SYLLABUS

For

M. A./M.Sc. in MATHEMATICS

Four Semester

(Effective from the academic session 2007 – 2008 and onwards)

THE UNIVERSITY OF BURDWAN

RAJBATI, BURDWAN

WEST BENGAL

THE UNIVERSITY OF BURDWAN

Syllabus For M. A./M.Sc. in Mathematics

Duration of P.G. course of studies in Mathematics shall be two years with Semester-I, Semester-II, Semester-III and Semester-IV each of six months duration leading to Semester-I, Semester-II, Semester-III and Semester-IV examination in Mathematics at the end of each semester. Syllabus for P.G. courses in Mathematics is hereby framed according to the following schemes and structures.

Scheme: Total Marks = 1000 with 250 Marks in each semester comprising of five papers in each semester with 50 marks in each paper. In each theoretical paper 10% Marks is allotted for Internal Assessment. There are four theoretical papers and one practical paper in Semester-II. All students admitted to P.G. course in Mathematics shall take courses of Semester-I and Semester-II; and from the Semester-III they will opt for either Pure Stream or Applied Stream in Mathematics. The option norm is to be framed by the Department in each year. In each stream of Semester-III, the first three papers are general and the last two papers are special papers. In each stream of Semester-IV, the first two papers are general and the next two papers are special papers and the fifth paper is the term paper. In the Semester-III and Semester-IV, the Department will offer a cluster of special papers and the students will have to choose one according to the norms to be decided by the Department. The term paper is related with the respective special papers and the mark distribution is 30 for written submission, 15 for Seminar presentation and 5 for Viva-Voice. It should be noted that some special papers will be included in future as per discretion of the Department.

COURSE STRUCTURE
SEMESTER STRUCTURE OF M.A./M.SC. SYLLABUS IN MATHEMATICS
(SEMESTER-I, II, III, IV)

SEMESTER-I

Duration: 6 Months
Total Marks: 250 **Total No. of Lectures: 50 Hours per paper**

Each Theoretical Paper Containing 45 Marks and 5 Marks for Internal Assessment

Paper		Marks
MCG101:	Functional Analysis-I (27+3)	30
	Real Analysis-I (18+2)	20
MCG102:	Linear Algebra-I (27+3)	30
	Modern Algebra-I (18+2)	20
MCG103:	Elements of General Topology (27+3)	30
	Complex Analysis-I (18+2)	20
MCG104:	Ordinary Differential Equations & Special Functions (27+3)	30
	Operations Research-I (18+2)	20
MCG105:	Principle of Mechanics-I (27+3)	30
	Numerical Analysis (18+2)	20

SEMESTER-II

Duration: 6 Months
Total Marks: 250 **Total No. of Lectures: 50 Hours per paper**

Each Theoretical Paper Containing 45 Marks and 5 Marks for Internal Assessment

Paper		Marks
MCG201:	Complex Analysis-II (27+3)	30
	Real Analysis-II (18+2)	20
MCG202:	Partial Differential Equations (27+3)	30
	Differential Geometry (18+2)	20
MCG203:	Operations Research-II (27+3)	30
	Principle of Mechanics-II (18+2)	20
MCG204:	Computer Programming (27+3)	30
	Continuum Mechanics-I (18+2)	20
MCG205:	Computer Aided Numerical Practical	50

Semester III & IV Separated for Pure and Applied Stream

SEMESTER-III: Pure Stream
Duration: 6 Months

Total Marks: 250 **Total No. of Lectures: 50 Hours per paper**

Each Theoretical Paper Containing 45 Marks and 5 Marks for Internal Assessment

Paper		Marks
MPG301:	Modern Algebra-II (27+3)	30
	General Topology-I (18+2)	20
MPG302:	Graph Theory (36+4)	40
	Set Theory-I (9+1)	10
MPG303:	Set Theory –II & Mathematical Logic (27+3)	30
	Functional Analysis-II (18+2)	20
MPS304:	Special Paper-I (45+5)	50
MPS305:	Special Paper-II (45+5)	50

SEMESTER-IV: Pure Stream

Duration: 6 Months
Total Marks: 250 **Total No. of Lectures: 50 Hours per paper**

Each Theoretical Paper Containing 45 Marks and 5 Marks for Internal Assessment

Paper		Marks
MPG401:	Modern Algebra-III (45+5)	50
MPG402:	General Topology-II (27+3)	30
	Functional Analysis-III (18+2)	20
MPS403:	Special Paper-III (45+5)	50
MPS404:	Special Paper-IV (45+5)	50
MPT405:	Term Paper (30+15+5)	50

Term Paper MPT405 is related with the Special papers and the Marks distribution is 30 Marks for written submission and 15 Marks for Seminar Presentation and 5 Marks for Viva-Voce.

SEMESTER-III: Applied Stream

Duration: 6 Months

Total Marks: 300 **Total No. of Lectures: 50 Hours per paper**

Each Theoretical Paper Containing 45 Marks and 5 Marks for Internal Assessment

Paper		Marks
MAG301:	Methods of Applied Mathematics -I (45+5)	50
MAG302:	Methods of Applied Mathematics -II (27+3)	30
	Theory of Electro Magnetic Fields (18+2)	20
MAG303:	Continuum Mechanics-II (27+3)	30
	Dynamical Systems (18+2)	20
MAS304:	Special Paper-I (45+5)	50
MAS305:	Special Paper-II (45+5)	50

SEMESTER-IV: Applied Stream

Duration: 6 Months

Total Marks: 250 **Total No. of Lectures: 50 Hours per paper**

Each Theoretical Paper Containing 45 Marks and 5 Marks for Internal Assessment

Paper		Marks
MAG401:	Continuum Mechanics-III (45+5)	50
MAG402:	Elements of Quantum Mechanics (27+3)	30
	Chaos and Fractals (18+2)	20
MAS403:	Special Paper-III (45+5)	50
MAS404:	Special Paper-IV (45+5)	50
MAT405:	Term Paper (30+15+5)	50

Term Paper MAT405 is related with the Special papers and the Marks distribution is 30 Marks for written submission and 15 Marks for Seminar Presentation and 5 Marks for Viva-Voce.

Cluster of Special Paper-I &III For Semester-III &IV respectively each of 50 marks (Pure Stream):

- **A** Differential Geometry of Manifolds-I & II
- **B** Advanced Real Analysis-I & II
- **C** Advanced Functional Analysis-I & II
- **D** Rings of Continuous Function-I & II
- **E** Theory of Rings and Algebra-I & II
- **F** Non-linear Optimization in Banach Spaces-I & II
- **G** Harmonic Analysis-I & II
- **H** Applied Functional Analysis-I & II

Cluster of Special Paper-II & IV For Semester-III & IV respectively each of 50 marks (Pure Stream):

- **A** Measure and Integration- I & II
- **B** Operator Theory and Applications- I & II
- **C** Algebraic Topology- I & II
- **D** Lattice Theory-I & II
- **E** Advanced Operations Research- I & II
- **F** Geometric Functional Analysis- I & II
- **G** Proximities, Nearnesses and Extensions of Topological Spaces- I & II
- **H** Advanced Complex Analysis- I & II

Cluster of Special Paper-I & III For Semester–III & IV respectively each of 50 marks (Applied Stream):

- **A** Viscous Flows, Boundary Layer Theory and Magneto Hydrodynamics-I & II
- **B** Elasticity-I & II
- **C** Elasticity and Theoretical Seismology-I & II
- **D** Applied Functional Analysis -I & II

Cluster of Special Paper-II & IV For Semester–II & IV respectively each of 50 marks (Applied Stream) :

- **A** Quantum Mechanics- I & II
- **B** Advanced Operations Research- I & II
- **C** Inviscid Compressible Flows and Turbulence- I & II

D Computational Fluid Dynamics- I & II

* All the students will have to take the Special paper-I & III for Semester-III & IV and Special Paper-II & IV for Semester- III & IV respectively from the same topic, and the Special paper-I & II and Special paper-III & IV from the respective clusters of special papers for Semester-III and Semester-IV respectively. The clusters of special papers to be offered in a particular year shall be decided by the Department. Students of Applied Mathematics stream may also opt ***Applied Functional Analysis-I & II*** as the Special paper-I and Special paper-III respectively, if they so desire. Students of Pure Mathematics Stream may also opt the ***Advanced Operations Research-I & II*** as the Special paper-II and Special paper-IV respectively, if they so desire.

DETAILED SYLLABUS

SEMESTER-I

Paper – MCG101

(Functional Analysis-I & Real Analysis-I)

Unit-1

Functional Analysis-I

Total Lectures : 40 **(Marks – 30)**

Baire category theorem. Normed linear spaces, continuity of norm function, Banach spaces, Spaces $\mathbf{C}^n$, C [a,b] (with supmetric) , c_0, l_p ($1 \le p \le \infty$) etc; (10L)

Linear operator, boundedness and continuity, examples of bounded and unbounded linear operators. (10L)

Banach contracton Principle – application to Picard's existence theorem and Implicit function theorem. (8L)

Inner product, Hilbert spaces, examples such as l_2 spaces, $L_2[a,b]$ etc; C-S inequality, Parallelogram law, Pythagorean law, Minkowski inequality, continuity and derivatives of functions from $\mathbf{R}^m$ to $\mathbf{R}^n$. (12L)

Unit-2

Real Analysis-I

Total Lectures : 25 **(Marks – 20)**

Monotone functions and their discontinuities, Functions of bounded variation on an interval, their properties, Riemann-Stieltjes integral, existence, convergence problem and other properties. (12L)

Lebesgue outer measure, countable subadditivity, measurable sets and their properties, Lebesgue measure, measurable functions, equivalent functions, continuity and measurability, monotonocity and measurability, operation on collection of measurable functions, pointwise limit of a sequence of measurable functions, measurability of Supremum and Infimum, simple function and measurable function. (13L)

References

1. I. P. Natanson – *Theory of Functions of a Real Variable,* Vol. I, Fedrick Unger Publi. Co., 1961.
2. Lusternik and Sovolev-*Functional Analysis*
3. A.H. Siddiqui- *Functional Analysis with applications*, TMG Publishing Co. Ltd, New Delhi
4. K.K. Jha- *Functional Analysis, Student's Friends*,1986
5. Vulikh- *Functional Analysis*
6. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966
7. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958
8. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989
9. L.V. Kantorvich and G.P. Akilov-*Functional Analysis*, Pergamon Press,1982
10. B.K. Lahiri-*Elements of Functional Analysis*, The world Press Pvt. Ltd., Kolkata, 1994
11. G.F. Simmons- *Introduction to Topology and Modern Analysis* ,Mc Graw Hill, New York, 1963
12. B.V. Limaye- *Functional Analysis*, Wiley Easten Ltd
13. Burkil & Burkil – *A second Course of Mathematical Analysis, CUP, 1980.*
14. Goldberg – *Real Analysis, Springer-Verlag, 1964*
15. Royden – Real Analysis, PHI, 1989
16. Lahiri & Roy – *Real Analysis, World Press, 1991.e*
17. Apostol – *Mathematical Analysis, Narosa Publi. House, 1985.*

18. Titchmarsh – *Theory of Functions, CUP, 1980*

19. W. Rudin- *Principle of Mathematical Analysis, Mc Graw Hill, Student Edn.*

20. Charles Swartz: Measure, Integration and Function Spaces, World Scientific, 1994.

Paper – MCG102

(Linear Algebra & Modern Algebra-I)

Unit-1

Linear Algebra

Total Lectures : 40 **(Marks – 30)**

Vector spaces, Euclidean space, Unitary space, orthonormal basis, Gram-Schmidt orthogonalization process. (8L)

Linear transformation in finite dimensional spaces, matrix of linear, rank and nullity, annihilator of a subset of a vector space. (5L)

Eigen vectors, spaces spanned by eigen vectors, similar and congruent matrices, characteristic polynomial, minimal polynomial, diagonalization, diagonalization of symmetric and Hermitian matrices, Cayley-Hamilton theorem, reduction of a matrix to normal form, Jordan Canonical form. (17L)

Quadratic form, Reduction to normal form, Sylvester’s law of inertia, simultaneous reduction of two quadratic forms, applications to Geometry & Mechanics. (10L)

Unit-2

Modern Algebra -I

Total Lectures : 25 **(Marks – 20)**

Groups: Homomorphism, Isomorphism of groups, First and second isomorphism theorems, automorphisms and automorphism group, Inner automorphisms, groups of order 4 and 6, Normal sub groups and correspondence theorem for groups, simple groups. (10L)

Rings : Ring, commutative rings with identity, Prime & irreducible elements, division ring, Quaternions, idempotent element, Boolean ring, ideals, Prime ideal, maximal ideal, Isomorphism theorems, relation between Prime and maximal ideal, Euclidean domain, Principal ideal domain, Unique factorization domain, Polynomial rings. (15L)

References:

1. I. N. Herstein – *Topics in Algebra* (Vikas).
2. P. B. Bhattacharya, S. K. Jain & S. R. Noyapal – *Basic Abstract Algebra* (Cambridge)
3. T. W. Hungerford – Algebra (Springer).
4. Malik, Mordeson & Sen – *Fundamentals of Abstract Algebra (Tata MaGraw-Hill)*
5. *Sen, Ghosh & Mukhopadhyay – Topics in Abstract Algebra (University Press).*
6. *P. M. Cohn – Basic Algebra.*
7. *S. Lang – Algebra.*
8. *S. Lang – Linear Algebra.*
9. Hoffman & Kunze – Linear Algebra (Prentice Hall).
10. S. Kumareson – Linear Algebra.
11. Rao & Bhimsankaran – Linear algebra.

Paper – MCG103

(Elements of General Topology & Complex Analysis-I)

Unit-1

Elements of General Topology

Total Lectures : 40 **(Marks – 30)**

Topological spaces; definition, open sets, closed sets, closure, denseness, neighbourhood, interior points, limit points, derived sets, basis, subbasis, subspace. (10L)

Alternative way of defining a topology using Kuratowski closure operators and neighbourhood systems. (5L)

Continuous functions, homeomorphism and topological invariants. (3L)

First and second countable spaces, Lindelöf spaces, separable spaces and their relationship.(8L)

Separation axioms: T_0, T_1, T_2, T_3, $T_{3½}$, T_4 spaces, their simple properties and their relationship. (8L)

Introduction to connectedness and compactness. (6L)

Unit-2

Complex Analysis -I

Total Lectures : 25 **(Marks – 20)**

Complex Integration, line integral and its fundamental properties, Cauchy's fundamental theorem, Cauchy's integral formula and higher derivatives, power series expansion of analytic functions.(14L)

Zeros of analytic functions and their limit points, entire functions, Liouville's theorem. Fundamental theorem of algebra.(6L)

Simply connected region and primitives of analytic functions, Morera's theorem. (5L)

References

1. Simmons – *Introduction to Topology & Modern Analysis*
2. Munkresh – *Topology*
3. W. J. Thron – *Topological Structures*
4. Joshi – *General Topology*
5. J. L. Kelley – *General Topology*
6. J. B. Conway – *Functions of one Complex Variable* [Narosa]
7. R. B. Ash – *Complex Variable* [A.P.]
8. Punoswamy – *Functions of Complex Variable*
9. Gupta & Gupta – *Complex Variable*
10. W. Churchil- *Theory of Functional of Complex variable*
11. E. T. Copson- Functions of Complex variable
12. Philips- Functions of Complex variable

Paper – MCG104

(Ordinary Differential Equations & Special Functions, Operations Research-I)

Unit-1

Ordinary Differential Equations & Special Functions

Total Lectures : 40 **(Marks – 30)**

Ordinary Differential Equations

First order system of equations: Well-posed problems, existence and uniqueness of the solution, simple illustrations. Peano's and Picard's theorems (statements only) (8L)
Linear systems, non-linear autonomous system, phase plane analysis, critical points, stability, Linearization, Liapunov stability, undamped pendulum, Applications to biological system and ecological system (12L).

Special Functions

Series Solution : Ordinary point and singularity of a second order linear differential equation in the complex plane; Fuch's theorem, solution about an ordinary point, solution of Hermite equation as an example; Regular singularity, Frobenius' method – solution about a regular singularity, solutions of hypergeometric, Legendre, Laguerre and Bessel's equation as examples.(10L)
Legendre polynomial : its generating function; Rodrigue's formula, recurrence relations and differential equations satisfied by it; Its orthogonality, expansion of a function in a series of Legendre Polynomials.(6L)
Adjoint equation of n-the order: Lagrange's identity, solution of equation from the solution of its adjoint equation, self-adjoint equation, Green's function.(4L)

Unit-2

Operations Research-I

Total Lectures : 25 **(Marks – 20)**

Introduction, Definition of O.R., Drawbacks in definition, Scope of O.R., O.R. and decision making, Application of O.R. in different sectors, Computer application in O.R.(3L)
Fundamental theorem of L.P.P. along with the geometry in n-dimensional Euclidean space (hyperplane, separating and supporting plane).(3L)

Standard forms of revised simplex method, Computational procedure, Comparison of simplex method and revised simplex method, Sensitivity analysis, Bounded variable method, The Primal Dual Method.(14L)

Mathematical formulation of Assignment Problem, Optimality condition, Hungarian method, Maximization case in Assignment problem, Unbalanced Assignment problem, Restriction on Assignment, Travelling salesman problem.(5L)

References :

1. Wagner – *Principles of Operations Research* (PH)
2. Sasievir, Yaspan, Friedman – *Operations Research*: *Methods and Problems* (JW)
3. J. K. Sharma – *Operations Research – Theory and Applications*
4. Taha – *Operations Research*
5. Schaum's Outline Series – *Operations Research*
6. Hillie & Lieberman – *Introduction to Operations Research*
7. Swarup, Gupta & Manmohan – *Operations Research*
8. J. C. Burkill – *The Theory of Ordinary Differential Equations* [Oliver & Boyd, London]
9. E. A. Codington and Levinson – *Theory of Ordinary Differential Equations* [TMH]
10. R.P. Agarwal & R. C. Gupta – *Essentials of Ordinary Differential Equations* [MGH]
11. G. F. Simmons - Di*fferential Equations* [TMH]
12. G. Birkhoff & G. Rota - *Ordinary Differential Equation* [Ginn]
13. E. D. Rainville – *Special Functions* [Macmillan]
14. I. N. Sneddon - *Special Functions of mathematical Physics & Chemistry* [Oliver & Boyd, London]
15. N. N. Lebedev - *Special Functions and Their Applications* [PH]

Paper – MCG105

(Principle of Mechanics-I & Numerical Analysis)

Unit-1

Principle of Mechanics-I

Total Lectures : 40 **(Marks – 30)**

Generalised co-ordinates: Degrees of freedom, Constraint, Principle of Virtual Work. Lagrangian formulation of Dynamics: Lagrange's equations of motion for holonomic and non-holonomic systems. Ignoration of coordinates. (10L)

Routh's processs for the ignoration of co-ordinates. Rayleigh's dissipation function. Calculus of variation and Euler-Lagrange differential equations. Brachistochrone problem. (10L)

Configuration space and system point. Hamilton's principle; Hamilton's cannocical equations of motion. Principle of energy.(10L)

Principle of least action, Canonical Transformations, Poisson Bracket. (10L)

Unit-2

Numerical Analysis

Total Lectures : 25 **(Marks – 20)**

Numerical Methods : Algorithm and Numerical stability. (2L)

Graffae's root squaring method and Bairstow's method for the determination of the roots of a real polynomial equation. (4L)

Polynomial Approximation : Polynomial interpolation; Errors and minimizing errors; Tchebyshev polynomials; Piece-wise polynomial approximation. Cubic splines; Best uniform approximations, simple examples. (4L)

Richardson extrapolation and Romberg's integration method; Gauss' theory of quadrature. Evaluation of singular integral. (4L)

Operators and their inter-relationships : Shift, Forward, Backward, Central differences; Averaging operators, Differential operators and differential coefficients.(2L)

Initial Value Problems for First and Second order O.D.E. by

(i) 4th order R – K method

(ii) RKF_4- method

(iii) Predictor – Corrector method by Adam-Bashforth, Adam-Moulton and Milne's method. (3L)

Boundary value and Eigen-value problems for second order O.D.E. by finite difference method and shooting method. (3L)

Elliptic, parabolic and hyperbolic P.D.E. (for two independent variables) by finite difference method; Concept of error, convergence & numerical stability. (3L)

References :

1. F. Chorlton – *A Text Book of Dynamic*
1. Synge and Griffith – *Principles of Mechanics*
2. D. T. Green Wood – *Classical Dynamics*
3. E. T. Whittaker – *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies*
4. K. C. Gupta – *Classical Mechanics of Particles and Rigid Bodies*
5. F. Gantmacher – *Lectures in Analytical Mechanics*
6. H. Goldstein – *Classical Mechanics*
7. F. B. Hildebrand – *Introduction to Numerical Analysis*
8. Demidovitch and Maron – *Computational Mathematics*
9. F. Scheid – *Computers and Programming* (Schaum's series)
10. G. D. Smith – *Numerical Solution of Partial Differential Equations* (Oxford)
11. Jain, Iyengar and Jain – *Numerical Methods for Scientific and Engineering Computation*
12. A. Gupta and S. C. Basu – *Numerical Analysis*
13. Scarborough – *Numerical Analysis*
14. Atkinson – *Numerical Analysis*
15. Raulstan – *Numerical Analysis*

SEMESTER-II

Paper – MCG201

(Complex Analysis-II & Real Analysis-II)

Unit-1

Complex Analysis-II

Total Lectures : 40 **(Marks – 30)**

Open mapping theorem.(5L)

Singularities. Laurent's series expansion and classification of isolated singularities, essential singularities and Casorati-Weierstrass's theorem. Cauchy's residue theorem and evaluation of improper integrals.(12L)

Argument principle, Rouche's theorem and its application.(5L)

Maximum modulus theorem.(3L)

Conformal mappings, Schwarz's Lemma and its consequence.(10L)

Introduction to Analytic continuation.(5L)

Unit-2

Real Analysis-II

Total Lectures : 25 **(Marks – 20)**

Lebesgue integral of a simple function, Lebesgue integral of a non-negative (bounded or unbounded) measurable function, Integrable functions and their simple properties, Lebesgue integral of functions of arbitrary sign, Integrable functions, basic properties of the integral, Integral of point wise limit of sequence of measurable functions- Monotone convergence theorem and its consequences, Fatou's lemma, Lebesgue dominated convergence theorem. Comparison of Lebesgue's integral and Riemann integral, Lebesgue criterion of Riemannian integrability. (17L)

Fourier series, Dirichlet's kernel, Riemann-Lebesgue theorem, Pointwise convergence of Fourier series of functions of bounded variation. (8L)

1. J. B. Conway – *Functions of one Complex Variable* [Narosa]
2. R. B. Ash – *Complex Variable* [A.P.]
3. Punoswamy – *Functions of Complex Variable*

4. Gupta & Gupta – *Complex Variable*
5. I. P. Natanson – *Theory of Functions of a Real Variable,* Vol. I
6. C. Goffman – *Real Functions*
7. Burkil & Burkil – *Theory of Functions of a Real Variable*
8. Goldberg – *Real Analysis*
9. Royden – Real Analysis
10. Lahiri & Roy – *Theory of Functions of a Real Variable*
11. Apostol – *Real Analysis*
12. Titchmarsh – *Theory of Functions*
13. Charles Scwarz-*Measure, Integration and Functions Spaces.*

Paper – MCG202

(Partial Differential Equations & Differential Geometry)

Unit-1

Partial Differential Equations

Total Lectures : 40 **(Marks – 30)**

General solution and complete integral of a partial differential equation; Singular solution; Integral surface passing through a curve and circumscribing a surface.(4L)
First order P.D.E, : Characteristics of a linear first order P.D.E.; Cauchy's problem; Solution of non-linear first order P.D.E. by Cauchys method of characteristics; Charpit's method (application only).(8L)
Second order linear P.D.E. : Classification, reduction to normal form; Solution of equations with constant coefficients by (i) factorization of operators, (ii) separation of variables; Solution of one-dimensional wave equation and diffusion equation; Solution of Laplace equation in Cylindrical and spherical polar co-ordinates. Formulation of Initial and Boundary Value Problem of P.D.E; Solution of Dirichlet's and Numann's problem of Laplace's equation for a circle.(28L)

Unit-2

Differential Geometry

Total Lectures : 25 **(Marks – 20)**

Reciprocal base system, Intrinsic derivative, Parallel vector field along a curve Space Curve, Serret – Frenet formula. (8L)

Metric tensor of the surface, angle between two curves lying on the surface, parallel vector field on a surface, Geodesics on a surface, Its differential equation, Geodesic curvature of a surface curve, Tensor derivative. (10L)

First fundamental form of the surface, Gauss's formula and second fundamental form of the surface, Meusnier theorem and Euler's theorem. (7L)

References:

1. T.Amarnath – *Partial Differential Equation*
2. I. N. Sneddon – *Partial Differential Equation*
3. H. Goldstein – *Classical Mechanics*
4. P. Phoolan Prasad & R. Ravichandan – *Partial Differential Equations*
5. C. E. Weatherburn – *Differential Geometry*
6. M. Postrikov – *Lectures in Geometry, Linear Algebra and Differential Geometry*
7. U. C. De- *Differential Geometry of Curves and Surfaces in E3, Anamaya Publi., 2007.*
8. M. P. Do Carmo- *Differential Geometry of Curves and Surfaces*
9. B. O'Neill- *Elementary Differential Geometry*
10. Rutter- *Geometry of Curves*
11. Andrew Pressely- *Elementary Differential Geometry*

Paper – MCG203

(Operations Research-II & Principle of Mechanics-II)

Unit-1

Operations Research-II

Total Lectures : 40 **(Marks – 30)**

Deterministic Inventory control Models: Introduction, Classification of Inventories, Advantage of Carrying Inventory, Features of Inventory System, Deterministic inventory models including price breaks.(14L)

Standard form of Integer Programming, The concept of cutting plane, Gomory's all integer cutting plane method, Gomory's mixed integer method, Branch and Bound method.(10L)

Processing of n jobs through two machines, The Algorithm, Processing of n jobs through m machines, Processing of two jobs through m machines.(6L)

Project scheduling by PERT/CPM : Introduction, Basic differences between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM network Components and Precedence Relationships, Critical Path analysis, Probability in PERT analysis, Project Crashing, Time cost Trade-off procedure, Updating of the Project, Resource Allocation.(10L)

Unit-2

Principle of Mechanics-II

Total Lectures : 25 **(Marks – 20)**

Theory of small oscillations. Normal co-ordinates. Euler's dynamical equations of motion of a rigid body about a fixed point. Torque free motion. Motion of a top on a perfectly rough floor. Stability of top motion. Motion of a particle relative to rotating earth. Foucault's pendulum.(20L)

Special Theory of Relativity : Postulates; Special Lorentz Transformation ; Fitz-Gerald contraction and time-dilation. Einstein's velocity addition theorem. Relativistic mechanics of a particle, Energy equation $E = mc^2$. (5L)

References :

1. F. Chorlton – *A Text Book of Dynamic*
2. Synge and Griffith – *Principles of Mechanics*
3. D. T. Green Wood – *Classical Dynamics*
4. E. T. Whittaker – *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies*
5. K. C. Gupta – *Classical Mechanics of Particles and Rigid Bodies*
6. I. S. Sokolnikoff – Mathematical Theory of Elasticity
7. Merovitch- *A treatise on dynamics*
8. Wagner – *Principles of Operations Research* (PH)

9. Sasievir, Yaspan, Friedman – *Operations Research*: *Methods and Problems* (JW)
10. J. K. Sharma – *Operations Research – Theory and Applications*
11. Taha – *Operations Research*
12. Schaum's Outline Series – *Operations Research*
13. Hillie & Lieberman – *Introduction to Operations Research*
14. Swarup, Gupta & Manmohan – *Operations Research*

Paper – MCG204
(Computer Programming & Continuum Mechanics-I)

Unit-1

Computer Programming

Total Lectures : 40 **(Marks – 30)**

Structured Programming in FORTRAN – 77: Subscripted variables, Type declaration, DIMENSION, DATA, COMMON, EQUIVALENCE, EXTERNAL statements. Function and subroutine sub – programs; Programs in FORTRAN – 77 (12L)

Programming in C: Introduction, Basic structures, Character set, Keywords, Identifiers, Constants, Variable-type declaration, Operators : Arithmetic, Relational, Logical, assignment, Increment, decrement, Conditional. (13L)

Operator precedence and associativity, Arithmetic expression, Evaluation and type conversion, Character reading and writing, Formatted input and output, Decision making (branching and looping) – Simple and nested IF, IF – ELSE, WHILE – DO, FOR. Arrays-one and two dimension, String handling with arrays – reading and writing, Concatenation, Comparison, String handling function, User defined functions. (15L)

Unit-2

Continuum Mechanics-I

Total Lectures : 40 **(Marks – 30)**

Continuous media, Deformation, Lagrangian and Eulerian approach; Analysis of strain (infinitesimal theory);.(10L)

Analysis of stress; Invariants of stress and strain tensors. Principle of conservation of mass; Principle of balance of linear and angular momentum; Stress equation of motion. (20L)

Necessity of constitutive equations. Hooke's law of elasticity, displacement equation of motion. Newton's law of viscosity (statement only). (10L)

References :

1. Ram Kumar – *Programming With Fortran –77*
2. P. S. Grover - *Fortran – 77/90*
3. Jain & Suri – *FORTRAN –77 Programming Language including FORTRAN – 90.*
4. G. C. Layek, A. Samad and S. Pramanik- *Computer Fundamentals, Fortran – 77 and Numerical Problems including C, S. Chand & Co.*
5. Xavier, C. – *C Language and Numerical Methods*, (New Age International (P) Ltd. Pub.)
6. *Gottfried, B. S. – Programming with C* (TMH).
7. Balaguruswamy, E. – *Programming in ANSI C* (TMH).
8. F. Scheid – *Computers and Programming* (Schaum's series)
9. T. J. Chang – *Continuum Mechanics* (Prentice – Hall)
10. Truesdell – *Continuum Mechanics* (Schaum Series)
11. Mollar – *Theory of Relativity*
12. F. Gantmacher – *Lectures in Analytical Mechanics*
13. J. L. Bansal – *Viscous Fluid Dynamics* (Oxford)
14. R. N. Chatterjee – *Contunuum Mechanics*
15. H. Goldstein – *Classical Mechanics*

Paper – MCGP205

Computer Aided Numerical Practical

Total Practical Classes : 65 **(Marks – 50)**

(Numerical Practical Using FORTRAN – 77)

[Problem – 25, Viva – 10 & Sessional – 15]

(Viva to be conducted on Paper – MG205 & MG206 only)

1. *Inversion of a non-singular square matrix. (6L)*

2. *Solution of a system of linear equations by Gauss – Seidel method. (4L)*
3. *Integration by Romberg's method. (5L)*
4. *Initial Value problems for first and second order O.D.E. by*

(i) Milne's method (First order) (6L)

(ii) 4th order Runge – Kutta method (Second order) (5L)

5. *Dominant Eigen – pair of a real matrix by power method (largest and least). (14L)*
6. *B.V.P. for second order O.D.E. by finite difference method and Shooting method. (5L)*
7. *Parabolic equation (in two variables) by two layer explicit formula and Crank–Nickolson – implicit formula. (12L)*
8. *Solution of one dimensional wave equation by finite difference method. (8L)*

References :

1. Ram Kumar – *Programming With Fortran –77*
2. P. S. Grover - *Fortran – 77/90*
3. Jain & Suri – *FORTRAN –77 Programming Language including FORTRAN – 90.*
4. G. C. Layek, A. Samad and S. Pramanik- *Computer Fundamentals, Fortran – 77 and Numerical Problems including C, S. Chand & Co..*
5. Xavier, C. – *C Language and Numerical Methods*, (New Age International (P) Ltd. Pub.)
6. *Gottfried, B. S. – Programming with C* (TMH).
7. Balaguruswamy, E. – *Programming in ANSI C* (TMH).

SEMESTER-III

PURE MATHEMATICS STREAM

Paper – MPG301

(Modern Algebra-II & Set Theory-I)

Unit-1

Modern Algebra-II

Total Lectures : 40 **(Marks – 30)**

Groups : *Direct product (internal and external), Group action on a set, Conjugacy classes and conjugacy class equation, p-groups, Cauchy's theorem, converse of Lagrange's theorem for finite commutative groups, Syllow theorems and applications, Normal series, solvable* *series, solvable and Nilpotent groups, Jördan-Holder Theorem, Finitely generated Abelian groups, Free Abelian groups.* *(20L)*

Rings : *Unique factorization domain; Factorization of polynomials over a field; Maximal, Prime and primary ideal; Noetherian and Artinian Rings; Hilbert basis theorem. (20L)*

References :

1. *I. N. Herstein* – Topics In Algebra *(Wiley Eastern Ltd, New Delhi).*
2. *M. Artin* – Algebra *(P.H.I.).*
3. *P. M. Cohn* – Algebra, *Vol. – I. II, & III. (John Wiley & Sons).*
4. *N. Jacobson* – Basic Algebra *Vol. I, II.*
5. *D. S. Malik, J. N. Mordeson & M. K. Sen* – Fundamentals of Abstract Algebra *(McGraw – Hill, International Edition).*
6. *J. B. Fraleigh* – A First Course in Abstract Algebra *(Narosa).*
7. *M. Gray* – A Radical Approach to Algebra *(Addison Wesley Publishing Company).*
8. *Hungerford – Algebra.*
9. *S. Lang – Algebra.*
10. *N. H. McCoy – The theory of Rings.*
11. *Burton – Ring Theory.*
12. *Gallian – Algebra.*

Unit-2

General Topology-I

Total Lectures : 25 **(Marks – 20)**

Normal spaces, Urysohn's lemma and Tietze's extension theorem. (5L)

Product spaces, embedding lemma, Tychonoff spaces and characterization of Tychonoff spaces as subspaces of cubes. (6L)

Nets, filters subnets and convergence (4L)

Compactness, Compactness and continuity, countable compactness, sequential compactness, BW compactness and their relationship, Local compactness, Tychonoff theorem (on Product of Compact Spaces) (10L)

References :

1. J. Dugundji – *Topology* (Allayn and Bacon, 1966)

2. J. L. Kelley – *General Topology* (Van Nostrand, 1955)
3. J. R. Munkres – *Topology – A First Course* (Prentice-Hall of India, 1978)
4. G. F. Simmons – *Introduction to Topology and Modern Analysis* (McGraw-Hill, 1963)
5. W. J. Thron – *Topological Structures* (Holt Reinhurt and Winston, 1966)

Paper – MPG302

(Graph Theory & Set Theory-I)

Unit-1

Graph Theory

Total Lectures : 55 **(Marks – 40)**

Graph, Subgraph, Complement, Isomorphism, Walks, Paths, cycles, connected components, Cut vertices and cut edges, Distance, radius and center, Diameter, Degree sequence, Havel-Hakimi Theorem (Statement only) (10L)

Trees, Centres of trees, Spanning trees, Eulerian and Semi Eulerian Graphs. Hamiltonian Graphs, Travelling Salesman Problem. (10L)

Vertex and edge connectivities, Blocks, Mengers Theorem. Clique Number, Independence number, Matching number, Vertex and edge conserving number, domination number, Ramsay's Theorem. (8L)

Chromatic number, Bipartite graph. Broke's Theorem, Mycielski Construction, Chromatic polynomial, edge colouring number, König Theorem. (6L)

Adjacency matrix, Incidence matrix, Cycle rank and co-cycle rank, Fundamental Cycles with respect to Spanning tree and Cayley's theorem on trees. (5L)

Planar graphs, Statement of Kuratowski Theorem, Isomorphism properties of graphs, Eulers formula, 5 colour theorem. Statement of 4 colour theorem, Dual of a planar Graph. (8L)

Directed Graph, Binary relations, directed paths, fundamental Circuits in Digraphs, Adjacency matrix of a Digraph. (8L)

References:

1. J. A. Bondy U.S.R. Murty – *Graph Theory with Applications* (Macmillan, 1976)

2. Nar Sing Deo – *Graph Theory* (Prentice-Hall, 1974)
3. F. Harary – *Graph Theory* (Addison-Wesley, 1969)
4. K. R. Pathasarthy – *Basic Graph Theory* (TMH., 1994).

Unit-2

Set Theory-I

Total Lectures : 15 **(Marks – 10)**

Axiom of choice, Zorn's Lemma, Hausdorff maximality principle, Well-ordering theorem and their equivalence, General Cartesian product of sets, Cardinal numbers and their ordering, Schröder-Bernstein theorem. (15L)

References :

1. K. Kuratowski – *Introduction to Set Theory and Topology*
2. E. Mendelson – *Introduction to Mathematical Logic*
3. R. R. Stoll – *Set Theory and Logic*
4. I. M. Copi – *Symbolic Logic*
5. W. Sierpienski – *Cardinal and Ordinal Numbers*
6. A. G. Hamilton – *Logic for Mathematicians* (Cambridge University Press)

Paper – MPG303

(Set Theory-II & Mathematical Logic, Functional Analysis-II)

Unit-1

Set Theory-II & Mathematical Logic

Total Lectures : 40 **(Marks – 30)**

Set Theory-II

Addition, multiplication and exponentiation of cardinal numbers, the cardinal numbers N_0 and C and their relation. (8L)

Totally ordered sets, order type, well-ordered sets, ordinal numbers, initial segments, ordering of ordinal numbers, addition and multiplication of ordinal numbers, sets of ordinal numbers, Transfinite induction. (7L)

Mathematical Logic

Statement calculus : Propositional connectives, statement form, truth functions, truth tables, Tautologies, contradiction, adequate sets of connectives (10L)

Arguments : Proving validity rule of conditional proof. Formal statement calculus, Formal axiomatic theory L, Deduction theorem (8L)

Consequences. Quantifiers, Universal and existential; symbolizing everyday language. (7L)

References :

1. K. Kuratowski – *Introduction to Set Theory and Topology*
2. E. Mendelson – *Introduction to Mathematical Logic*
3. R. R. Stoll – *Set Theory and Logic*
4. I. M. Copi – *Symbolic Logic*
5. W. Sierpienski – *Cardinal and Ordinal Numbers*
6. A. G. Hamilton – *Logic for Mathematicians* (Cambridge University Press)

1. K. Kuratowski – *Introduction to Set Theory and Topology*
2. E. Mendelson – *Introduction to Mathematical Logic*
3. R. R. Stoll – *Set Theory and Logic*
4. I. M. Copi – *Symbolic Logic*
5. W. Sierpienski – *Cardinal and Ordinal Numbers*
6. A. G. Hamilton – *Logic for Mathematicians* (Cambridge University Press)

Unit-2

Functional Analysis-II

Total Lectures : 25 **(Marks – 20)**

Completion of Metric space. Equicontinuous family of Functions. Compactness in C[0,1] (Arzela-Ascoli's Theorem). Convex sets in linear spaces. (8L)

Properties of normed linear spaces. Finite dimensional normed linear spaces. Riesz's Lemma, and its application in Banach spaces. Convergence in Banach Spaces. Equivalent Norms and their properties. (10L)

Principle of Uniform Boundedness (Banch-Steinaus), Open Mapping theorem. Closed graph theorem., Extension of continuous linear mapping. (7L)

References :

1. Lusternik and Sovolev-*Functional Analysis*
2. A.H. Siddiqui- *Functional Analysis with applications*, TMG Publishing Co. Ltd, New Delhi

3. K.K. Jha- *Functional Analysis, Student's Friends*,1986
4. Vulikh- *Functional Analysis*
5. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966
6. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958
7. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989
8. L.V. Kantorvich and G.P. Akilov-*Functional Analysis*, Pergamon Press,1982
9. B.K. Lahiri-*Elements of Functional Analysis*, The world Press Pvt. Ltd., Kolkata, 1994
10. G.F. Simmons- *Introduction to Topology and Modern Analysis* ,Mc Graw Hill, New York, 1963
11. B.V. Limaye- *Functional Analysis*, Wiley Easten Ltd

Paper – MPS304

(Special Paper-I)

Total Lectures : 65 **(Marks – 50)**

A: Differential Geometry of Manifolds-I

Definition and examples of differentiable manifolds. Tangent spaces. Jacobian map. One parameter group of transformations. Lie derivatives. Immersions and imbeddings. Distributions. (32L)

Exterior algebra. Exterior derivative. (10L)

Topological groups. Lie groups and Lie algebras. Product of two Liegroups. One parameter subgroups and exponential maps. Examples of Liegroups. Homomorphism and Isomorphism. Lie transformation groups. General linear groups. (15L)

Principal fibre bundle. Linear frame bundle. Associated fibre bundle. Vector bundle. Tangent bundle. Induced bundle. Bundle homomorphisms. (8L)

References :

1. R. S. Mishra, *A course in tensors with applications to Riemannian Geometry*, Pothishala (Pvt.) Ltd., 1965.
2. R. S. Mishra, *Structures on a differentiable manifold and their applications*, Chandrama Prakashan, Allahabad, 1984.

3. B. B. Sinha, *An Introduction to Modern Differential Geometry*, Kalyani Publishers, New Delhi, 1982.
4. K. Yano and M. Kon, *Structure of Manifolds*, World Scientific Publishing Co. Pvt. Ltd., 1984.
5. U. C. De and A. A. Shaikh, Differential Geometry of Manifolds, Narosa Publishing House Pvt. Ltd., 2007.

B: Advanced Real Analysis-I

Upper and lower limits of real function and their properties. (5L)
Pointwise differentiation of functions of linear intervals. Derivates and derivatives. Measurability of derivates. Differentiation of real functions. Dini derivates and their properties. Monotonicity theorem. Example of a continuous nowhere differentiable function. (30L)
Vitali's covering theorem in one dimension. Differentiability of monotone functions. Absolutely continuous functions and singular functions. Cantor ternery set and Cantor function. Indefinite Lebesgue Integral. Fundamental theorem of integral calculus for Lebesgue integral. Lusin's condition (N). Characterization of absolutely continuous functions (Banach-Zaricki theorem). (30L)

References :

1. Hewitt and Stormberg – *Real and Abstract Analysis*
2. H. L. Royden – *Real Analysis*
3. Saks – *Theory of Integrals*
4. W. Rudin – *Real and Abstract Analysis*
5. M. E. Munroe – *Measure and Integration*
6. I. P. Natanson – Theory of Functions of a Real Variable, Vols. I & II.
7. E. W. Hobson – Theory of Functions of a Real Variable, Vols. I & II

C: Advanced Functional Analysis-I

Topological vector spaces, Local base and its properties, Separation properties, Locally compact topological vector space and its dimension. Convex Hull and representation Theorem, Extreme points, Symmetric sets, Balanced sets, absorbing sets, Bounded sets in topological vector space. Linear operators over topological vector space, Boundedness and continuity of Linear operators, Minkowski functionals, Hyperplanes, Separation of convex sets by Hyperplanes, Krein-Milman Theorem on extreme points. (30L)

Locally convex topological vector spaces, Criterion for normability, Seminorms, Generating family of seminorms in locally convex topological vector spaces. Barreled spaces and Bornological spaces, Criterion for Locally convex topological vector spaces to be (i) Barreled and (ii) Bornological. (15L)

Strict convexity and Uniform convexity of a Banach space. Uniform Convexity of a Hilbert Space. Reflexivity of a uniformly convex Banach space, Weierstrass approximation theorem in C[a,b] (20L)

References :

1. W. Rudin-*Functional Analysis*, TMG Publishing Co. Ltd., New Delhi,1973
2. A.A. Schaffer-*Topological Vector Spaces*, Springer , 2nd Edn., 1991
3. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966
4. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989
5. Diestel- *Application of Geometry of Banach Spaces*
6. Narici & Beckerstein- *Topological Vector spaces*, Marcel Dekker Inc, New York and Basel,1985
7. G.F. Simmons- *Introduction to topology and Modern Analysis* ,Mc Graw Hill, New York, 1963
8. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958
9. Lipschitz-*General Topology*, Schaum Series
10. K. Yosida-*Functional Analysis*, Springer Verlog, New York, 3rd Edn., 1990
11. Brown and Page-*Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
12. Holmes-*Geometric Functional Analysis and its Application*
13. J. Horvoth-*Topological Vector spaces and Distributions*, Addison-Wesley Publishing Co., 1966
14. C. Goffman and G. Pedrick-First *Course in Functional Analysis*, PHI, New Delhi,1987
15. R. E. Edwards- *Functional Analysis*, Holt Rinchart and Wilson, New York,1965
16. A. Wilansky-*Functional Analysis*, TMG Publishing Co.Ltd, New Delhi, 1973

D: Rings of Continuous Function-I

The ring C(X) of the real valued continuous function on a topological space X, its subrings, the subring $C^*(X)$, their Lattice structure, ring homomorphisms and lattice homomorphism.(15L)

Zero-sets cozero-sets, their unions and intersection, completely separated sets, C^* -embedding, Urysohn's extension theorem and C-embedding. Pseudocompactness and internal characterization of Pseudocompact spaces.(15L)

Ideals, Z-filters, maximal ideals, prime ideals, prime filters and their relation.(5L)

Completely regular spaces and the zero-sets, weak topologies determined by C(X) and $C^*(X)$. Stone-Čech's therem concerning adequacy of Tychonoff spaces X for investigation of C(X) and $C^*(X)$, compact subsets and C – embedding, locally compact spaces and their properties.(10L)

Convergence of Z – filters, cluster points, prime Z – filters and convergence and fixed Z-filters.(5L)

Fixed ideals and compactness, fixed maximal ideals of C (X) and $C^*(X)$, their characterizations, the residue class rings modulo fixed maximal ideals in C(X) and $C^*(X)$ and the field of reals. Relation between fixed maximal ideals in C(X) and $C^*(X)$. Compactness and fixed ideals.(10L)

P- spaces, P-points and their properties, characterization of P-spaces, properties of P-spaces.(5L)

References :

1. Richard E. Chandler, *Hausdorff Compactifications* (Marcel Dekker, Inc. 1976).
2. L. Gillmen and M. Jerison, *Rings of Continuous Functions* (Von Nostrand, 1960).
3. *Topological Structures* (Halt Reinhurt and Winston, 1966).

E: Theory of Rings And Algebras-I

Rings and Ideals : Definitions, Ideal. Quotient rings and homorphisms, The field of quotients, Minimal and maximal conditions, Primary decomposition, Polynomial rings. (15L)

The Classical Radical : Nilpotent ideals and the radical, The radical of related rings, Artinian & Noethrian rings, Direct sum decompositions, Ideals in semisimple rings, Matrix rings, The Wedderburn theorem. (20L)

Modules : Preliminaries, Direct sums and free modules, projective modules, Tensor products, field and matrix representations, Algebras. (20L)

The Jacoson Radical : Primitive rings, The Density Theorem, Structure theorems. (10L)

References :

1. Mary Gray – *A Radical Approach to Algebra* (Addison-Wesley Publishing Company).
2. Ernst – August Behrems (Translated by Clive Reis) – *Ring Theory* (Academic Press, New York, London).
3. Stanley Burris & H. P. Sankappanvar – *A Course in Universal Algebra* (Springer-Verlag, New York, Berlin)
4. L. H. Rowen – *Ring Theory* (Academic Press)
5. T. Y. Lam – *Noncommutative Rings* (Springer-Verlag)
6. N. Jacolson – *Basic Algebra –II*
7. I. N. Herstein – *Noncommutative Rings*
8. N. J. Divisky – *Rings and Radicals*
9. N. H. Mc Coy – The Theory of Rings
10. M. R. Adhikari – Groups, Rings, Modules and applications

F: Non Linear Optimization In Banach Spaces-I

Review of Weak Convergence in normed spaces, reflexivity of Banach spaces, Hahn-Banach theorem and partially ordered linear spaces. (20L)

Existence Theorems for Minimal Points –Problem formulation. Existence theorems. Set of minimal points. (15L)

Applications to approximations and optimal control problems. (15L)

Generalised Derivatives-Directional derivative. Gâteaux and Frechet derivatives. Subdifferential. Quasidifferential Clarke derivative. (15L)

References :

1. Johannes John – *Introduction to the Theory of Nonlinear Optimization* (Springer-Verlag, 1994)
2. V. Bartu and T. Precupanu – *Convexity and Optimization in Banach Spaces* (Editura Acad. Bucaresti, 1986).
3. A. V. Balakrishnan – *Applied Functional Analysis* (Springer-Verlag)

G: Harmonic Analysis-I

Basic properties of topological groups, subgroups, quotient groups and connected groups. Discussion of Haar Measure without proof on R, T, Z, and some simple matrix groups. $L^1(G)$ and convolution with special emphasis on $L^1(R)$, $L^1(T)$, $L^1(Z)$. Approximate identities. (20L)

Fourier series. Fejer's theorem. The classical kernels. Fejer's Poisson's and Dirichlet's summability in norm and point wise summability. Fatou's Theorem. The inequalities of Hausdorff and Young. (20L)

Examples of conjugate function series. The Fourier transform. Kernels of R. The Plancherel theorem on R Planchere measure on R, T, Z. Maximal ideal space of $L^1(R)$, $L^1(T)$ and $L^1(Z)$. (25L)

References :

1. Henry Helson - *Harmonic Analysis* (Hindustan Pub. Corp., 1994)
2. E. Hewitt and K. A. Ross – *Abstract Harmonic Analysis* Vol. I (Springer-Verlag, 1993)
3. Y. Katznelson – *An Introduction to Harmonic Analysis,* (John Wiley, 1968)
4. P. Koosis – *Introduction of H^p Spaces* (Cambridge Univ. Press).
5. R. R. Goldberg – *Fourier transforms*
6. T. Huissain – *Introduction to topological groups*

H: Applied Functional Analysis-I

Review of basic properties of Hilbert spaces. Convex programming-support functional of a convex set. Minkowski functional. Separation Theorem. Kuhn-Tucker Theorem. Minimax theorem. Farkas theorem. (20L)

Spectral theory of operators. Spectral Theory of compact operations. Operators on a separable Hilbert space. Krein factorization theorem for continuous kernels and its consequences. L_2 spaces over Hilbert spaces. (30L)

Multilinear forms. Analyticity Theorems. Non-linear Volterra operators. (15L)

References :

1. A. V. Balakrishnan- *Applied Functional Analysis,* Springer-Verlag.
2. Dunford and Schwartz-*Linear operators,* vol. 1 & 11.

3. S. G. Krein-Linear Differential Equations in a Banach space.
4. K. Yosida-Functional Analysis.

Paper – MPS305

(Special Paper-II)

Total Lectures : 65 **(Marks – 50)**

A: Measure and Integration-I

Algebra and σ-algebra of sets. Monotone class of sets. Borel sets. Fσ and Gδ sets. Countably additive set function. Measure on σ – algebra. Outer measure and measurability. Extension of measures. Complete measures and completion of a measure space. Construction of outer measures. Regular outer measure. Lebesgue Stieltjes measures and distribution function. Example of non-measurable sets (Lebesgue). (30L)

Measurable functions. Approximation of measurable functions by simple functions. Egoroff's Theorem. Lusin's Theorem. Convergence in measure. Integrals of simple functions. Integral of measurable functions. Properties of Integrals and Integrable functions. Monotone convergence theorem. Fatou's Lemma, Dominated convergence Theorem, Vitali convergence theorem. (35L)

References :

1. I. P. Rana – *Measure and Integration*
2. G. D. Barra – *Measure and Integration*
3. Hewitt and Stormberg – *Real and Abstract Analysis*
4. H. L. Royden – *Real Analysis*
5. Saks – *Theory of Integrals*
6. W. Rudin – *Real and Abstract Analysis*
7. M. E. Munroe – *Measure and Integration*
8. Taylor - *Measure and Integration*
9. I. P. Natanson – *Theory of Functions of a Real Variable*, Vols. I & II.
10. Charles Schwartz- Measure , Integration and Function spaces, World Scientific Publi., Singapore, 1994.

B: Operator Theory And Applications-I

Adjoint operators over normed linear spaces; their algebraic properties. Compact operators on normal linear spaces, Sequence of Compact operators, Compact extensions, Weakly compact-operators(10L)

operator equation involving compact operators, Fredholm alternative; Adjoint operators on Hilbert-spaces, Self-adjoint operators, their algebraic properties; Unitary operators, normal operators in Hilbert spaces, positive operators, their-sum, product; Monotone sequence of positive operators, square-root of positive operator, Projection operators. (20L)

Their sum and product; Idempotent operators, positivity norms of Projection operators; Limit of monotone increasing sequence of Projection operators. (35L)

References:

1. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966
2. B.V. Limaye- *Functional Analysis*, Wiley Easten Ltd
3. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989
4. B.K. Lahiri-*Elements of Functional Analysis*, The world Press Pvt. Ltd., Kolkata, 1994
5. G.F. Simmons- *Introduction to topology and Modern Analysis* ,Mc Graw Hill, New York, 1963
6. N. Dunford and J.T. Schwartz-*Linear Operators, Vol-1&II*, Interscience, New York,1958
7. K. Yosida-*Functional Analysis*, Springer Verlog, New York, 3rd Edn., 1990
8. Brown and Page-*Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
9. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958
10. L.V. Kantorvich and G.P. akilov-*Functional Analysis*, Pergamon Press,1982
11. Vulikh- Functional Analysis
12. J. Tinsley Oden& Leszek F. Dernkowicz- Functional Analysis, CRC Press Inc, 1996.
13. Lipschitz-General Topology, Schaum Series

C: Algebraic Topology-I

Homotopy : Definition and some examples of homotopies, homotopy type and homotopy equivalent spaces, retraction and deformation, H-space.

Category : Definitions and some examples of category, factor and natural transformation. (10L)

Fundamental group and covering spaces : Definition of the fundamental group of a space, the effect of a continuous mapping on the fundamental group, fundamental group of a product space, notion of covering spaces, liftings of paths to a covering space, fundamental groups of a circle, (20L)

Universal cover, its existence, calculation of fundamental groups using covering space. Projection space and torus, homomorphisms and automorphisms of covering spaces, deck transformation group, Borsuk – Ulam theorem for S^2, Brower fixed-point theorem in dimension 2. (35L)

References :

1. W. S. Massey – *Algebraic Topology*
2. W. S. Massey – *Singular Homology Theory*
3. E. H. Spanier – *Algebraic Topology*
4. B. Gray – *Homotopy Theory An Introduction to Algebraic Topology*
5. C. R. Bredon – *Geometry and Topology*

D: Lattice Theory-I

Introduction : Partially ordered sets, graphs, order isomorphism, Maximal minimal condition, Jordan-Dedekind chain condition, dimension function. (10L)

Definition of an algebra, Lattices as algebras, density principle, Lattices as partially ordered sets sublattices Ideals, complements, semicomplements, atoms, Irreducible and prime elements, Morphisims homomorphisims, ideals direct products. (20L)

Closure operation, Dedekind condition, Dedekind cuts. Completion, interval topology.(15L)

Distributive and modular lattices, modularity and distributivity criterion, distributive sublattices of modular lattices, transposed intervals, meet representation in modular and distributive lattices. (20L)

References :

1. *G. Szasz* – Lattice Theory
2. *G. Birkhoff* – Lattice Theory
3. *B. H. Arnold* – Logic and Boolean Algebra
4. *D. E. Rutherford* – Lattice Theory

E: Advanced Operations Research-I

Non-linear Optimization : Local and global minima and maxima, convex functions and their properties, Method of Lagrange multiplier. (8L)

Optimality in absence of differentiability, Slater constraint qualification, Karlin's constraint qualification, Kuhn-Tuckers Saddle point optimality conditions, Optimality criterion with differentiability and convexity, separation theorems, Kuhn-Tuckers sufficient optimality theorem. (10L)

Unconstrained Optimization : Search method : Fibonacci search, Golden Section search; Gradient Methods : Steepest descent Quasi-Newton's method, Davidon-Fletecher-Powell method, Conjugate direction method (Fletecher-Reeves method). (15L)

Optimality conditions : Kuhn-Tucker conditions – non negative constraints (6L)

Quadratic Programming : Wolfe's Modified Simplex method, Beale's method (8L)

Separable convex programming, Separable Programming Algorithm. (6L)

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, Minflow max-cut theorem. (12L)

References:

1. G. Hadly – *Non-Linear and Dynamic Programming,* Addision –Wesley, Reading Mass.
2. G. Hadly – Linear Programming, Narosa Publishing House.
3. S. S. Rao –*Optimization theory and Applications,* Wiley Eastern Ltd., New Delhi.
4. O. L. Mangasarian – *Non-Linear Programming,* McGraw Hill, New York.
5. Luenberger – *Introduction to Linear and Non-Linear Programming*
6. S. Dano – *Non-Linear and Dynamic Programming*
7. H. A. Taha – *Operations Research – An Introduction,* Macmillan Publishing Co., Inc., New York.
8. Swarup, Gupta & Manmohan – *Operations Research,* Sultan Chand & Sons, New Delhi.
9. *N.S. Kambo- Mathematical Programming Techniques,* Affiliated East-West Press Pvt. Ltd., New Delhi
10. M. C. Joshi and K.M. Moudgalya, Optimization theory and Practice, Narosa Publishing House, New Delhi
11. C.R. Bector, S. Chandra and J. Dutta, Principles of optimization Theory, Narosa Publishing House, New Delhi

12. M. A. Bhatti, Practical Optimization Methods, Springer -Verlag

F: Geometric Functional Analysis-I

Convexity in Linear spaces. Convex functions Basic separation Theorems. Convexity, and orderings. Alternate formulation of the separation Principle. Some Application. Extremal sets. Locally convex spaces. (30L)

Convexity and Topology. Weak Topology. (35L)

References :

1. Holmes – *Geometric Functional Analysis and Its Applications*

G: Proximities, Nearnesses and Extensions of Topology Spaces-I

Čech closure operator, closure spaces, symmetric Čech closure operator, continuity, homeomorphisms and their properties. Linkage compact topological spaces and their relation with compact topological spaces in presence of regularity condition. Extensions of closure spaces, trace system, principal (strict) extensions, ordering of extensions. Representation of principal T_0 extension of a T_0 topological space with a given trace system. The set of principal T_0 extensions of a T_0 topological spaces is a partially ordered set and its consequence for the class of T_2 compactification of a Tychonoff space. (35L)

(Basic) proximities, induced closure operators, proximity spaces, proximal neighbourhoods, p-continuous functions and their properties. Lattice structure of the basic proximities compatible with a symmetric closure space. Clans, clusters and relation between them. Basic proximities are clan generated structures. Classification of basic proximities : Riesz (RI-) proximities, Lodato (LO-) proximities, Efremovič (EF-) proximities, their characterization and relation between them. (30L)

References :

1. S. A. Naimpully and B. D. Wanack – *Proximity Spaces(*Cambridge Track No. 59, Cambridge, 1970)
2. W. J. Thron – *Topological Structures*(Halt Reinhurt and Winster, 1966)
3. E. Čech – *Topological Structures*(English Transl. Wiley, New York, 1966)

H: Advanced Complex Analysis-I

Analytic function, the functions M(r) and A(r). Theorem of Borel and Caratheodary, Convex function and Hadamard three-circle theorem, Phragmen-Lindelof theorem. (20L)

Harmonic function, Mean value property, Maximum principle, Harmonic function on a disk, Hamaek's inequality, Dirichlet's problem. (15L)

Integral function, Poisson Jenson formula, construction of an integral function with given zeros –Weierstrass theorem, Jensen's inequality, order, exponent of convergence of zeros of an integral function, canonical product, genus, Hadamard's factorization theorem, Borel's theorems, Picard's first and second theorems. (30L)

References :

1. J. B. Conway – *Functions of One Complex Variable*
2. L. V. Ahlfors – *Complex Analysis*
3. W. Rudin – *Real and Complex Analysis*
4. E. C. Titchmarsh – *Theory of Functions*
5. E. T. Copson – *Function of a Complex Variable*
6. R. P. Boas – *Entire Functions*
7. H. Cartan – *Analytic Functions*
8. A. I. Markusevich - *Theory of Functions of a Complex Variables*, Vol. I & II.
9. M. Dutta and Lokenath Debnath – *Elliptic Functions*.

SEMESTER-IV

PURE MATHEMATICS STREAM

Paper – MPG 401

(Modern Algebra-III)

Total Lectures : 65 **(Marks – 50)**

Field Theory: *Extension of fields, Simple extensions, Algebraic and Transcendental extensions, Splitting fields, Algebraically closed fields, normal extension, separable extensions, Perfect field. (30L)*

Automorphism of fields, Galois field, Galois extension, Fundamental Theorem of Galois theory, primitive elements, Solution of polynomial equations by radicals, Insolvability of the general equation of degree five or more by radicals, Cyclotomic extensions, Ordered field, Valuation, Completion. (20 L)

Modules: *Artinian and Noetherian Modules, Fundamental Structure Theorem for finitely generated modules over a P.I.D. and its application to finitely generated Abelian groups. (15L)*

References :

1. *S. Lang* – Algebra *(P.H.I.)*
2. *Hungerford* – Algebra.
3. *D. S. Malik, J. N. Mordeson & M. K. Sen* – Fundamentals of Abstract Algebra *(McGraw – Hill).*
4. *I. T. Adamson* – Introduction to Field Theory *(Cambridge University Press)*
5. *S. Lang – Algebra.*
6. *M. M. Postnikov – Fundamentals of Galois' Theory.*
7. *Dommit & Foote – Abstract Algebra.*

Paper – MPG402

(General Topology-II & Functional Analysis-II)
Unit-1

General Topology-II

Total Lectures : 40 **(Marks – 30)**

Connectedness and charecterization of connected subsets, union of connected subsets. Connected subsets of the real line, local connectedness, components, structure of open sets in locally connected second countable spaces, connectedness of the product spaces (10L)

One-point Compactification, Stone-Čech compactification(without proof) (3L)

Compactness in metric spaces, Properties of Compact metric spaces (4L)

Urysohn's metrization theorem, Uniform structure, uniform topology, uniform spaces, uniform continuity, Cauchy filter, total boundedness, completeness and compactness. (13L)

Homotopy of paths, covering spaces, fundamental group. Definition of the fundamental group of the circle. (10L)

References :

1. J. Dugundji – *Topology* (Allayn and Bacon, 1966)
2. J. L. Kelley – *General Topology* (Van Nostrand, 1955)
3. J. R. Munkres – *Topology – A First Course* (Prentice-Hall of India, 1978)
4. G. F. Simmons – *Introduction to Topology and Modern Analysis* (McGraw-Hill, 1963)
5. W. J. Thron – *Topological Structures* (Holt Reinhurt and Winston, 1966)
6. B. K. Lahiri- Algebraic topology, Narosa publishing House Pvt. Ltd., New Delhi.

Unit-2

Functional Analysis-II

Total Lectures : 25 **(Marks – 20)**

Invertible Mappings and their properties. Linear functionals. Hahn-Banach theorem and its applications. Conjugate spaces. Reflexive spaces (6L)

Properties of strong and weak convergence. Adjoint (Conjugate) operators and their properties. Hilbert Spaces, $L_p[a, b]$ $(1 \leq p \leq \infty)$. (5L)

Continuity of inner product. Convergence, Orthogonality and orthogonal decomposition of a Hilbert Space, Orthogonal set. Bessel's inequality. Perseval's identity. Minimization of norm problem. Complete orthonormal set. Riesz-Fischer theorem. Riesz representation theorem for bounded linear functionals on Hilbert spaces. (14 L)

References :

1. Lusternik and Sovolev-*Functional Analysis*

2. A.H. Siddiqui- *Functional Analysis with applications*, TMG Publishing Co. Ltd, New Delhi

3. K.K. Jha- *Functional Analysis, Student's Friends*,1986

4. Vulikh- *Functional Analysis*

5. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966

6. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958

7. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989

8. L.V. Kantorvich and G.P. Akilov-*Functional Analysis*, Pergamon Press,1982

9. B.K. Lahiri-*Elements of Functional Analysis*, The world Press Pvt. Ltd., Kolkata, 1994

10. G.F. Simmons- *Introduction to Topology and Modern Analysis* ,Mc Graw Hill, New York, 1963
11. B.V. Limaye- *Functional Analysis*, Wiley Easten Ltd

Paper – MPS403

(Special Paper-III)

Total Lectures : 65 **(Marks – 50)**

A: Differential Geometry of Manifolds-II

Riemannian manifolds. Riemannian connection. Curvature tensors. Sectional Curvature. Schur's theorem. Geodesics in a Riemannian manifold. Projective curvature tensor. Conformal curvature tensor. (30L)

Submanifolds and Hypersurfaces. Normals. Gauss' formulae. Weingarten equations. Lines of curvature. Generalized Gauss and Mainardi-Codazzi equations. (10L)

Almost Complex manifolds. Nijenhuis tensor. Contravariant and covariant almost analysis vector fields. F-connection. (15L)

References :

1. R. S. Mishra, *A course in tensors with applications to Riemannian Geometry*, Pothishala (Pvt.) Ltd., 1965.
2. R. S. Mishra, *Structures on a differentiable manifold and their applications*, Chandrama Prakashan, Allahabad, 1984.
3. B. B. Sinha, *An Introduction to Modern Differential Geometry*, Kalyani Publishers, New Delhi, 1982.
4. K. Yano and M. Kon, *Structure of Manifolds*, World Scientific Publishing Co. Pvt. Ltd., 1984.
5. U. C. De and A. A. Shaikh, Differential Geometry of Manifolds, Narosa Publishing House Pvt. Ltd., 2007.

B: Advanced Real Analysis-II

Density of arbitrary linear sets. Lebsegue density theorem. Approximate continuity. Properties of approximately continuous functions. Bounded approximately continuous function over [a,b] and exact derivative. (15L)

The Perron integral : Definitions and basic properties, Comparison with Lebesgue integral and Newton integral. (10L)

Trigonomeric system and Trigonometric Fourier series. Summability of Fourier series by (C, I), means. Fejer's theorem. Lebesgue's theorem. Completeness of Trigonometric system. (15L)

Sets of the 1^{st} and of the 2^{nd} categories. Baires theorem for G_δ, residual and perfect sets, points of condensatia of a set. (10L)

Baire classification of functions. Functions of Baire class one. Baire's theorem. Semicontinuous functions. (15L)

References :

1. Hewitt and Stormberg – *Real and Abstract Analysis*
2. H. L. Royden – *Real Analysis*
3. Saks – *Theory of Integrals*
4. W. Rudin – *Real and Abstract Analysis*
5. M. E. Munroe – *Measure and Integration*
6. I. P. Natanson – *Theory of Functions of a Real Variable*, Vols. I & II.
7. E. W. Hobson – *Theory of Functions of a Real Variable*, Vols. I & II

C: Advanced Functional Analysis-II

Stone-Weierstrass W-capital theorem in C(X,R) and C(X,C) where X is a compact Hausdorff space, Representation theorem for bounded linear functionals on C[a,b], l_p $(1 \leq p < \infty)$ and $L_p[a,b]$, $(1 \leq p < \infty)$, consequences of uniform boundedness principle, weak topology, weak* topology, Banach-Alaoglu theorem. (25L)

Approximation Theory in Normal Linear space, Best approximation, Uniqueness Criterion, Separable Hilbert Space. (15L)

Banach Algebra, Identity element, analytic property of resolvent Operator, Compactness of Spectrum, Spectral radius and Spectral mapping Theorem for polynomials, Gelfand Theory on representation of Banach Algebra, Gelfand Neumark Theorem. (25L)

References :

1. W. Rudin-*Functional Analysis*, TMG Publishing Co. Ltd., New Delhi,1973
2. A.A. Schaffer-*Topological Vector Spaces*, Springer , 2nd Edn., 1991
3. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966
4. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989
5. Diestel- *Application of Geometry of Banach Spaces*
6. Narici & Beckerstein- *Topological Vector spaces*, Marcel Dekker Inc, New York and Basel,1985
7. G.F. Simmons- *Introduction to topology and Modern Analysis* ,Mc Graw Hill, New York, 1963
8. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958
9. Lipschitz-*General Topology*, Schaum Series
10. K. Yosida-*Functional Analysis*, Springer Verlog, New York, 3rd Edn., 1990
11. Brown and Page-*Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
12. Holmes-*Geometric Functional Analysis and its Application*
13. J. Horvoth-*Topological Vector spaces and Distributions*, Addison-Wesley Publishing Co., 1966
14. C. Goffman and G. Pedrick-First *Course in Functional Analysis*, PHI, New Delhi,1987
15. R. E. Edwards- *Functional Analysis*, Holt Rinchart and Wilson, New York,1965
16. A. Wilansky-*Functional Analysis*, TMG Publishing Co.Ltd, New Delhi, 1973

D: Rings of Continuous Function-II

Partially ordered rings, convex ideals, absolutely convex ideals, properties of convex ideals, lattice ordered rings, total orderedness of the residue class rings modulo prime ideals in C(X) and $C^*(X)$, real ideals, hyper-real ideals in C(X). Limit ordinal, non-limit ordinals, compactness of the spaces of the ordinals, first uncountable ordinals space and its "one point compactification" and relation between the rings of continuous function on them, Characterization of real ideals.(20L)

Cluster point and convergence of Z–filters on a dense subset of a Tychonoff space. Characterization of C^*- embedded dense subset of a Tychonoff space. Construction of Stone-Čech compactification. More specific properties of βN and βQ and βR.(15L)

Characterization of maximal ideas in $C^*(X)$ and $C(X)$. Gelfand-Kolmogorov theorem. Structure space of a commutative ring - another description of βX. The Banach-Stone theorem.(15)

Partial ordered set $K(X)$ of the T_2 Compactifications of a Tychonoff space X, elements of $K(X)$ and the subsets of $C^*(X)$. Local compactness and the complete lattice $K(X)$.(15L)

References :

1. Richard E. Chandler, *Hausdorff Compactifications* (Marcel Dekker, Inc. 1976).
2. L. Gillmen and M. Jerison, *Rings of Continuous Functions* (Von Nostrand, 1960).
3. *Topological Structures* (Halt Reinhurt and Winston, 1966).

E: Theory of Rings And Algebras -II

Other Radicals and Radical Properties : The Levitzki Radical, Brown-Mcloy radicals, Amitsur's properties, Relations among the radicals. (15L)

Generalizations of the notions of radicals to other systems : Algebras, Group Algebras, Near rings, Groups, Lattices. (10L)

Lie & Jordan Algebras : Definitions, Nilpotenoy and Solvability, A structure theorem for nonassociative algebras, Jordan Algebras, Lie Algebras, Simple Lie and Jordan algebras. (20L)

Category Theory : Definition, Functions, Objects and morphisms, Kernels and images, Exact Categories, Products & limits, abelian Categories.

Radical subcategories, Applications of sheaf theory to the study of rings.

Elements of Universal Algebra. (20L)

References :

1. Mary Gray – *A Radical Approach to Algebra* (Addison-Wesley Publishing Company).
2. Ernst – August Behrems (Translated by Clive Reis) – *Ring Theory* (Academic Press, New York, London).
3. Stanley Burris & H. P. Sankappanvar – *A Course in Universal Algebra* (Springer-Verlag, New York, Berlin)
4. L. H. Rowen – *Ring Theory* (Academic Press)
5. T. Y. Lam – *Noncommutative Rings* (Springer-Verlag)
6. N. Jacolson – *Basic Algebra –II*I.
7. N. Herstein – *Noncommutative Rings*

8. N. J. Divisky – *Rings and Radicals*
9. N. H. Mc Coy – *The Theory of Rings*
10. M. R. Adhikari – *Groups, Rings, Modules and applications*

F: Non Linear Optimization In Banach Spaces-II

Tangent Cones-Definition and properties. Optimality Conditions. Lyusternik theorem. Generalized Lagrange Multiplier Rule – Problem formulation. Necessary and Sufficient optimality conditions. Application to optimal control problems. (20L)

Duality-Problem formulation. Duality theorem. Saddle point theorems. Linear problems. Application to approximation problems. (15L)

Some special optimization problems-Linear quadratic optimal control problems. Time optimal control problems. (30L)

References :

1. Johannes John – *Introduction to the Theory of Nonlinear Optimization* (Springer-Verlag, 1994)
2. V. Bartu and T. Precupanu – *Convexity and Optimization in Banach Spaces* (Editura Acad. Bucaresti, 1986).
3. A. V. Balakrishnan – *Applied Functional Analysis* (Springer-Verlag)

G: Harmonic Analysis-II

Hardy spaces on the unit circle. Invariant subspaces. Factoring. Proof of the F. and M. Riesz theorem. Theorems of Beurings and Szego in multiplication operator form. Structure of inner and outer functions. (20L)

The Inequalities of Hardy and Hilbert. Conjugate functions. Theorems of Kolmogorov & Zygmund and M. Riesz & Zygmund on conjugate functions. (20L)

The conjugate function as a singular integral. Statement of theBurkholder-Gundy Silverstein Theorem on T. Maximal functions of Hardy and Littlewood Translation. The Theorems of Wiener and Beurling. The Titchmarsh Convolution Theorem. Wiener's Tauberian Theorem. Spectral sets of bounded functions. (25L)

References :

1. Henry Helson - *Harmonic Analysis* (Hindustan Pub. Corp., 1994)
2. E. Hewitt and K. A. Ross – *Abstract Harmonic Analysis* Vol. I (Springer-Verlag, 1993)

3. Y. Katznelson – *An Introduction to Harmonic Analysis,* (John Wiley, 1968)
4. P. Koosis – *Introduction of H^p Spaces* (Cambridge Univ. Press).
5. R. R. Goldberg – *Fourier transforms*
6. T. Huissain – *Introduction to topological groups*

H: Applied Functional Analysis-II

Semigroups of linear operators-general properties of semigroups. Generation of semigroups. Dissipative semigroups. Compact semigroups. (20L)

Holomorphic semigroups, Elementary examples of semigroups. Extension. Differential Equations. Cauchy Problem, Controllability. State reduction. Ovservability. Stability and stabilizability. Evolution equations. (30L)

Optimal Control Theory-Linear quadratic regulator problem. The same problem with infinite time interval. Hard constraints. Final value control. Time optimal control problems. (15L)

References :

1. A. V. Balakrishnan- *Applied Functional Analysis,* Springer-Verlag.
2. Dunford and Schwartz-*Linear operators,* vol. 1 & 11.
3. S. G. Krein-*Linear Differential Equations in a Banach space.*
4. K. Yosida-*Functional Analysis.*

Paper – MPS404

(Special Paper-IV)

Total Lectures : 65 **(Marks – 50)**

A: Measure and Integration-II

Signed measures, Hahn-decomposition theorem. Jordan decomposition theorem. Radon-Nidodym theorem. Radon-Nikodym derivative. Lebesgue decomposition theorem. Complex measure. Integrability of fuctions w.r.t. signed measure and complex measure. (30L)

Measurable Rectangles, Elementary sets. Product measures. Fubini’s theorem. (20L)

L_p [a,b] – spaces ($1 \le p \le \infty$). Holder and Minkowski inequality. 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 representations. (15L)

References :

1. I. P. Rana – *Measure and Integration*
2. G. D. Barra – *Measure and Integration*
3. Hewitt and Stormberg – *Real and Abstract Analysis*
4. H. L. Royden – *Real Analysis*
5. W. Rudin – *Real and Abstract Analysis*
6. M. E. Munroe – *Measure and Integration*
7. Taylor - *Measure and Integration*
8. I. P. Natanson – *Theory of Functions of a Real Variable*, Vols. I & II.
9. Charles Schwartz- Measure, Integration and Functions Spaces, World Scientific Publi., 1994.

B: Operator Theory And Applications-II

Spectral properties of bounded-Linear operators in normed linear space; Spectrum, regular value, resolvant of operator; closure property and boundedness property of spectrum, spectral radius. (20L)

Eigenvalues, eigen-vectors of self-adjoint operators in Hilbert space, Resolvant sets, real property of spectrum of self-adjoint operators, range of spectrum, Orthogonal direct sum of Hilbert space,(20L)

Spectral-theorem for compact normal operators, Sesquilinear functionals, property of boundedness and symmetry, Generalisation of Cauchy-Schwarz inequality. (15L)

Unbounded-operators and their adjoint in Hilbert spaces. (10L)

References:

1. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966
2. B.V. Limaye- *Functional Analysis*, Wiley Easten Ltd
3. E. Kreyszig-*Introductory Functional Analysis with Applications*, Wiley Eastern,1989
4. B.K. Lahiri-*Elements of Functional Analysis*, The world Press Pvt. Ltd., Kolkata, 1994
5. G.F. Simmons- *Introduction to topology and Modern Analysis* ,Mc Graw Hill, New York, 1963

6. N. Dunford and J.T. Schwartz-*Linear Operators, Vol-1&II*, Interscience, New York,1958
7. K. Yosida-*Functional Analysis*, Springer Verlog, New York, 3rd Edn., 1990
8. Brown and Page-*Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
9. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958
10. L.V. Kantorvich and G.P. akilov-*Functional Analysis*, Pergamon Press,1982
11. Vulikh- Functional Analysis
12. J. Tinsley Oden& Leszek F. Dernkowicz- Functional Analysis, CRC Press Inc, 1996.
13. Lipschitz-General Topology, Schaum Series

C: Algebraic Topology-II

Introduction of singular homology and cohomology group by Eilenberg and steenrod axioms. Existence and Uniqueness of singular homology and cohomology theory. (20L)

Calculation of homology and chomology groups for circle. Projective spaces, torus relation between $H_1(X)$ and $\pi_1(X)$. (20L)

Singular cohomology ring, calculation of cohomology ring for projective spaces. Fibre bundles : Definitions and examples of bundles and vector bundles and their morphisms, cross sections, fibre products, induced bundles and vector bundles and their morphisoms, cross sections, fibre products, induced bundles and vector bundles, homotopy properties of vector bundles. Homology exact sequence of a fibre bundle.(25L)

References :

1. W. S. Massey – *Algebraic Topology*
2. W. S. Massey – *Singular Homology Theory*
3. E. H. Spanier – *Algebraic Topology*
4. B. Gray – *Homotopy Theory An Introduction to Algebraic Topology*
5. C. R. Bredon – *Geometry and Topology*

D: Lattice Theory-II

Covering condition in modular lattice, modular lattices of locally finite length, Complemented modular lattices, Boolean algebras, complete Boolean algebras, Boolean algebras and Boolean rings, valuation of a lattice, metric and quasimetric lattice. (25L)

Complete Lattice, conditionally complete Lattices, Fix point theorem, Compactly generated lattices, subalgebra lattices. (20L)

Birkhoff lattices, Semimodular lattices, Complemented semimodular lattices, Ideal chains, Ideal lattices, Distributive lattices and ring of sets, Congruence relations, Ideals and congruence relations. (20L)

References :

1. *G. Szasz* – Lattice Theory
2. *G. Birkhoff* – Lattice Theory
3. *B. H. Arnold* – Logic and Boolean Algebra
4. *D. E. Rutherford* – Lattice Theory

E: Advanced Operations Research-II

Dynamic Programming : Characteristics of Dynamic Programming problems, Bellman's principle of optimality (Mathematical formulation)

Model –1 : Single additive constraint, multiplicative separable return,

Model – 2 : Single additive constraint, additively separable return,

Model – 3 : Single a multiplicative constraint, additively separable return,

Multistage decision process – Forward and Backward recursive approach, Dynamic Programming approach for solving linear and non-linear programming problems, Application – Single-item N-period deterministic inventory model. (25L)

Geometric Programming : Elementary properties of Geometric Programming and its applications. (8L)

Queuing Theory : Introduction, characteristic of Queuing systems, operating characteristics of Queuing system. Probability distribution in Queuing systems. Classification of Queuing models. Poisson and non-Poisson queuing models (32L)

References:

1 G. Hadly – *Non-Linear and Dynamic Programming,* Addision –Wesley, Reading Mass.

2 S. Dano – *Non-Linear and Dynamic Programming*

3 H. A. Taha – *Operations Research – An Introduction,* Macmillan Publishing Co., Inc., New York..

4 Swarup, Gupta & Manmohan – *Operations Research,* Sultan Chand & Sons, New Delhi.
5 N.S. Kambo- *Mathematical Programming Techniques,* Affiliated East-West Press Pvt. Ltd., New Delhi

F: Geometric Functional Analysis-II

Extreme points. Convex functions and optimization. Some More Applications: The category Theorems. (30L)

The Smulian Theorems. The theorem of James. Support Points and smooth points. Some further Application. Isomorphism of certain conjugate spaces. Universal spaces. (35L)

References :

1. Holmes – *Geometric Functional Analysis and Its Applications*

G: Proximities, Nearnesses and Extensions of Topology Spaces-II

Separated proximities, separation axioms satisfied by the closure operators induced by RI – (LO -, EF-) proximities. The Lattice structure of the class of RI – (LO-, EF-) proximities compatible with a suitable closure operator. (Basic) nearness, near families, contiguities, contigual families, closure operators, proximities and contiguities induced by a (basic) nearnesses, merotopic spaces. Nearness preserving maps. Separated nearnesses. The class of basic nearnesses compatible with a symmetric closure space (a proximity space, a contiguity space) and their Lattice structure. (30L)

Clans, clusters and cluster generated (concrete) nearnesses. Nearnesses are not clan generated structures. Classification of basic nearness : Riesz (RI -) nearnesses, Lodato (LO -) nearnesses and Efremovič (EF -) nearnesses, their characterization and relationship between them. Nearness spaces, cluster generated nearness spaces, contigual nearness spaces and proximal nearness spaces and relation between them.

Correspondence between the principle (strict) T_1 extensions of a T_1 topological space X and the cluster generated compatible LO – nearnesses on X ; the correspondence between principal T_1 compactification of X and the compatible contigual LO – nearnesses on X ; the correspondence between the principal T_1 linkage compactifications of X and the compatible proximal LO – nearnesses on X . The correspondence between EF – nearnesses on a Tychonoff space X and the T_2 compactifications of X. (35L)

References :

1. S. A. Naimpully and B. D. Wanack – *Proximity Spaces(*Cambridge Track No. 59, Cambridge, 1970)
2. W. J. Thron – *Topological Structures*(Halt Reinhurt and Winster, 1966)
3. E. Čech – *Topological Structures*(English Transl. Wiley, New York, 1966)

H: Advanced Complex Analysis-II

Spaces of continuous functions, Ascoli-Arzela theorem, Spaces of Analytic functions, Hurwitz's theorem, Riemann mapping theorem. (20L)

Meromorphic function, Mittag-Leffler's theorem. (10L)

Elliptic function, weirstrass's elliptic function p(z), addition theorem for p(z), differential equation satisfied by p(z), the numbers e_1, e_2, e_3. (35L)

References :

1. J. B. Conway – *Functions of One Complex Variable*
2. L. V. Ahlfors – *Complex Analysis*
3. W. Rudin – *Real and Complex Analysis*
4. E. C. Titchmarsh – *Theory of Functions*
5. E. T. Copson – *Function of a Complex Variable*
6. R. P. Boas – *Entire Functions*
7. H. Cartan – *Analytic Functions*
8. A. I. Markusevich - *Theory of Functions of a Complex Variables*, Vol. I & II.
9. M. Dutta and Lokenath Debnath – *Elliptic Functions*.

Paper – MPT405

Term Paper

Marks: 50

Term paper MPT405 is related with the special papers of the pure stream offered by the department in each session and the topic of the term paper will also be decided by the department in each session. However the mark distribution is 30 marks for written submission, 15 marks for seminar presentation and 5 marks for viva-voce.

SEMESTER-III

APPLIED MATHEMATICS STREAM

Paper – MAG301

(Methods of Applied Mathematics -I)

Methods of Applied Mathematics -I

Total Lectures : 65 **(Marks – 50)**

Integral Transforms

Fourier Transform and its properties, Inversion formula of F.T.; Convolution Theorem; Parseval's relation. Applications. Outline of Finite Fourier transform and its inversion formula. (10L)

Laplace's Transform and its properties. Inversion by analytic method and by Bromwitch path. Lerch's Theorem. Convolution Theorem; Applications. (10L)

Integral Equations

Linear Integral Equation, Reduction of differential equation to integral equation, Existence, Uniqueness and iterative solution of Fredholm and Volterra Integral equations; examples, Solution of Fredholm integral equation for degenerate kernel; Examples, Faltung type(closed cycle type) integral equation, Singular integral equation; Solution of Abel's integral equation. (20L)

Generalised Functions

Generalised function; Elementary properties; Addition, Multiplication, Transformation of variables. Generalized function as the limit of a sequence of good functions, Differentiation of generalized function. Simple examples, Antiderivative, Regularisation of divergent integral : Simple example, Fourier Transform of generalized function, Examples, Convergence of a sequence of generalized functions; Examples, Laplace transform of generalized function. (12L)

Operator Equations on Hilbert Spaces

Inner product spaces, Hilbert spaces; orthonormality; closedness, and completeness of sets, Fourier expansion, Reisz Fischer theorem. (Proof not reqd.). Isometric isomorphism between a separable Hilbert space and l_2, Linear operators on Hilbert space, continuity, boundedness, adjointness, self-adjointness, invertibility, boundedness and unboundedness of inverse.

Compactness, illustrative examples. Eigen value problems, Spectral theorem for compact self-adjoint operatiors, Application to Regular Sturm-Liouivile problem, Integral equations with Hilbert-Schmidt kernel, implications on Laplace operatior. Solvability of operator equations, Fredholm alternatives. (13L)

References :

1. Gelfand & Shilov – *Generalised Functions* (Academic Press)
2. I. N. Sneddon – *Fourier Transforms* (MacGraw-Hill)
3. R. V. Churchill – *Operational Methods*
4. Lusternik & Sobolev – *Functional Analysis*
5. Erwin Lareyizey – *Introductory Functional Analysis with Applications*
6. S. G. Mikhlin – *Integral Equation* (Pergamon Press)
7. F. G. Tricomi – *Integral Equation* (Interscience Publishers)
8. WE. V. Lovit. – *Linear Integral Equations* (Dover Publishers)
9. F. John – *Partial Differential Equations*
10. Williams - *Partial Differential Equations*
11. Epstein - *Partial Differential Equations*
12. Chester - *Partial Differential Equations*
13. Arnold – *Ordinary Differential Equatios*

Paper – MAG302

(Methods of Applied Mathematics –II, Theory of Electro Magnetic Fields)

Unit-1

Methods of Applied Mathematics -II

Total Lectures : 40 **(Marks – 30)**

Linear ordinary differential equations; generalized solution, fundamental solution, inverse of a differential operator. Two-point boundary value problem for a second-order linear O.D.E. Green's functions and its bilinear expansion, particular integral, Analogy between linear simultaneous algebraic equations and Linear differential equation. (6L)

Mathematical models and initial boundary value problems of 2nd order partial differential equation (PDE); wellposedness; necessity of classification and canonical forms. Invariance of nature of an equation and its characteristics under coordinate transformation; transformation of semilinear 2^{nd} order PDE in two independent variables; linear transformations, and linear PDE's with more than two independent variables. (5L)

Linear hyperbolic PDE's in two independent variables Cauchy problem. Cauchy-Kowalasky theorem (statement only) reason for restriction on cauchy ground curve. Rieman-Green function. Domain of dependence and influence. Possible discontunuites of solutions; d'Alemberts solution and meaning of generalized solution. (6L)

Linear parabolic equations : Heat equation in two independent variables, solution of Cauchy problem using Dirac Delta function and Fourier transform, maximum principle for initial – boundary value (for Dirichlet boundary condition) problem, uniqueness and stability of solution.

Methods of Eigen function empansion and Green's function; Separation of variables, formulation of eigenvalue problems related to wave, heat and Laplace equations. (8L)

Linear elliptic equation: Laplace equation : boundary value problems of Dirichlet, Neumann and Robin. Greens formulas involving Laplacian; mean value theorem, maximum principle, uniqueness and stability of solutions; Dirichlet principle, Rayleigh-Ritz method. (5L)

Greens function for Dirichlet problem on Laplace eqn. its properties and methods of construction. Method of images. Method of conformal mapping for 2-dimentional problem with problem of a unit circle as an example. Bilinear expansion for Green's funcion; Green's function for heat equation by the method of Eigen function expansion and Bilinear expansion for Dirac Delta function. (10L)

References :

1. G. F. C. Duff and D. Naylor – *Differential Equations of Applied Mathematics* (Wiley International).
2. Stakgold – *Greens Functions and Boundary Value Problems* (John Wiley & Sons.)
3. D. H. Griffet – *Applied Functional Analysis* (Ellis Horwood Ltd. John Wiley & Sons.)
4. V. S. Vladiminov – *Equations of Mathematical Physics* (Marcel Danker, Inc. N.Y.)
5. Tikhnov & Samarski – *Equations of Mathematical Physics*

Unit-2

Theory of Electro Magnetic Fields

Total Lectures : 25 **(Marks – 20)**

Empirical basis of Maxwell's Equations : Coulomb's law, Gauss' law, Electrostatic potential, Steady current, Equation of continuity of charge, Biot-Savart's law, Magnetic induction, Ampere's law, Faraday's law, Maxwell's equations for electromagnetic field and their empirical basis. Material equations, Conditions at an interface, Electromagnetic potentials, Electromagnetic energy, Poynting theorem. (15L)

Application of Maxwell's Equations :

Plane electromagnetic Waves in vacuo, dielectric and conducting media, Group velocity and phase velocity, Retarded and accelerated potentials, Reflection and Refraction of plane waves at the plane boundary between two dielectrics, Field of a point charge in uniform motion. (10L)

References :

1. *W. K. H. Panofsky & M. Phillips* – Classical Electricity and Magnetism *(Addison-Wesley Pub. Co. Inc., 1962).*
2. *J. R. Reitz & F. J. Milford* – Foundations of Electromagnetic Theory *(Addison-Wesley Pub. Co., 1966)*
3. *D. J. Griffth* – Classical Electrodynamics *(Wiley Eastern, 1965)*

Paper – MAG303

(Continuum Mechanics-II, Dynamical Systems)

Unit-1
Continuum Mechanics-II

Total Lectures : 40 **(Marks – 30)**

General : Body, configuration, axiom of continuity, Motion of a body. Reference configuration, deformation. Material and spatial coordinates. Material and spatial time derivatives – relation between them. Velocity and acceleration. Physical components of acceleration in general curvilinear coordinates – in cylindrical coordinates and spherical polar coordinates, Deformation gradient tensor, Reynolds transport theorem for volume property. Principle of conservation of mass – Path lines, stream lines and streak lines. Material surface. (Bounding surface). Lagrange's criterion for material surface, Polar decomposition theorem (Statement), polar decomposition of deformation gradient tensor – stretch and rotation tensors, principal stretches. Classical theory of infinitesimal *deformations. Compatibility equations, Relative deformation gradient tensor, relative stretch tensors and relative rotation tensor. Rate-of –strain tensor-its principal values and invariants rate-of rotation tensor – vorticity vector; velocity gradient tensor, General principles of momenta balance; Euler's laws of motion. Body forces and contact forces. Cauchy's laws of motion: Stress equation of motion and symmetry of stress tensor for non-polar material. Energy balance – first and second laws of thermodynamics. (20L)*

Constitutive equation (stress-strain relations) for isotropic elastic solid. Elastic modulii. Strain-energy function. Beltrami-Michel compatibility equations for stresses. Equations of equilibrium and motion in terms of displacement. Fundamental boundary value problems of elasticity and uniqueness of their solutions (statement only). Saint-Venant's principle – solution of simple problems. Wave propagation in an infinite elastic medium, Waves of distortion and dilatation. (20L)

References :

1. Leigh, D. C. – *Non-Linear Continuum Mechanics* (MacGraw-Hill)
2. Truesdell, C – *Continuum Mechanics*
3. Chung, T. J. – *Contunuum Mechanics* (Prentice-Hall)
4. Truesdell, C and Nol, W. – *Encyclopaedia of Physics.* Vol. III/3, 1965 (Ed. S. Flugge)
5. Sokolnikoff, I. S. – *Mathematical Theory of Elasticity*
6. Milne – Thomson, L. M.- *Theoretical Hydrodynamics*
7. Pai, S. L. – *Viscous Flow Theory*
8. Schilichting, H. – *Boundary Layer Theory*
9. Eriengen, A. C. – *Non-linear Theory of Continuous Media* (MacGraw-Hill)
10. F. Chorlton – *A Text Book of Fluid Mechanics*
11. Kolin, Kebel & Roze – *Theoretical Hydromechanics*
12. Besand & Ramsey – *Fluid Mechanics*
13. J. Bansal – *Viscous Flow Theory*

Unit-2

Dynamical Systems

Total Lectures: 25 ***Marks: 20***

Dynamical Systems : *Phase variables and Phase space, continuous and discrete time systems, flows(vector fields), maps (discrete dynamical systems), orbits, asymptotic states, fixed (equilibrium) points periodic points, concepts of stability and SDIC (sensitive dependence of initial conditions) chaotic behaviour, dynamical system as a group. (6L)*

Linear systems : Fundamental theorem and its application. Properties of exponential of a matrix, generalized eigenvectors of a matrix, nilpotent matrix, stable, unstable and center subspaces, hyperbolicity, contracting and expanding behaviour. (6L)

Nonlinear Vector Fields : Stability characteristics of an equilibrium point. Liapunov and asymptotic stability. Source, sink, basin of attraction. Phase plane analysis of simple systems, homoclinic and heteroclinic orbits, hyperbolicity, statement of Hartmann-Grobman theorem and stable manifold theorem and their implications. (6L)

Liapunov function and Liapunov theorem. Periodic solutions, limit cycles and their stability concepts. Statement of Lienard's theorem and its application to vander Pol equation, Poineare-Bendixsom theorem (statement and applications only), structural stability and bifurcation through examples of saddle-node, pitchfork and Hopf bifurcations. (7L)

References :

1. *P. Glendinning* – Stability, Instability and Chaos *(Cambridge University Press 1994).*
2. *Strogartz* – Non-linear Dynamics
3. *M. W. Hirsch & S. Smale* – Differential Equations, Dynamical Systems and Linear Algebra *(Academic Press 1974)*
4. *L. Perko* – Differential Equations and Dynamical Systems *(Springer – 1991)*
5. *Arnold* – Ordinary Differential Equations

Paper – MAS304

(Special Paper-I)

Total Lectures: 65 ***Marks: 50***

A: Viscous Flows, Boundary Layer Theory and Magneto Hydrodynamics-I

Viscous Flows

Some exact solutions of Navier – Stokes' Equations: the flow due to suddenly accelerated plane wall; the flow near an oscillating plane wall; plane stagnation point flow (Hiemenz flow); the flow near a rotating disk; Hele-shaw flow; Bodewadt flow. (18L)

Navier-Stokes equations in non-dimensional form; Reynolds number. Creeping motion; hydrodynamical theory of lubrication; Stokes's flow past a sphere and a cylinder : Stokes paradox; Oseen approximation,Oseen's solution for a sphere. (18L)

Laminar Boundary Layer Theory

Concept of boundary layer : Prandtl's assumptions. Two dimensional B.L. Equations for flow over a plane wall : Boundary layer on a flat plate ; Blasius-Topfer solution, 'Similar solutions' of the B. L. equations : B. L. flow past a wedge; B. L. flow along the wall of a convergent channel; B. L. flow past a circular cylinder; (20L)

Separation of boundary layer.

The spread of a jet :

(i) *plane free jet (two-dimensional jet),*

(ii) *circular jet (axisymmetric jet).*

Prandtl-Mises transformation :

Karman momentum integral equation. Karman – Pohlhausen method : simple applications. (9L)

References:

1. *S. W. Yuan: Foundations of Fluid Mechanics, PHI, 1969*
2. *H. Schlichting: Boundary Layer Theory, Mc Graw-Hill Book Comp., 2004.*
3. *L.D. Landau and E. M. Lifshitz: Fluid Mechanics, Pergamon Press, 1959.*
4. *J. L. Bansal: Viscous Fluid Dynamics, 2003.*
5. *J. A. Shercliff: A text Book of Magnetrohydrodynamics*
6. *V. C. A. Ferraro and C. Plumpton: An Introduction to magneto fluid Mechanics, Oxford Univ. Press, 1961.*

B: Elasticity-I

1. *Generalised Hooke's law Orthotropic and transversely isotropic media. Stress-strain relations in isotropic elastic solid. (5L)*
2. *Saint-Venant's semi-inverse method of solution (Statement). Formulation of torsion problem and the equations satisfied by the torsion function and the boundary condition. Formulation of torsion problem as an internal Neumann problem,. Dirichlet's problem and Poisson's problem. Prandtl's stress function. shearing stress in torsion problem.*

Solution of torsion problem for simple sections Method of sol. of torsion problem by conformal mapping. (30L)

3. *Flexure problem : Reduction of flexure problem to Neumann problem. Solution of flexure problem for simple sections. (10L)*
4. *Potential energy of deformation. Reciprocal theorem of Betti and Rayleigh. Theorem of min. Potential energy. (10L)*
5. *Plane problem : plane strain, plane stress, generalised plane stress. Basic equations. Airy's stress function. Solution in terms of complex analytic function. (10L)*

References :

1. *Y. A. Amenzade* – Theory of Elasticity *(MIR Pub.)*
2. *A. E. H. Love* – A treatise on the Mathematical Theory of Elasticity, CUP, 1963.
3. *I. S. Sokolnikoff* – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
4. *W. Nowacki* – Thermoelasticity *(Addison Wesley)*
5. *Y. C. Fung- Foundations of Solid Mechanics, PHI, 1965.*
6. *S. Timoshenk and N. Goodies, Theory of Elasticity, Mc Grwa Hill Co., 1970.*
7. *N. I. Muskhelishvili- Some Basic Problems of the mathematical theory of Elasticity, P. Noordhoff Ltd., 1963.*

C: Elasticity and Theoretical Seismology-I

Elasticity

Generalised Hooke's law. Transversely isotropic media. Stress-strain relations in isotropic media. (10L)

Saint-Venant's semi-inverse method of solution. Torsion problem. Equation satisfied by torsion function and the boundary condition. Prandtl's stress function. Max shearing stress. Solution of torsion problem for simple sections. (20L)

Flexure problem. Differential Equation and the boundary condition. Solution for simple sections.

Potential energy of deformation. Reciprocal theorem of Betti and Rayleigh. Theorem of minimum potential energy. (20L)

Plane strain, plane stress. Basic equations. Airy's stress function. Thermo-elasticity : Thermal stress. Stress-strain relation in Thermo-elasticity. (15L)

References :

1. *Y. A. Amenzade* – Theory of Elasticity *(MIR Pub.)*

2. *A. E. H. Love* – A treatise on the Mathematical Theory of Elasticity, CUP, 1963.
3. *I. S. Sokolnikoff* – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
4. *W. Nowacki* – Thermoelasticity *(Addison Wesley)*
5. *Y. C. Fung- Foundations of Solid Mechanics, PHI, 1965.*
6. *S. Timoshenk and N. Goodies, Theory of Elasticity, Mc Grwa Hill Co., 1970.*
7. *N. I. Muskhelishvili- Some Basic Problems of the mathematical theory of Elasticity, P. Noordhoff Ltd., 1963.*

D: Applied Functional Analysis-I

Review of basic properties of Hilbert spaces. Convex programming-support functional of a convex set. Minkowski functional. Separation Theorem. Kuhn-Tucker Theorem. Minimax theorem. Farkas theorem. (20L)

Spectral theory of operators. Spectral Theory of compact operations. Operators on a separable Hilbert space. Krein factorization theorem for continuous kernels and its consequences. L_2 spaces over Hilbert spaces. (30L)

Multilinear forms. Analyticity Theorems. Non-linear Volterra operators. (15L)

References :

5. A. V. Balakrishnan- *Applied Functional Analysis,* Springer-Verlag.
6. Dunford and Schwartz-*Linear operators,* vol. 1 & 11.
7. S. G. Krein-Linear Differential Equations in a Banach space.
8. K. Yosida-Functional Analysis.

Paper – MAS305

(Special Paper-II)

Total Lectures : 65 **(Marks – 50)**

A: Quantum Mechanics -I

1. Transformation Theory : Adjoint operator, Hermitian operator, Projection operator, Degeneracy, Unitary transformation, Matrix representation of wave functions and operators, Change of basis, Transformation of matrix elements, Dirac's Bra and Ket

notation, Completeness and normalization of eigen functions, Common set of eigen functions of two operators, Compatibility of observables. (15L)

2. *Symmetries and Invariance : Angular momentum eigenvalues and eigenfunctions, Spin, Addition of two angular momenta, Rotation groups, Identical particles, Pauli exclusion principle, Invariance and conservation theorems. (15L)*

3. *Relativistic Kinematics : Kelin-Gordon equation, Dirac equation for a free particle and its Lorentz covariance, Hole theory and positron, Electron spin and magnetic moment. (15L)*

4. *Approximation Methods (time-independent)*
Rayleigh-Schrödinger perturbation method, An harmonic oscillator, Stark effect in hydrogen atom, Zeeman effect, Ground state energy of helium atom. (10L)

5. *Elements of Second Quantization of A System : Creation and Annihilation operator, Commutation and Anti-commutation rules, Relation with Statistics - Bosons and Fermions. (10L)*

References :

1. *A. Messiah* – Quantum Mechanics, *Vol. I & II (North – Holland Pub. Co., 1962).*
2. *B. H. Bransden & C. J. Joachain* – Introduction to Quantum Mechanics *(Oxford University Press, 1989).*
3. *P. G. Burke* – Potential Scattering in Atomic Physics *(Plenum Press, New York, 1977)*
4. *C. J. Joachain* – Quantum Collision Theory *(North-Holland Pub. Co., 1975)*
5. *B. H. Bransden* – Atomic Collision Theory *(W. A. Benjamin Inc., N. Y., 1970)*
6. *S. Geltman* – Topics in Atomic Collision Theory *(Academic Press. 1969)*
7. *T. Y. Wu and T. Olmura* – Quantum Theory of Scattering *(Prentice Hall, New Jersey, 1962)*
8. *N. F. Mott & H. S. W. Massey* – Theory of Atomic collisions *(3rd ed.), (Clarendon Press, Oxford, 1965)*
9. *M. L. Goldberger & K. M. Watson* – Collision Theory *(Wiley, N. Y., 1964)*
10. *R. G. Newton* – Scattering Theory of Waves and Particles *(McGraw – Hill, 1966)*

B: Advanced Operations Research-I

Non-linear Optimization : Local and global minima and maxima, convex functions and their properties, Method of Lagrange multiplier. (8L)

Optimality in absence of differentiability, Slater constraint qualification, Karlin's constraint qualification, Kuhn-Tuckers Saddle point optimality conditions, Optimality criterion with differentiability and convexity, separation theorems, Kuhn-Tuckers sufficient optimality theorem. (10L)

Unconstrained Optimization : Search method : Fibonacci search, Golden Section search; Gradient Methods : Steepest descent Quasi-Newton's method, Davidon-Fletecher-Powell method, Conjugate direction method (Fletecher-Reeves method). (15L)

Optimality conditions : Kuhn-Tucker conditions – non negative constraints (6L)

Quadratic Programming : Wolfe's Modified Simplex method, Beale's method (8L)

Separable convex programming, Separable Programming Algorithm. (6L)

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, Minflow max-cut theorem. (12L)

References:

13. G. Hadly – *Non-Linear and Dynamic Programming,* Addision –Wesley, Reading Mass.
14. G. Hadly – Linear Programming, Narosa Publishing House.
15. S. S. Rao –*Optimization theory and Applications,* Wiley Eastern Ltd., New Delhi.
16. O. L. Mangasarian – *Non-Linear Programming,* McGraw Hill, New York.
17. Luenberger – *Introduction to Linear and Non-Linear Programming*
18. S. Dano – *Non-Linear and Dynamic Programming*
19. H. A. Taha – *Operations Research – An Introduction,* Macmillan Publishing Co., Inc., New York.
20. Swarup, Gupta & Manmohan – *Operations Research,* Sultan Chand & Sons, New Delhi.
21. *N.S. Kambo- Mathematical Programming Techniques,* Affiliated East-West Press Pvt. Ltd., New Delhi
22. M. C. Joshi and K.M. Moudgalya, Optimization theory and Practice, Narosa Publishing House, New Delhi
23. C.R. Bector, S. Chandra and J. Dutta, Principles of optimization Theory, Narosa Publishing House, New Delhi
24. M. A. Bhatti, Practical Optimization Methods, Springer -Verlag

C: Inviscid Compressible Flows and Turbulence-I

Basic thermodynamics; Equations of state; Polytropic gases. Euler's equations of Motion; conservation of energy. Circulation theorem; Propagation of a small disturbance : Sound waves. Steady isentropic motion : Bernoulli's eqn. Subsonic and supersonic flows. Irrotational flow : velocity potential; Bernoulli's eqn. for unsteady flow. Stream function for steady two-dimensional motion. Steady flows through stream tubes, De Laval Nozzle. (30L)
Method of characteristics, unsteady one-dimensional flow. Normal and oblique shock relations; shock polar diagram. (10L)

Exact solution for two-dimensional steady motions : Radial flow : vortex flow, Prandtl-Mayer flows. Hodograph method : Molenbroek transformation; Legendre transformation; Solution of Chaplygine's equation. Limit lines; Linearization by the method of small perturbation : Prandtl-Glauert transformation. Subsonic and supersonic flow past thin bodies. Rayleigh-Janzen's method for flow past a circular cylinder. (25L)

References:

1. *S. W. Yuam: Foundations of Fluid Mechanics, PHI, 1969*
2. *H. Schlichting: Boundary Layer Theory, Mc Graw-Hill Book Comp., 2004.*
3. *L.D. Landau and E. M. Lifshitz: Fluid Mechanics, Pergamon Press, 1959.*
4. *J. L. Bansal: Viscous Fluid Dynamics, 2003.*
5. *J. A. Shercliff: A text Book of Magnetrohydrodynamics*
6. *V. C. A. Ferraro and C. Plumpton: An Introduction to magneto fluid Mechanics, Oxford Univ. Press, 1961.*

D: Computational Fluid Dynamics-I

Finite Difference methods : Solution of O.D.E., The method of factoriazation, iterative methods, upwind corrected schemes, Hermitian method. Solution of a one-dimensional linear parabolic equation; Noncentered schemes, Leapfrog Dufort-Frankel scheme, Solution of one-dimensional Non-linear parabolic and hyperbolic equations, Explicit and Implicit methods, The ADI method, Explicit splitting method for two dimensional equation. (40L)
Finite Element Methods : Variational formulation of operator equations and Galerkin's method, the construction of the finite elements, convergence rates for F. E. M., Stability of F. E. M., Elementary ideas of Finite volume method, Spectral method. Some simple applications of Fluid Dynamics Problems. (25L)

References:

1. *Peter Linz – Theoretical Numerical Analysis, An Introduction To Advance Technique (John Wiley & Sons.)*
2. *R. Peyret and T. D. Taylor – Computational Methods for fluid Flow (Springer – Verlag)*
3. *P. Wesseling – Principles of Computational Fluid Dynamics (Springer-Verlag, 2000)*
4. *J. D. Anderson – Computational Fluid Dynamics : The Basics With Applications (McGraw-Hill,1998)*
5. *C. A. J. Fletcher* – Computational Techniques for Fluid Dynamics, *Vol. I and II (Springer-Verlag).*
6. *Dale A. Anderson, John C. Tanehill, Richard H. Pletcher* – Computational Fluid Mechanics and Heat Transfer *(Hemisphere Publishing Corporation)*

SEMESTER-IV
APPLIED MATHEMATICS STREAM

Paper – MAG401

(Continuum Mechanics-III)

Total Lectures : 65 **(Marks – 50)**

Inviscid incompressible fluid : Definitions, Constitutive equation for inviscid fluid. Euler's equation of motion – vector invariant form. Steady motion – Bernoulli's equation and other consequences. Euler's momentum theorem; D'Alembert's paradox Helmholtz equation for vorticity. Circulation. Kelvin's theorem on circulation. Irrotational motion, velocity potential, acyclic irrotational motion. Permanence of irrotational motion. Some properties of acyclic irrotatioal motion (using Greeen's theorem) and Uniqueness theorems. General equation for impulsive motion and properties of motion under surface impulse. Kelvin's minimum energy theorem. Three dimensional source, sink and doublet (definitions only). Two dimensional motion. Stream function. Complex potential. Circular line vortex. Complex potentials for line source (sink), line doublet and line vortex. Circle theorem. Method of Images. Blasius theorem for thrust on an obstacle- applications to circular cylindrical boundary. Flow past a circular cylinder with circularion; Kutta-Joukowski's lift formula. Axi-symmetic motion.

Stokes stream function. Vortex motion-vortex surface, vortex tube and vortex filament. Fundamental properties (Helmholtz properties) of vortex motion. Velocity field due to a distribution of vorticity. Velocity field due to a closed vortex filament. (40L)

Gravity waves (water waves) surface condition, Cisotti's equation for complex polential of small height gravity waves. Progressive waves – cases of deep and shallow water. Stationary waves – possible wavelengths in a rectangular tank. Paths of particles for different waves. Energy for progressive waves and stationary wave. Group velocity and its dynamical significance. (10L)

Linearly viscous incompressible fluid:-

Constitutive equations (stress-rate-of strain relations) for linearly viscous fluid. Navier-Stokes equations-vector invariant form. Boundary conditions. Helmholtz equation for diffusion of vorticity.Dissipation of energy. Non-dimensional form of N.S. equations. Principle of similitude. Reynolds number Simple exact solutions of N-S equations: Parallel flow, Generalized Couette flow-plane. Plane Poiseuille flow and simple Couette flow. Hagen-Poiseuille flow through a circular pipe. Viscometric flow-Couette circular motion. (15L)

References :

1. Leigh, D. C. – *Non-Linear Continuum Mechanics* (MacGraw-Hill)
2. Truesdell, C – *Continuum Mechanics*
3. Chung, T. J. – *Contunuum Mechanics* (Prentice-Hall)
4. Truesdell, C and Nol, W. – *Encyclopaedia of Physics.* Vol. III/3, 1965 (Ed. S. Flugge)
5. Sokolnikoff, I. S. – *Mathematical Theory of Elasticity*
6. Miline – Thomson, L. M.- *Theoretical Hydrodynamics*
7. Pai, S. L. – *Viscous Flow Theory*
8. Schilichting, H. – *Boundary Layer Theory*
9. Eriengen, A. C. – *Non-linear Theory of Continuous Media* (MacGraw-Hill)
10. F. Chorlton – *A Text Book of Fluid Mechanics*
11. Kolin, Kebel & Roze – *Theoretical Hydromechanics*
12. Besand & Ramsey – *Fluid Mechanics*
13. J. Bansal – *Viscous Flow Theory*
14. Leigh, D. C. – *Non-Linear Continuum Mechanics* (MacGraw-Hill)
15. Truesdell, C – *Continuum Mechanics*
16. Chung, T. J. – *Contunuum Mechanics* (Prentice-Hall)
17. Truesdell, C and Nol, W. – *Encyclopaedia of Physics.* Vol. III/3, 1965 (Ed. S. Flugge)
18. Sokolnikoff, I. S. – *Mathematical Theory of Elasticity*

19. Miline – Thomson, L. M.- *Theoretical Hydrodynamics*

20. Pai, S. L. – *Viscous Flow Theory*

21. Schilichting, H. – *Boundary Layer Theory*

Paper – MAG402

(Elements of Quantum Mechanics, Chaos and Fractals)

Unit-1

Elements of Quantum Mechanics

Total Lectures : 40 **(Marks – 30)**

1. *Origin of the Quantum Theory :*

   Black-body radiation, Inadequacy of classical theory, The old quantum theory, Bohr-Sommerfeld theory, Atomic Spectra, Photoelectric effect and Compton effect, Matter waves, Wave-particle duality, Electron diffraction experiment. (15L)

2. *Basic Concepts :*

   Wave function of a free particle, Uncertainty and Complementarity principles, Gedanken experiments, wave packet, Schrödinger wave equation, Statistical interpretation of the wave function, Formal solution of the Schrödinger equation. (10L)

3. Simple Applications (exact solutions) :

   One dimensional potential step, Potential barrier, Square-well potential, Linear harmonic oscillator, Three-dimensional box potential, Spherically symmetric potential, Hydrogen atom bound-state problems. (10L)

4. Dynamical Variables and Operators :

Operators corresponding to physical observables, Expectation values of observables, The virial theorem, Eigenfunction and eigenvalues of operators, Discrete and continuous spectra, Commutativity of operators, Heisenberg's uncertainty relations, The minimum uncertainty product, Heisenberg's equation of motion for operators. (5L)

References :

1. *Heisenberg* – The Physical Principles of the Quantum Theory *[Dover Pub., 1930]*
2. *P. A. M. Dirac* – The Principles of Quantum Mechanics *[Oxford University Press, 1981]*
3. *F. Mandl* – Quantum Mechanics *[Butterworths Sci. Pub., London, 1957]*
4. *P. T. Mathews* – Introduction to Quantum Mechanics *[MacGraw Hill, 1963]*

5. *L. I. Schiff* – Quantum Mechanics *[MacGraw Hill, 1968]*

Unit-2

Chaos and Fractals

Total Lectures : 25 **(Marks – 20)**

Chaos and Fractals : *Examples, graphical analysis, orbits, phase diagrams fixed and periodic points stable and unstable sets smooth maps and conditions for stable and unstable periodic points hyperbolicity. (10)*
SDIC, topological transivity (mixing) and Devancey's definition of chaos, binary decimal representation of numbers and saw tooth map. One parameter family of maps and bifurcations (through examples only) topological conjugacy, Logistic map, period doubling route to chaos (10L)
Cantor sets, examples of fractals, definitions of topological and capacity dimensions, Horse shoe and the theorem : "period 3 implies chaos". (5L)

References :

1. *P. Glendinning* – Stability, Instability and Chaos *(Cambridge University Press 1994).*
2. *Strogartz* – Non-linear Dynamics
3. *R. L. Devaney* – A First Course In Chaotic Dynamical Systems
4. *R. A. Holmgren* - A First Course In Discrete Dynamical Systems *(Springer, 1991)*
5. *R. L. Devaney* – An Introduction To Chaotic Dynamical System *(Addison-Wesley 1987)*
6. *H. O. Peitgen* – Fractals and Chaos.

Paper – MAS403

(Special Paper-III)

Total Lectures: 65 ***Marks: 50***

A: Viscous Flows, Boundary Layer Theory & Magneto-Hydrodynamics-II

Electromagnetic equations for moving media, Ohm's law including Hall current, Lorentz force. MHD approximations. Stress-tensor formulation of Lorentz force; frozen-in-magnetic field. Alfven's Theorem; Alfven waves. Equations of motion and induction; their nondimensional forms; dimensionless parameters, Lundquist's criterion. Energy equation : Viscous and Joule dissipation, Poynting theorem. Boundary conditions. (25L)

Steady viscous incompressible flows : unidirectional flow under a transverse magnetic field : decoupling of MHD equations. Hartmann flow; Couette flow. Flow through a rectangular duct. Unsteady incompressible flows. Rayleigh's problem. MHD waves : propagation of small disturbances; plane waves; Reflection and transmission of plane harmonic waves; existence of finite amplitude MHD waves. Alfven waves with ohmic damping; Skin effect. (25L)

Magnetohydrostatics; equilibrium-configurations, Pinch effect, force-free fields, non-existence of force-free field of finite extent. General solution for a force-free field, special cases.

Dynamo problem, Cowling's theorem, Ferraro's law of isorotation. (15L)

References:

1. *S. W. Yuan: Foundations of Fluid Mechanics, PHI, 1969*
2. *H. Schlichting: Boundary Layer Theory, Mc Graw-Hill Book Comp., 2004.*
3. *L.D. Landau and E. M. Lifshitz: Fluid Mechanics, Pergamon Press, 1959.*
4. *J. L. Bansal: Viscous Fluid Dynamics, 2003.*
5. *J. A. Shercliff: A text Book of Magnetrohydrodynamics*
6. *V. C. A. Ferraro and C. Plumpton: An Introduction to magneto fluid Mechanics, Oxford Univ. Press, 1961.*

B: Elasticity-II

Vibration problems : Longitudinal vibration of thin rods, Torsional vibration of a solid circular cylinder and a solid sphere. Free Rayleigh and Love waves. (15L)

Thermoelasticity : Stress-strain relations in Thermo elasticity. Reduction of statistical thermo-elastic problem to a problem of isothermal elasticity. Basic equations in dynamic thermo elasticity. Coupling of strain and temperature fields. (30L)

Magneto-elasticity : Interaction between mechanical and magnetic field. Basic equations Linearisation of the equations. (20L)

References :

1. *Y. A. Amenzade* – Theory of Elasticity *(MIR Pub.)*
2. *A. E. H. Love* – A treatise on the Mathematical Theory of Elasticity, CUP, 1963.
3. *I. S. Sokolnikoff* – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
4. *W. Nowacki* – Thermoelasticity *(Addison Wesley)*
5. *Y. C. Fung- Foundations of Solid Mechanics, PHI, 1965.*
6. *S. Timoshenk and N. Goodies, Theory of Elasticity, Mc Grwa Hill Co., 1970.*
7. *N. I. Muskhelishvili- Some Basic Problems of the mathematical theory of Elasticity, P. Noordhoff Ltd., 1963.*

C: Elasticity and Theoretical Seismology-II

Theoretical Seismology

Theory of elastic waves; Motion of a surface of discontinuity – kinematical condition and dynamical conditions. Kirchoff's solution of inhomogeneous wave equation. (20L)

Reflection and refraction of elastic body waves. (10L)

Surface waves : Rayleigh, Love and Stonely waves (10L)

Dispersion and Group Velocity of elastic body waves. (10L)

Some problems : Application of pressure and twist on the walls of a spherical cavity in an elastic medium. (10L)

Line source and point source on the surface of a semi-infinite elastic medium. (5L)

References :

1. *Y. A. Amenzade* – Theory of Elasticity *(MIR Pub.)*
2. *A. E. H. Love* – A treatise on the Mathematical Theory of Elasticity, CUP, 1963.
3. *I. S. Sokolnikoff* – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
4. *W. Nowacki* – Thermoelasticity *(Addison Wesley)*
5. *Y. C. Fung- Foundations of Solid Mechanics, PHI, 1965.*
6. *S. Timoshenk and N. Goodies, Theory of Elasticity, Mc Grwa Hill Co., 1970.*
7. *N. I. Muskhelishvili- Some Basic Problems of the mathematical theory of Elasticity, P. Noordhoff Ltd., 1963.*
8. *E. Savarensky- Seismic waves, MIR Pub.*
9. *B.L. N. Kennett, Seismic wave propagation in Stratified Media, CUP*
10. *K.E. Bullen, An Introduction to the theory of Seismology, CUP.*
11. *Arinben-Menahem Sarva Jit Singh- Seismic waves and Sources, Springer-Verlag.*

D: Applied Functional Analysis-II

Semigroups of linear operators-general properties of semigroups. Generation of semigroups. Dissipative semigroups. Compact semigroups. (20L)

Holomorphic semigroups, Elementary examples of semigroups. Extension. Differential Equations. Cauchy Problem, Controllability. State reduction. Ovservability. Stability and stabilizability. Evolution equations. (30L)

Optimal Control Theory-Linear quadratic regulator problem. The same problem with infinite time interval. Hard constraints. Final value control. Time optimal control problems. (15L)

References :

1. A. V. Balakrishnan- *Applied Functional Analysis,* Springer-Verlag.
2. Dunford and Schwartz-*Linear operators,* vol. 1 & 11.
3. S. G. Krein-*Linear Differential Equations in a Banach space.*
4. K. Yosida-*Functional Analysis.*

Paper – MAS404

(Special Paper-IV)

Total Lectures : 65 **(Marks – 50)**

A: Quantum Mechanics -II

Collision Theory : Basic concepts, Cross sections, Laboratory and center-of-mass coordinates, Rutherford scattering, Quantum mechanical formulation — time independent and time-dependent, Scattering of a particle by a short-range potential, Scattering by Coulomb potential, Scattering by screened Coulomb field, Scattering by complex potential. (15L)

Integral Equation Formulation: Lippmann-Schwinger integral equation and its formal solutions, Integral representation of the scattering amplitude, Convergence of the Born Series, Validity of Born approximation, Transition probabilities and cross sections. (12L)

Semi-Classical Approximations : WKB approximation, Eikonal approximation. (8L)

Variational Principles in the Theory of Collisions : General formulation of the variational principle, Hulthen, Kohn-Hulthen and Schwinger variational methods, Determination of Phase shifts, Scattering length and scattering amplitude for central force problems, Bound (minimum) principles. (20L)
Analytic Properties of Scattering Amplitude : Jost function, Scattering matrix, Bound states and resonances, Levinson theorem, Dispersion relations, Effective range theory. (10L)

References :

1. *A. Messiah* – Quantum Mechanics, *Vol. I & II (North – Holland Pub. Co., 1962).*
2. *B. H. Bransden & C. J. Joachain* – Introduction to Quantum Mechanics *(Oxford University Press, 1989).*
3. *P. G. Burke* – Potential Scattering in Atomic Physics *(Plenum Press, New York, 1977)*
4. *C. J. Joachain* – Quantum Collision Theory *(North-Holland Pub. Co., 1975)*
5. *B. H. Bransden* – Atomic Collision Theory *(W. A. Benjamin Inc., N. Y., 1970)*
6. *S. Geltman* – Topics in Atomic Collision Theory *(Academic Press. 1969)*
7. *T. Y. Wu and T. Olmura* – Quantum Theory of Scattering *(Prentice Hall, New Jersey, 1962)*
8. *N. F. Mott & H. S. W. Massey* – Theory of Atomic collisions *(3^{rd} ed.), (Clarendon Press, Oxford, 1965)*
9. *M. L. Goldberger & K. M. Watson* – Collision Theory *(Wiley, N. Y., 1964)*
10. *R. G. Newton* – Scattering Theory of Waves and Particles *(McGraw – Hill, 1966)*

B: Advanced Operations Research-II

Dynamic Programming : Characteristics of Dynamic Programming problems, Bellman's principle of optimality (Mathematical formulation)
Model –1 : Single additive constraint, multiplicative separable return,
Model – 2 : Single additive constraint, additively separable return,
Model – 3 : Single a multiplicative constraint, additively separable return,
Multistage decision process – Forward and Backward recursive approach, Dynamic Programming approach for solving linear and non-linear programming problems, Application – Single-item N-period deterministic inventory model. (25L)

Geometric Programming : Elementary properties of Geometric Programming and its applications. (8L)

Queuing Theory : Introduction, characteristic of Queuing systems, operating characteristics of Queuing system. Probability distribution in Queuing systems. Classification of Queuing models. Poisson and non-Poisson queuing models (32L)

References:

6 G. Hadly – *Non-Linear and Dynamic Programming,* Addision –Wesley, Reading Mass.

7 S. Dano – *Non-Linear and Dynamic Programming*

8 H. A. Taha – *Operations Research – An Introduction,* Macmillan Publishing Co., Inc., New York..

9 Swarup, Gupta & Manmohan – *Operations Research,* Sultan Chand & Sons, New Delhi.

10 N.S. Kambo- *Mathematical Programming Techniques,* Affiliated East-West Press Pvt. Ltd., New Delhi

C: Inviscid Compressible Flows and Turbulence-II

Turbulence:

Introduction. Reynold's equations of mean motion for turbulent flow, Reynold's stress-tensor; eddy viscosity. Phenomenological theories. Mixing length Prandtl's momentum transfer theory, Taylor's vorticity transfer theory. Karman's similarity hypothesis. Velocity distribution in channel flow under constant pressure gradient. (30L)

Spread of turbulence: Mixing zone between two parallel flows, (two-dimensional) turbulent wake behind (i) symmetrical cylinder (ii) a row of parallel rods. Turbulent flow through smooth circular pipes; Seventh power velocity distribution law; turbulent boundary layer on a flat plate. (20L)

Statistical approach; Introductory concepts; double correlation between velocity components, longitudinal and lateral; correlations in homogeneous turbulence; Eulerian correlation with respect to time, Taylor's one-dimensional energy spectrum. Energy relations in turbulent flows. (15L)

References:

1. *S. W. Yuam: Foundations of Fluid Mechanics, PHI, 1969*
2. *H. Schlichting: Boundary Layer Theory, Mc Graw-Hill Book Comp., 2004.*

3. *L.D. Landau and E. M. Lifshitz: Fluid Mechanics, Pergamon Press, 1959.*
4. *J. L. Bansal: Viscous Fluid Dynamics, 2003.*
5. *J. A. Shercliff: A text Book of Magnetrohydrodynamics*
6. *V. C. A. Ferraro and C. Plumpton: An Introduction to magneto fluid Mechanics, Oxford Univ. Press, 1961.*

D: Computational Fluid Dynamics-II

Multigrid method, Conjugate – Gradient method. Incompressible Navier – Stokes (NS) equations – Boundary conditions, Spatial and temporal discretization on collocated and on staggered grids. Development of the MAC Method for NS equations, Implementation of boundary conditions. (35L)

Grid Generation by Algebraic mapping : One-dimensional stretching functions, Boundary – Filted Coordinate Systems : Elliptic Grid generation. Solution of Euler Equations in General Co-ordinates. Numerical Solution of NS Equations in General Co-ordinates. (30L)

References :

1. Peter Linz – *Theoretical Numerical Analysis, An Introduction To Advance Technique* (John Wiley & Sons.)
2. R. Peyret and T. D. Taylor – *Computational Methods for fluid Flow* (Springer – Verlag)
3. P. Wesseling – *Principles of Computational Fluid Dynamics* (Springer-Verlag, 2000)
4. J. D. Anderson – *Computational Fluid Dynamics : The Basics With Applications* (McGraw-Hill,1998)
5. C. A. J. Fletcher – *Computational Techniques for Fluid Dynamics,* Vol. I and II (Springer-Verlag).
6. Dale A. Anderson, John C. Tanehill, Richard H. Pletcher – *Computational Fluid Mechanics and Heat Transfer* (Hemisphere Publishing Corporation)

Paper – MAT405

Term Paper

Marks: 50

Term paper MAT405 is related with the special papers of the applied stream offered by the department in each session and the topic of the term paper will also be decided by the department in each session. However the mark distribution is 30 marks for written submission, 15 marks for seminar presentation and 5 marks for viva-voce.