : 100

Complete orthonormal sequence and separability in Hilbert spaces. Complete orthonormal sequence in $L[0, 2\pi]$, Isometric isomorphism of every infinite dimensional separable Hilbert space with the space l_2 . (6)

The weak* topology of the conjugate of a normal space, Banach-Alaoglu theorem. Annihilators of subspaces of X and X^* , where X is a Banach space ; Conjugates of subspaces and of quotient spaces of X . The Krein-Milman theorem on extreme points in normed spaces. (6)

Representation theorems for bounded linear functionals on $C[a, b]$ and on l_p ($1 \leq p < +\infty$). (4)

Stone-Weiestrass theorem, Approximation in normed spaces, Best approximation, and uniqueness. (4)

Reflexive spaces, Reflexivity of Hilbert spaces, Reflexive Banach space, Subspaces of reflexive spaces, Bounded sequence contains a weakly convergent subsequence, Existence of an element of smallest norm, Strict convexity, Uniform convexity in relation to reflexivity. (12)

Spectrum of a bounded linear operator, Spectral mapping theorem, Spectrums of completely continuous operator and of self adjoint operator. Spectral representation of self-adjoint operator. (8)

Banach Algebra, Banach Algebra with identity. Resolvent operator, Gelfand transform in commutative Banach Algebra. (10)

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No

Gateaux derivative, uniqueness, representation when domain and range are finite dimensional. Frechet derivative, relation with Gateaux derivative, and complete continuity of Frechet derivative. (10)

References :

1. G. Bachman and L. Narici : Functional Analysis.
2. S. Berberian : Introduction to Hilbert Spaces.
3. A. L. Brown and A. Page : Elements of Functional Analysis.
4. J. B. Conway : A Course in Functional Analysis.
5. N. Dunford and L. Schwartz : Linear Operators.
6. E. Kreyszig : Introductory Functional Analysis with Applications.
7. B. V. Limaye : Functional Analysis.
8. W. Rudin : Functional Analysis.
9. B. K. Lahiri : Elements of Functional Analysis.
10. E. Rickart : Banach Algebra.

Set-Valued Analysis

Optional Subject (Pure Stream)

Marks : 100

Upper limit and Lower limit, and Limit of sequences of sets in metric spaces ; Basic properties and examples. Calculus of upper and lower limits. Zorankiewicz's compactness theorem in separable metric spaces. (10)

Set-valued maps (Multifunctions) ; their graph, domain, image, inverse. Inverse image and Core of a set by a set-valued map. The operations of union, intersection, difference, vector sum (in vector spaces), composition product and square product of set-valued maps ; their basic properties. (14)

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Upper semicontinuous, Lower semicontinuous, continuous and Lipschitz set-valued maps in metric spaces and normed spaces. Upper and lower limits of set-valued maps. Proper set-valued maps. Marginal function. Maximum theorem. Ekeland's Variational Principle theorem. Michael's theorem on continuous selection. (15)

Closed convex processes in normed spaces ; Open mapping theorem, Closed graph theorem, Uniform boundedness theorem. (5)

Contingent cone, Adjacent cone and Circatangent cone to subsets of normed spaces ; their basic properties. Special properties of the tangent cones to convex sets. Contingent derivative. Adjacent derivative and circatangent derivative of set-valued maps in normed spaces ; Their basic properties and expressions as limits of differential quotients. (16)

References :

1. J. P. Aubin and H. Frankowska : Set-valued Analysis.
 2. K. Kuratowski : Topologie.
 3. H. Frankowska : Set-Valued Analysis and Control Theory.
 4. J. P. Audin and I. Ekeland : Applied Non-linear Analysis.
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Abstract Harmonic Analysis
Optional Subject (Pure Stream)

Marks : 100

Fourier Transforms : The Fourier transform on the line for functions in L^1 :
Definition of Fourier transform. Inversion using $(C, 1)$ summability. Uniqueness of
Fourier Transform. Convolution, the approximate identity. Analytic function of
Fourier transforms. Closure of translates in L^1 . The Wiener theorem and its converse.
Reformulation of some of the preceding results in terms of ideals in a commutative
Banach algebra (12)

The Fourier transform on L^2 : Definition of Fourier transforms of $f \in L^2$:
Plancherel's theorem. Parseval's relation. (4)

Generalisation of Wiener's theorem: The Zeros of Fourier transform. Some
generalisations of Wiener's theorem. (3)

Banach Algebra : Analytic vector-valued function. Normed and Banach Algebras.
Banach Algebra with identity. Resolvent operator. Spectral radius and the spectral
mapping theorem for polynomials. The Gelfand theory, weak topologies and the
Gelfand topology. (6)

Topological group : Definition of a topological group, examples, set products.
Neighbourhood and open basis of the identity and their basic properties. Subgroup,
Normal subgroup. Compact subsets of topological groups. Quotient groups with
special reference to locally compact groups. Totally disconnected topological
groups. (6)

Measure Theory : Integration over locally compact space: Topological preliminaries.
Riesz representation theorem. Regularity properties of Borel measures. (4)

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$L^p[a, b]$ -spaces ($1 \leq p \leq \infty$) : Hölder and Minkowski inequalities. Completeness and other properties of $L^p[a, b]$ spaces. Dense subspaces of $L^p[a, b]$ -spaces. Bounded linear functionals on $L^p[a, b]$ -spaces and their representation. Reformulation of some of the preceding results in arbitrary measure space and when the functions are complex-valued. (10)

Complex measure : Total variations, absolute continuity, Radon-Nikodym theorem and its consequences. Radon-Nikodym derivative. Bounded linear functionals on L^p . Riesz representation theorem. (8)

Invariant functionals : Haar integral and Haar measure. The set of all complex regular Borel measures a LCTG as a Banach algebra. (4)

Fourier analysis on groups : Characters and the dual groups of a locally compact abelian topological group. Characters and the dual group, examples of characters. (3)

Generalisation of the Fourier Transform to $L_1(G)$ and $L_2(G)$, Plancherel's theorem. (2)

References :

1. R. R. Goldberg : Fourier Transforms.
2. E. Hewitt and K. Ross : Abstract Harmonic Analysis, (Vol.1).
3. L. Loomis : An Introduction to Abstract Harmonic Analysis.
4. W. Rudin : Fourier Analysis on Groups.
5. G. Bachman and L. Narici : Functional Analysis .
6. G. Bachman : Elements of Abstract Harmonic Analysis.
7. W. Rudin : Real and Complex Analysis.
8. S. K. Berberian : Measure and Integration.
9. T. Husain : Introduction to Topological Group.

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Advanced General Topology
Optional Subject (Pure Stream)

Marks : 100

Locally Connected space, Various Disconnected spaces, and Quotient Spaces :

Local Connected spaces, Zero-dimensional spaces, totally and extremally disconnected spaces, characterizations and their basic properties. Quotient spaces. (6)

Nets and Filters: Inadequacy of sequence, Directed set, definition of net, convergence by net. Cluster point of a net, subnet, ultranet, Topological concepts via nets. (5)

Definition of a filter. Free and fixed filter. Filter bases, image and inverse image of filter base and filter, induced filter. Ultrafilter and its existence and characterization. Convergence of filters. Properties of convergence of filters. Cluster point of a filter and its properties. Characterizations of compactness in terms of nets and filters. Alternative proof of Tychonoff product Theorem using ultranet / ultrafilter. Net based on filter, filter generated by net. (10)

Compactification : Locally compact spaces : Examples and various characterizations, compactification of topological spaces. Alexandroff compactification. Stone-Cech compactification. Cardinality of $\beta\mathbb{N}$. (10)

Paracompactness : Star refinement, barycentric refinement and their relation. Various characterizations of paracompactness. A. H. Stone's theorem concerning paracompactness of metric spaces. Interconnection between paracompactness and (i) Hausdorffness, (ii) Regularity and (iii) Lindelöfness. Properties of paracompactness with regard to subspaces and product space. (10)

Embedding and Metrization : Evaluation map, Embedding theorem for Tychonoff spaces, Urysohn's metrization theorem. (5)

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Uniform spaces : Definition and examples of uniform spaces. Base and subbase of a uniformity, uniform topology. Uniformity and separation axioms. Uniformizable spaces. Uniform continuity and product uniformity. Uniform property. Uniformity of pseudometric spaces and uniformity generated by a family of pseudometric. Compactness of uniform spaces.

Cauchy filter. Relation between completeness and compactness in uniform spaces. (10)

Proximity spaces : Definition and examples. Topology induced by proximity. Alternate description of proximity (the concept of δ -neighbourhood). Separated proximities. Proximal neighbourhoods. p -map, p -isomorphism. Subspaces and product of proximity spaces. Proximities induced by uniformities. Compactness and proximities. (5)

$C(X)$ and $C^*(X)$: The function rings $C(X)$ and $C^*(X)$, C -embedded and C^* embedded sets in X . Urysohn's extension theorem, Z -filters and Z -ultrafilters on X , their duality with ideals and maximal ideals of $C(X)$. Fixed ideals and compact spaces. (9)

References :

1. J. L. Kelley : General Topology.
2. S. Willard : General Topology.
3. J. Dugundji, Topology.
4. R. Engelking : Outline of General Topology.
5. S. A. Naimpally and B. D. Warrack : Proximity Space.
6. J. Nagata : Modern General Topology.
7. L. Gillman and M. Jerison : Rings of continuous functions.
8. J. Nagata : Modern Dimension Theory.

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Dated : 12.09.07

No

Advanced Algebraic Topology
Optional Subject (Pure Stream)

Marks : 100

Covering spaces : Basic properties, Classification of covering spaces. Universal covering spaces. Applications – Borsuk Ulam Theorem. (12)

Higher Homotopy Groups : Basic properties and examples. Homotopy Groups of Spheres. Relation between homology groups and homotopy groups. Lefschetz fixed point theorem. Brouwer fixed point theorem. (15)

Singular Homology Theory : Singular Chain Complex. Singular Homology group. Chain map, induced map between homology groups. Chain homotopy, Mayer-Vietoris sequences. Axioms for homology theorem. (15)

Cohomology and Duality Theorems : Definitions and Calculation Theorems. Poincaré duality. Alexander duality and Lefschetz duality. (8)

CW-complexes : Definition, Cellular maps. Homotopy groups of CW-complexes. Whitehead Theorem. Homology theory of CW-complexes. Betti number and Euler characteristics. Excision theorem and cellular homology, Hurewicz theorem.

Fiber spaces. Presheaves. Fine presheaves. Application of cohomology to presheaves. (15)

References :

1. Fred. H. Croom : Basic Concepts of Algebraic Topology.
2. C. R. F. Maunder : Algebraic Topology.
3. Edwin H. Spanier : Algebraic Topology.
4. J. Mayer : Algebraic Topology.
5. B. Gray : Homotopy Theory.
6. J. Dugundji : Topology.
7. Allen Hatcher : Algebraic Topology.

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Advanced Algebra – I
Optional Subject (Pure Stream)

Marks : 100

Groups : Generators, Fully Invariant Subgroups. Cyclic, Quasicyclic, Locally cyclic, Primary Free, Torsion, Torsion Free and Mixed groups, Complete group. (6)

Semirings : Semiring, Absorbing zero, Hemiring, Halfring, Semi-domain, Hemiring Homomorphism, Congruence Relation on a Semiring, Bourne Congruence relation on a Semiring, Additively Regular Semiring, Ideal of a Semiring, Completely Prime Ideal of Semiring and their properties. (10)

Finite Fields and Field Extensions : Finite Field of Characteristic p (prime integer), Field Extension F / Z_p , Normal Extension, Splitting Field, K -automorphism for the Field extension F / K . Galois Theory, Galois Group, Fixed Field, Galois Extension. The Fundamental Theorem of Galois Theory, Galois Group of the polynomial equations, Roots of Unity and Cyclotomic polynomials over Q , Solvability of Polynomials by Radicals. (20)

Coding Theory : Binary Codes, Codeword, Encoding and Decoding Schemes, parity-check code, Repetition code, Decoding Error, Binary Symmetric channel, Encoding by Matrix Multiplication, Parity-check Matrix, $(m-n)$ Hamming code, Group Code, Polynomial and Cyclic codes, Linear Binary Cyclic Code with Codeword Set, Bose-Chaudhuri Hocquenghem Codes (BCH Codes). (20)

Application to Theoretical Computer Science : Machines and semigroups, Mealy Machines, Connecting up Mealy-Machines, Automata, Coverings and Cryptography. (10)

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No

Geometric Constructions : Constructible Real Numbers, Trisection of 60° Angle and square the circle by straight edge and compass. Dublication of a cube. Construction of a Regular Septagon. Constructibility of Regular 9-gon and regular 20-gon. (8)

References :

1. A. G. Kurosh : The Theory of Groups.
2. T. W. Hungerford : Algebra
3. S. T. Hu : Elements of Modern Algebra.
4. E. Artin : Galois Theory (2nd Edition).
5. N. Jacobson : Lectures in Abstract Algebra (Vol. -I).
6. M. Nagata : Field Theory.
7. J. A. Gallian : Contemporary Abstract Algebra.
8. D. S. Malik, J. M. Mardeson and M. K. Sen : Fundamental of Abstract Algebra.
9. M. R. Adhikari and Avishek Adhikari : Groups, Rings, and Modules with Applications.

Advanced Algebra – II
Optional Subject (Pure Stream)

Marks : 100

Modules : Modules Homomorphisms. Exact sequences.

Free modules, Projective and injective modules. Divisible abelian groups.
Embedding of a module in an injective module. (6)

Modules over PID, Torsion-free modules, Finitely generated modules over PID. (4)

Tensor product of modules, Tensor product of free modules. (5)

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Commutative Rings and Modules : Noetherian and Artinian modules, Composition series in modules. Primary decomposition of a submodule of a module. (7)

Noetherian rings, Cohen's theorem, Krull intersection theorem, Nakayama lemma. Hilbert basis theorem. (5)

Extension of a ring, Integral extension of a ring, Integral closure, Lying-over and Going-up theorems. (3)

Transcendence base of a field over a subfield. Algebraically independence subset of an extension field over a field. Algebraically closed field extensions of isomorphic fields with equal transcendence degree are isomorphic. (5)

Affine varieties of algebraic sets. Noether normalization lemma, Hilbert Nullstellensatz. (5)

Structure of Rings : Left artinian rings, Simple rings, Primitive rings, Jacobson density theorem, Wedderburn Artin theorem on simple (left), Artinian rings. (5)

The Jacobson radical, Jacobson semisimple rings, subdirect product of rings, Jacobson semisimple rings as subdirect products of primitive rings, Wedderburn-Artin theorem on Jacobson semisimple (left), Artinian rings. (6)

Simple and Semisimple modules, Semisimple rings, Equivalence of semisimple rings with Jacobson (left) Artinian rings, Properties of semisimple rings, Characterizations of semisimple rings in terms of modules. (4)

Group Representations: Group rings, Maschke's theorem, Character of a representation, Regular representations, Orthogonality relations, Burnside's $p^a q^h$ theorem. (10)

References :

1. Serge Lang : Algebra.
2. Nathan Jacobson : Basic Algebra (Vol. II).
3. M. Atiyah and I. G. MacDonald : Introduction to Commutative Algebra.

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4. I. Kaplansky : Commutative Rings.
5. O. Zarisky and P. Samuel : Commutative Algebra (Vols. I and II).
6. D. S. Malik, John M. Mordeson, and M. K. Sen : Fundamentals of Abstract Algebra.
7. N. McCoy : Theory of Rings.
8. I. N. Herstein : Non-Commutative Rings.
9. T. Y. Lam : A First Course in Non-commutative Rings.
10. C. W. Curtis and I. Reiner : Representation Theory of Finite Groups and Associated Algebras.

Advanced Geometry – I

Optional Subject (Pure Stream)

Marks : 100

Tensor Algebra : Vector Space, Dual Space, Tensor Product of vector spaces, Tensors, Transformation formula for tensors, Symmetric and skew-symmetric tensors, Contraction, Symmetric bilinear forms, Scalar Product . (12)

Manifold Theory: Differentiable manifold, Differentiable mapping, Differentiable transformations, Diffeomorphism, Vector field, Integral curve of a vector field, Lie bracket, Immersion, Imbedding, rank of a mapping, f-related vector fields. Total differential of a function. (10)

Tensor Calculus : Tangent vectors, Co-tangent vectors, Tangent and Cotangent spaces, Vector fields, Tensor fields, Tensorial forms, l-form, p-form, Exterior product, Exterior differentiation on forms and its elementary properties, Covariant tensors, Tensor Derivatives. (8)

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Riemannian Manifolds : Basic definitions, Metric Connection, Levi-Civita Connection and its existence, parallel translation, Geodesic, Curvature tensor, Ricci tensor, Scalar curvature, Sectional curvature, Properties of Riemann curvature tensor, Bianchi's identities, Gradient vector field, Definitions of Divergence, Hessian, laplacian, Conformal curvature tensor, Local Isometrics, Lie Derivatives and their elementary properties. (12)

Connections on Differentiable Manifolds : Definitions of Affine and linear connections according to Cartan view point, Co-ordinate view point, Invariant view point. Curvature tensor field, covariant derivative of a tensor field. (8)

Semi-Symmetric Metric connection : Definition, Relation between Semi-symmetric and Levi-Civita connections in a Riemannian manifold. Relation between their curvature tensors, certain properties of a Riemannian manifold that admits semi-symmetric metric connection with some restrictions on curvature and torsion of the semi-symmetric connection. (12)

Fibre Bundles : Basic definitions, Bundle Morphism, Transition functions, Structure group, Vector bundle, Tangent bundle, Frame bundle, Connections on principle fibre bundles. (6)

References :

1. N. J. Hicks : Notes on Differential Geometry.
2. S. Kobayasi and K. Nomizu : Foundations of Differential Geometry (Vol. 1).
3. W. M. Boothby : An Introduction to Differentiable Manifold and Riemannian Geometry.
4. Barrett O'Neil : Riemannian Geometry.
5. Barrett O'Neil : Semi-Riemannian Geometry with Application to Relativity.
6. U. C. De and A. A. Sheikh : Geometry of Differentiable Manifolds.

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Advanced Geometry – II
Optional Subject (Pure Stream)
Marks : 100

Complex Manifolds : Almost complex manifolds. Neijenhuis tensor. Complex manifolds. Contravariant almost analytic vector. Almost Hermite manifolds. Linear connection in an almost Hermite manifold. Kähler manifold. Almost Tachibana manifold. Tachibana manifold. Holomorphic sectional curvature. Almost product and almost decomposable manifold. Almost Einstein manifold. (20)

Contact Manifolds : Definition and examples of contact manifolds. Almost contact manifolds. K-contact and Sasakian structures. Sasakian space forms. Nearly Sasakian structures. (15)

Geometry of Theory of Relativity : Introduction to Special and General theory of relativity. Manifolds of special and general theory of relativity. Special theory of relativistic mechanics and electro-dynamics. Metric in a gravitational field. Motion of a free particle in a gravitational field. Einstein law of gravitation. Metrics with spherical, planetary orbits. Symmetries, Killing equations. Curvature collineation, Projective collineation, Conformal collineation (including affine collineation, conformal motion and homothetic motion). (30)

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No

References :

1. K. Yano : Differential Geometry on Complex and Almost Spaces.
 2. R. S. Mishra : Structures on a Differentiable Manifold and their Application.
 3. D. E. Blair : Contact Manifolds in Riemannian Geometry, Lecture Notes in Math, 509.
 4. D. F. Lawden : An Introduction to Tensor Calculus, Relativity and Cosmology.
 5. R. Resnik : Introduction to Special Relativity.
 6. S. K. Bose : An Introduction to General Relativity.
 7. A. N. Matveev : Mechanics and Theory of Relativity.
 8. E. Lord : An Introduction to Tensor Calculus. Relativity and Cosmology.
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A handwritten signature in black ink, appearing to read 'B. B. Pal'.

(B. B. Pal)

The Head of the Department of Mathematics