

**DHANAMANJURI UNIVERSITY: POST GRADUATE MATHEMATICS SYLLABUS**  
**COURSE STRUCTURE**

Course Code	Course Type	Course Title	Internal Ass'ment Marks	End Sem Marks	Total Marks	Class Hours per Week	No. of Credits (L+T)
<b>Semester-I</b>			100	400	500	30	30
MAT-1015	Core	Advanced Abstract Algebra-I	20	80	100	6	5+1
MAT-1025	Core	Real Analysis-I	20	80	100	6	5+1
MAT-1035	Core	Topology-I	20	80	100	6	5+1
MAT-1045	Core	Complex Analysis-I	20	80	100	6	5+1
MAT-1055	Core	Differential Eqn.(Ordinary)-I	20	80	100	6	5+1
<b>Semester-II</b>			120	480	600	36	36
MAT-2016	Core	Advanced Abst. Algebra-II	20	80	100	6	5+1
MAT-2026	Core	Real Analysis-II	20	80	100	6	5+1
MAT-2036	Core	Topology-II	20	80	100	6	5+1
MAT-2046	Core	Complex Analysis-II	20	80	100	6	5+1
MAT-2056	Core	Differential Eqn. (Partial)-II	20	80	100	6	5+1
MAT-2066	Open Elective	Fuzzy Set Theory and Mathematical Programming	20	80	100	6	5+1
MAT-2076	Open Elective	Discrete Mathematics	20	80	100	6	5+1
<b>Semester-III</b>			100	400	500	30	30
MAT-3015	Core	Functional Analysis	20	80	100	6	5+1
MAT-3025	Core	Measure and Integration	20	80	100	6	5+1
MAT-3035 MAT-3045 MAT-3055	Elective (Any One)	Fluid Dynamics Differential Geometry and Tensor Algebraic Coding Theory	20	80	100	6	5+1
MAT-3065	Elective	Optional Paper-I Optional Paper-II	20	80	100	6	5+1
<b>Semester-IV</b>			100	400	500	30	30
MAT-4015	Core	Number Theory	20	80	100	6	5+1
MAT-4025	Core	Mechanics	20	80	100	6	5+1
MAT-4035 MAT-4045 MAT-4055	Elective (Any One)	Algebraic Topology Commutative Algebra Algebraic Number Theory	20	80	100	6	5+1
MAT-4065	Elective	Optional-I (continued) Optional-II (continued)	20	80	100	6	5+1

**List of Optional Papers:**

- A. Operations Research
- B. General Relativity and Cosmology
- C. Cryptology
- D. Theory of Linear Operators

Note:-

1. Subject to availability of teacher(s), any one paper of the three given in MAT-303 & MAT- 403 will be offered.
2. The choice of two Optional Papers in III & IV semesters will solely depend upon the number of Optional Papers offered in the Department.

**Eligibility for Admission:**

Admission is done via two modes – entrance and merit with equal number of seats allotted to both modes. The details are as follows:

Mode	Category	Eligibility: Course requirement	Eligibility: Marks requirement
Entrance	1	Bachelor Degree in any subject and has studied at least 3 courses each of one year duration or 6 courses each of one semester duration in Mathematics	45% marks and above in aggregate
Merit	2	B.A./B.Sc. Mathematics (Hons.) Degree of DMU	60% marks in aggregate

## **I-SEMESTER**

### **ADVANCED ABSTRACT ALGEBRA-I**

**MAT-1015**

**Full Marks: 100**

**Unit-I Groups:** Normal and Subnormal Series, Composition Series, Jordan-Holder Theorem, Solvable Groups, Nilpotent Groups. **Marks: 30**

**Unit-II Field Theory:** Extension Fields, Algebraic and Transcendental Extensions, Separable and Inseparable Extensions; Normal Extensions. Perfect Fields; Finite Fields; Primitive Elements; Algebraically Closed Fields; Automorphisms of Extensions. **Marks: 30**

**Unit-III Galois Theory:** Galois Extensions, Fundamental Theorem of Galois Theory, Solution of Polynomial Equations by Radicals, Insolvability of the General Equation of Degree 5 by Radicals. **Marks: 20**

#### **References:**

1. **PB Bhattacharya, SK Jain and SR Nagpaul;** Basic Abstract Algebra (2<sup>nd</sup> Edition) Cambridge University Press.
2. **M Artin;** Algebra, Prentice Hall of India, 1991.
3. **PM Cohn;** Algebra, Vols. I, II & III, John Wiley and Sons, 1982, 1989, 1991.
4. **N Jacobson;** Basic Algebra, Vols. I & II, W.H. Freeman 1980.

### **REAL ANALYSIS-I**

**MAT-1025**

**Full Marks: 100**

**Unit-I** Definition and Existence of Riemann-Stieltjes Integral, Properties of the Integrals; Integration and Differentiation; Fundamental Theorem of Calculus; Integration of Vector Valued Functions; Rectifiable Curves. **Marks: 30**

**Unit-II** Rearrangement of Terms of a Series; Riemann's Theorem; Sequence and Series of Functions; Pointwise and Uniform Convergence, Cauchy's Criterion for Uniform Convergence; Weierstrass M-Test, Abel's Test and Dirichlet's Test for Uniform Convergence and Continuity, Uniform Convergence and Riemann-Stieltjes Integration; Uniform Convergence and Differentiation; Weierstrass Approximation Theorem. **Marks: 30**

**Unit-III** Functions of Several Variables, Linear Transformations; Derivatives in an Open Set  $R^n$ ; Chain Rule, Partial Derivatives, Interchange of the Order of Differentiation, Derivatives of Higher Order, Taylor's Theorem, Inverse Function Theorem, Implicit Function Theorem, Jacobians; Extremum Problems with Constraints, Lagrange's Multiplier Method, Differentiation of Integrals. **Marks: 20**

### References:

1. **Walter Rudin**; Principles of Mathematical analysis (3<sup>rd</sup> Edition) Mc Graw-Hill, Kogakusha, 1976, International student Edition.
2. **TM Apostol**; Mathematical analysis, Narosa Publishing House, New Delhi, 1985.
3. **AW White**; Real Analysis an Introduction, Addison-Wesley Publishing Co., Inc., 1968.
4. **G de Barra**; Measure Theory and Integration, Wiley Eastern Ltd., 1981.
5. **PK Jain and VP Gupta**; Lebesgue Measure and Integration, New Age International Pvt. Ltd., New Delhi, 2000.
6. **HL Royden**; Real Analysis; McMillan Pub. Co., Inc., 4<sup>th</sup> Edition NY, 1993.
7. **NL Carothers**; Real Analysis, Cambridge University Press, 2000.
8. **Walter Rudin**; Real and Complex Analysis, Tata McGraw-Hill Publishing Co.

### TOPOLOGY-I

**MAT-1035**

**Full Marks: 100**

**Unit-I** Metric Spaces, Topological Spaces, Closed Sets, Closure. Dense Subsets, Neighborhoods, Interior, Exterior and Boundary. Accumulation Points and Derived Sets. Bases and Subbases; Subspaces and Relative Topology. **Marks: 30**

**Unit-II** Continuous Functions and Homomorphism (Metric Space/Topological Spaces continued). First and Second Countable Spaces. Lindelof's Theorem, Separable Spaces, Continuity and Separability, Separation Axioms:  $T_0, T_1, T_2, T_3, T_{3\frac{1}{2}}, T_4, T_5, T_6$ . Their Characterization and Basic Properties, Urysohn's Lemma; Tietze Extension Theorem. **Marks: 30**

**Unit-III** Compactness, Continuous Functions and compact Sets. Basic Properties of Compactness and Finite Intersection Property; Sequentially and Countably Compact Sets; Local Compactness and One Point Compactification; Stone-Cech Compactification. Compactness in Metric Space; Equivalence of Compactness; Countable compactness and sequential Compactness in Metric Spaces. **Marks: 20**

### References:

1. **James R Munkres**; Topology, A first Course, Prentice Hall of India Pvt., Ltd., New Delhi, 2000.
2. **James R Munkres**; Topology, Pearson Education Asia, 2002.
3. **J Dugundji**; Topology, Allyn and Bacon, 1966.
4. **GF Simmons**; Introduction to Topology and Modern Analysis, McGraw-Hill and Company, 1963.
5. **KD Joshi**; Introduction to Topology, Wiley Eastern Ltd., 1983.
6. **JA Kelley**; General Topology, Van Nostrand Reinhold Co. NY, 1995.
7. **LA Steen and JA Seebach (Jr.)**; Counter Examples in Topology, Holt Rinehart and Winston, NY, 1970.

**COMPLEX ANALYSIS-I****MAT-1045****Full Marks: 100**

**Unit-I:** Limit, Continuity and Differentiability of  $f(z)$ ; Necessary and sufficient condition for  $w = f(z)$  to be analytic. Construction of regular function, Polar form of Cauchy-Riemann equations. Complex Integration; Cauchy-Goursat Theorem; Cauchy's Integral Formula; Poisson's Integral Formula; Higher Order Derivatives; Morera's Theorem. Cauchy's Inequality and Liouville's Theorem; The Fundamental Theorem of Algebra. **Marks: 30**

**Unit-II:** Taylor's Theorem; Laurent's Series; Maximum Modulus Principle. Isolated Singularity; Zeros of Analytic Function, Meromorphic Function; Schwarz Lemma; The Argument Principle; Rouché's Theorem; Open Mapping Theorem, Inverse Function Theorem; Residues; Cauchy's Residue Theorem; Evaluation of Integrals. **Marks: 30**

**Unit-III:** Definitions and Examples of Conformal Mappings; Necessary and Sufficient condition for  $w = f(z)$  to be Conformal. Bilinear Transformations, Their Properties and Classification. **Marks: 20**

**References:**

1. **JB Conway**; Functions of One Complex Variable, Springer Verlag, International Student-Edition, Narosa Publishing House.
2. **Liang-Shin Hahn and Bernard Epstein**; Classical Complex Analysis, Jones and Bertlett Pub. International, London.
3. **HS Kasana**; Complex Variables, Theory and Applications, Prentice-Hall of India, ND
4. **S Ponnusamy**; Foundations of Complex Analysis Narosa Pub. House.
5. **HA Priestly**; Introduction to Complex Analysis, Clarendon Press, Oxford.

**DIFFERENTIAL EQUATIONS-I****MAT-1055****Full Marks: 100**

**Unit-I** Power Series, Initial value problem and the equivalent integral equation, Existence, Uniqueness and continuity of the solution of ordinary differential equation of first order, Picard's method of successive approximation, Lipschitz condition, Picard's theorem of Existence and uniqueness, Existence and uniqueness of the solution of simultaneous differential equations of first order and ordinary differential equation of higher order with examples. **Marks: 30**

**Unit-II** Linear dependence and linear independence of solutions of linear differential equations, The Wronskian, Theorems on linearly independent solutions and linearly dependent set of functions, Homogeneous linear systems, non-homogeneous linear systems, linear systems with constant coefficient. **Marks: 30**

**Unit-III** : Oscillation theory, Adjoint equation, Self-Adjoint linear homogeneous second order differential equation, Abel's formula, oscillatory and non-oscillatory functions, Sturm separation

theorem, Sturm comparison theorem, Sturm Picone theorem, condition under which solution of a differential equation in self adjoint form may be oscillatory or non-oscillatory, Sturm- Liouville systems, Orthogonal set of functions and Orthonormal set of functions, Eigen (or characteristic) values and Eigen (or characteristic) functions.

**Marks: 20**

**References:**

1. EA Coddington; An Introduction to Ordinary Differential Equation, Prentice Hall of India, Pvt., Ltd., New Delhi.
2. EL Ince; Ordinary Differential Equations, Dover Publishing Inc.
3. W Leighton; Ordinary Differential Equations; Long-Man's Publication.
4. JC Bwekill; Ordinary Differential Equations, Oliver and Boyd.
5. G.f. simmons; Ordinary differential rquations with applications and historical notes, McGraw hill.
6. M.D. Raisinghania; Advanced differential equation, S.Chand and company ltd.
7. S.L. Ross, Differential equation, Wiley India

## II-SEMESTER

### ADVANCED ABSTRACT ALGEBRA-II:

MAT-2015

Full Marks-100

**Unit-I:** Direct sums and exact sequences, Cyclic modules, Simple modules, Semi-simple modules, Schur's lemma, Free modules, Projective modules and injective modules. **Marks: 30**

**Unit-II:** Noetherian and Artinian modules and rings, Hilbert basis theorem, Wedderburn-Artin theorem, Smith normal over a principal ideal domain and rank. **Marks: 30**

**Unit-III:** Fundamental structure theorem for finitely generated modules over a principal ideal domain and its applications to finitely generated abelian groups, Rational canonical forms, Generalized Jordan form over any field. **Marks: 20**

#### References:

1. **PB Bhattacharya, S K Jain and SR Nagpaul**, Basic Abstract Algebra (2<sup>nd</sup> Edition), Cambridge University Press, Indian Edition.
2. **M Martin**, Algebra, Prentice Hall of India.
3. **PM Cohn**, Algebra, Vol. I, II, III, John Weley and Sons.
4. **N Jacobson**, Basic Algebra, Vol. I and Vol. II, W.H. Freeman.
5. **S Lang**, Algebra, 3<sup>rd</sup> Edition, Addison-Wesley.
6. **I S Luther and IBS Passi**, Algebra Vol. I-Groups, Vol. II-Rings, Narosa.
7. **Bibek Sahai and Bikas Bist**, Algebra, Narosa Publishing House.

### REAL ANALYSIS-II

MAT-2026

Full Marks: 100

**Unit-I:** Lebesgue outer measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesgue measurability, Non-measurable sets, Integration of non-negative functions, The general integral, Integration of series, Riemann and Lebesgue integrals. **Marks: 30**

**Unit-II:** Differentiation and Integration, The four derivatives, Functions of bounded variations, Lebesgue differentiation theorem, Measures and outer measures, Extension of a measure, Uniqueness of extension, Completion of a measure, Measure spaces. Integration with respect to a measure. **Marks: 30**

**Unit-III:** The  $L^p$ -spaces, Convex functions, Jensen's inequality, Holder's and Minkowski's inequalities, Completeness of  $L^p$  spaces, Convergences in measure, Almost uniform convergence. **Marks: 20**

#### References:

1. **Walter Rudin**, Principles of Mathematical Analysis (3<sup>rd</sup> edition), McGraw-Hill.
2. **Walter Rudin**, Real and Complex Analysis, Tata McGraw-Hill, New Delhi.
3. **T M Apostol**, Mathematical Analysis, Narosa Publishing House, New Delhi.

4. **G de Barra**, Measure Theory and Integration, Wiley Easter Ltd.
9. **H L Royden**, Real Analysis; McMillan Pub. Co., Inc., 4<sup>th</sup> Edition NY, 1993.
5. **Sterling K. Berberian**, Measure and Integration, American Mathematical Society.
6. **P R Halmos**, Measure theory, Van Nostrand, Princeton.

## **TOPOLOGY –II**

**MAT-2036**

**Full Marks-100**

**Unit-I:** Connected spaces, Connectedness on the real line, Components, Locally connected spaces, Tychonoff product topology in terms of standard sub-base and its characterizations, Projection maps, Separation axioms and product spaces, Connected and product spaces, Countable product spaces, Embedding and metrization, Embedding lemma and Tychonoff embedding, The Uryson metrization theorem. **Marks: 30**

**Unit-II:** Nets and filters, Topology and convergence of nets, Hausdorffness and nets, Compactness and nets, Filters and their convergence, Compactness and product spaces (Tychonoff theorem), Canonical way of converting nets to filters and vice versa, Ultra filters and Compactness. **Marks: 30**

**Unit-III:** Metrization theorem and para-compactness-Local finiteness, The Nagata-Smirnov metrization theorem, Para-compactness, The Smirnov metrization theorem, The fundamental group and covering space-Homotopy of paths, The fundamental group, Covering spaces, the fundamental group of circle and the fundamental theorem of algebra. **Marks: 20**

### **References:**

1. **JR Munkres**, Topology, A first Course, Prentice Hall of India Pvt. Ltd. New Delhi.
2. **JR Munkres**, Topology, Pearson Education Asia.
3. **JDugundji**, Topology, Allyn and Bacon, 1966 Prentice Hall of India.
4. **George F Simons**, Introduction to Topology and Modern Analysis, McGraw-Hill.
5. **KD Joshi**, Introduction to General Topology, Wiley Eastern, Ltd.
6. **John L Kelley**, General Topology, Van Nostrand, Reinhold co., New York.
7. **R Engelking**, Foundations of General Topology, Polish scientific Publishers, Warszawa.

## **COMPLEX ANALYSIS-II**

**MAT-2046**

**Full Marks-100**

**Unit-I:** Weierstrass Factorization Theorem, Gamma function and its properties, Riemann Zeta function, Riemann's functional equation, Runge's theorem, Mittag-Leffler's theorem, Analytic Continuation, Uniqueness of direct analytic continuation, Uniqueness of analytic continuation along a curve, Power series method of analytic continuation, Schwarz's reflection principle. Montel's Theorem; Riemann Mapping Theorem; Spaces of Analytic Functions; Hurwitz's Theorem. **Marks: 30**



**Unit-II:** Harmonic functions on a disk, Harnack's inequality and Harnack's theorem, Dirichlet problem, Green's function, Canonical product, Jensen's formula, Poisson-Jensen formula, Hadamard's three circle theorem, Order of an entire function, Exponent of convergence, Borel's theorem, Hadamard's factorization theorem. **Marks: 30**

**Unit-III:** The range of an analytic function, Bloch's theorem, The Little Picard theorem, Schottky's theorem, Montel-Caratheodory theorem and the Great Picard theorem, Univalent functions, Bieberbach's conjecture and the one-fourth theorem. **Marks: 20**

**References:**

1. **JB Conway**, Functions of One Complex Variable, Springer-Verlag, International Student-Edition, Narosa.
2. **Liang-Shin Hahn & Bernhard Epstein**, Classical Complex Analysis, Jones and Berlett.
3. **Walter Rudin**, Real and Complex Analysis, McGraw Hill Book Co.
4. **S Ponusamy**, Foundations of Complex Analysis, Narosa.
5. **HA Priestly**, Introduction to Complex Analysis, Clarendon Press, Oxford.

**DIFFERENTIAL EQUATIONS (PARTIAL)-II**

**MAT-2056**

**Full Marks-100**

**Unit-I:** Definition of PDE, Formation of PDE, Cauchy's Problem for First Order PDE, Linear PDE of First Order, Integral Surfaces passing through a given Curve, Surfaces Orthogonal to a given System of Surfaces, Non-linear PDE of the First Order, Cauchy's Method of Characteristics, Compatible Systems of First Order Equations, Charpit's Method, Jacobi's Method. **Marks: 30**

**Unit-II:** Origin of Second Order PDE, Linear Second Order PDE with Constant Coefficients, Linear Second Order PDE with Variable Coefficients, Second Order PDE Method of Variation of Parameters, Monge's Method. **Marks: 30**

**Unit-III:** Canonical forms of Second order linear PDE's, Wave Equation, Solution of the wave Equation, D'Alembert's Solution of the Wave Equation, Heat (Diffusion) Equation, Solution of Heat Equation, Laplace Equation, Solution of Laplace Equation, Boundary Value Problems, Method of Separation of Variables, Families of Equipotential Surfaces, Laplace Transform, Fourier Transform and Application to Solution of PDE. **Marks: 20**

**References:**

1. **IN Sneddon**, Elements of Partial Differential Equations, McGraw Hill.
2. **J David Logan**, Partial differential Equations, Springer International Edition.
3. **Stanley J Farlow**, Partial Differential Equations for scientist and engineers, Dover.
4. **LC Evans**, Partial Differential Equations, American Mathematical Society.
5. **AR Forsyth**, Differential equation, A Treatise on Differential Equations, CBS.
6. **Clay C Ross**, Differential Equations, Springer.
7. **K Sankara Rao**, Introduction to Partial Differential Equations, PHI, Pvt. New Delhi.

## [OPEN ELECTIVE]

### **FUZZY SETS AND MATHEMATICAL PROGRAMMING: MAT-2066 Full Marks: 100**

Objectives and Outcome: The objective of this course is to explore various important areas of fuzzy set theory and Mathematical programming algorithms to solve real life problems.

**Unit I:** An overview of Crisp Sets, Basics of Fuzzy sets, Developing Membership Functions, Operations on Fuzzy sets, Fuzzy numbers and Fuzzy Arithmetic, Fuzzy logic, Defuzzification, Decision making in fuzzy Environment. **Marks: 30**

**Unit II:** Modeling with linear programming, Mathematical Formulation of the problem, Graphical solution method, Simplex method, Charnes method or Big M method, two phase Simplex method. **Marks: 30**

**Unit III:** Transportation problems, Transportation algorithm (Modi method), Assignment problems. The travelling Salesman problem, Network Scheduling by PERT and CPM **Marks: 20**

#### **References:**

1. **H A Taha**, Operations Research: An Introduction (Eighth edition), PHI Publications, New Delhi, 2006.
2. **FS Hiller and G J Lieberman**, Introduction to Operations Research, McGraw Hills Publication, International Edition, Industrial Engineering Series, 1995.
3. **Kanti Swarup, PK Gupta and Man Mohan**, Operation Research: S. Chand & Sons, ND.
4. **Rajjan Shingal**, Introduction to Fuzzy Logic: PHI Learning Private Limited, Delhi.
5. **SK Pundir and R Pundir**, Fuzzy Sets and their Applications, Pragati Prakashan.
6. **HJ Zimmermann**, Fuzzy Set Theory and its Applications Springer Science, New York.

### **DISCRETE MATHEMATICS:**

**MAT-2076**

**Full Marks-100**

Objective and Outcome: Discrete Mathematical structures have many objectives, few among which are that students learn the essentials of mathematics to acquire the logical thinking. People use to think that Mathematics has some inherent difficulties due to its abstract and cumulative nature. But the study of Discrete Mathematics will give students an immense taste of the subject matter.

**Unit-I:** Theory of Numbers and basic properties of Congruences, Linear Congruences, Divisibility tests, Check digits, Applications to Cryptography, Public key cryptosystems, Credit card check digit, Round-robin tournaments. **Marks: 30**

**Unit-II:** Mathematical Logic, Propositional logic, Operations on Statements, Removal of Brackets from a Statement formula, Adequate system of connectives, Truth Function, Translation of sentences, Predicate logic. Introduction to Boolean algebra, logic gate.

**Marks: 30**

**Unit-III:** Introduction to Graph theory, Preliminary Definitions and notations, walks, path, circuit, complete graph, connected graph, sub graphs, Trees and their properties, Binary trees, Spanning trees, Hamiltonian paths and Circuits, Partitioning, Representations of Graphs, adjacency matrix, incidence matrix, Path matrix, Circuit matrix.

**Marks: 20**

### References:

1. **Grimaldi RP**, Discrete and Combinatorial Mathematics, Addition-Wesley Publishing Company, 1994.
2. **Harary Frank**: Graph Theory, Addition-Wesley Publishing Company, 1994.
3. **Kelly John**: The Essence of Logic, Prentice Hall, 1997.
4. **Sen MK & Chakrabarty**, BC: Introduction to Discrete Mathematics, Books & Allied (P) Ltd., 2009.

## III-SEMESTER

### FUNCTIONAL ANALYSIS

**MAT-3015**

**Full Marks: 100**

**Unit-I:** Normed Linear spaces, Banach spaces and examples. Quotient space of normed linear spaces, Equivalent Norms. Riesz Lemma, Basic properties of normed linear spaces and compactness. Weak convergence and bounded linear transformations, normed linear spaces of bounded linear transformations, Dual spaces with examples.

**Marks: 30**

**Unit-II:** Uniform boundedness theorem and some of its consequences. Open mapping and closed graph theorems. Hahn-Banach theorem for linear spaces, complex spaces and normed linear spaces. Reflexive spaces. Weak Sequences compactness. Compact operators. Solvability of linear equations in Banach spaces. The closed Range theorem.

**Marks: 30**

**Unit-III:** Inner product spaces. Hilbert spaces. Orthonormal spaces. Bessel's inequality. Complete orthonormal sets and Parseval's identity. Structure of Hilbert spaces. Projection theorem. Riesz representation theorem. Adjoint of an operator on Hilbert spaces. Reflexivity of Hilbert spaces. Self adjoint Operators, Positive, Projection, Normal and Unitary operators. Abstract variational boundary value problems.

**Marks: 20**

**References:**

1. **HL Royden**, **Real Analysis**, Macmillan Pub Co. Inc. New York.
2. **C Goffman and G. Pedrick**, **First Course in Functional Analysis**, Prentice Hall of India
3. **E Kreyszig**, **Introductory Functional Analysis with Application**, John Wiley & Sons, NY
4. **RB Holmes**, **Geometric Functional Analysis and its Applications**, Springer-Verlag
5. **PK Jain, OP Ahuja and Khalil Ahmad**, **Functional Analysis**, New Age Int. & Wiley Eastern Ltd.

**MEASURE AND INTEGRATION****MAT-3025****Full Marks: 100**

**Unit-I** Signed measure, Hahn decomposition theorem, Mutually singular measures, Absolutely continuous measures, Radon-Nikodym theorem, Lebesgue decomposition theorem, Riesz representation theorem. **Marks: 30**

**Unit-II** Extension theorem (Caratheodory), Lebesgue-Stieltjes integral, Product measures, Fubini's theorem, Differentiation and Integration, Decomposition into absolutely continuous and singular parts. **Marks: 30**

**Unit-III** Baire sets, Baire measure, Continuous functions with compact support, Regularity of measures on locally compact spaces, Integration of continuous functions with compact support, Riesz-Markoff theorem. **Marks: 20**

**References:**

1. **HL Royden**, **Real Analysis**, Macmillan Publishing Co. Inc. New York, 4<sup>th</sup> Edition.
2. **PK Jain and VP Gupta**, **Lebesgue Measure and Integration**, New Age International Pvt. Ltd.
3. **IK Rana**, **Introduction to Measure and Integration**, Narosa Publishing House, Delhi.
4. **Sterling K Berberian**, **Measure and Integration**, American Mathematical Society, Chelsea.
5. **G de Barra**, **Measure Theory and Integration**, New Age International.

**FLUID DYNAMICS****MAT-3035****Full Marks: 100**

**Unit-I:** General Theory of Irrotational motion: Irrotational motion, Kelvin's circular theorem, cyclic motion. Kinetic energy of finite liquid, Kinetic energy of infinite liquid, Kelvin's minimum energy theorem. Mean value of velocity potential over a spherical surface. Uniqueness theorem. Green's theorem. **Marks: 30**

**Unit-II:** Vorticity: Vortex line, Vortex tube, Vortex filament, Properties of vortex filament, Strength of vortex, Rectilinear vortices, Motion due to  $m$  vortices, Centre of vortices, Two vortex filaments, Two infinite rows of vortices, Karman's vortex street, Helmholtz's velocity theorem. **Marks: 30**

**Unit-III:** Viscosity: Coefficient of viscosity, Viscous fluid, Most general motion of a liquid element, Strain, Stress Analysis, Analysis of motion, Principal stress and Stokes relation, **Marks: 30**

Navier-Stokes equation for a viscous fluid. Dissipation of energy due to viscosity, Circulation in a viscous fluid. Reynolds number.

**Marks: 20**

**References:**

1. **GK Batchelor**, An Introduction to Fluid Mechanics, Cambridge University Press.
2. **AJ Chorin and JF Marsden**, A Mathematical Introduction to Fluid Dynamics, Springer.
3. **F Chorlton**, Textbook of Fluid Dynamics, CBS Publication, Delhi.
4. **LD Landu and F Lipschitz**, Fluid Mechanics, Pregmon Press.
5. **O'Neil & F. Chorlton**, Ideal and Incompressible Fluid Dynamics, Ellis Horwood Ltd.

**DIFFERENTIAL GEOMETRY AND TENSOR**

**MAT-3045**

**Full Marks: 100**

**Unit-I:** Geodesics, Differential equation of a geodesic, Single differential equation of a geodesic, Geodesic on a surface of revolution, Geodesic curvature and torsion, Gauss-Bonnet theorem, Gauss's formulae, Gauss's characteristic equation, Weingarten equations, Mainardi-Coddazi equations, Fundamental existence theorem for surfaces.

**Marks: 30**

**Unit-II:** Tensor analysis, Tensor and their transformation laws, Contraction, Quotient law, Reciprocal tensors, Kronecker delta, symmetric and skew-symmetric tensors, metric tensors, Riemann space, Christoffel symbols and their transformation laws, covariant differentiation of tensors, Ricci's theorem, Intrinsic derivative. Geodesic co-ordinates.

**Marks: 30**

**Unit-III:** Riemann-Christoffel tensor and its properties, Covariant curvature tensor, Einstein space, Bianchi's identity, Einstein tensor, Flat space, Isotropic point, Schur's theorem.

**Marks: 20**

**References:**

1. **TJ Wilmore**, An Introduction to Differential Geometry, Dover Publication.
2. **CE Weatherburn**, An Introduction to Riemann Geometry & Tensor, Cambridge University Press.
3. **Ruchard S Millman & George D Parker**, Elements of Differential Geometry, Pearson Publication.
4. **Brain F Doolin**, An Introduction to Differential Geometry for Engineers, Dover Pub. Inc.

**ALGEBRAIC CODING THEORY**

**MAT-3055**

**Full Marks: 100**

**Unit-I:** Distance, error detecting and error correcting, polynomial codes, Generator and parity check matrices, Hamming codes, Finite field and Bose-Chaudhuri-Hocquenghem (BCH) codes.

**Marks: 30**

**Unit-II:** Linear codes, New codes obtained from a given codes, Cyclic codes, BCH and Hamming codes as cyclic codes, Non binary Hamming codes, Idempotent, Quadratic Residue codes, Golay codes. **Marks: 30**

**Unit-III:** Maximum Distance Separable (MDS) codes, Generator and parity check matrices of MDS codes, weight distribution of MDS codes, Necessary and Sufficient condition for a linear code to be MDS codes. **Marks: 20**

**References:**

1. **E Berlekamp**, Algebraic Coding Theory, McGraw Hill, New York, 1968.
2. **L R Vermani, Chapman and Hall**, Elements of Algebraic Number Theory, 1996.
3. **FJ Mac Williams and NJA Sloane**, Error-correcting codes, North Holland Publishing Company, 1977.
4. **WW Peterson and EJ Weldon, Jr.** Error-Correcting codes, MIT press, Cambridge, Massachusetts, 1972.

**GENERAL RELATIVITY AND COSMOLOGY-I      MAT-3065(A)      Full Marks: 100**

**Unit-I:** Transformation of coordinates. Tensors, Algebra of tensors, Symmetric and Skew Symmetric tensors, Contraction of tensors and Quotient law. Riemannian metric. Parallel transport. Christoffel symbols. Covariant derivatives, Intrinsic derivatives and Geodesics. Riemann Christoffel symbols, Riemann curvature tensor and its symmetric properties. Bianchi Identities, Einstein tensor, Weyl curvature tensor. **Marks: 30**

**Unit-II:** Review of the special theory of relativity and the Newtonian law of Gravitation. Principle of Equivalence and general covariance, Geodesic principle, Newtonian approximation of relativistic equation of motion. Einstein's field equations and Newtonian approximation. **Marks: 30**

**Unit-III:** Schwarzschild external solution and its isotropic form. Planetary orbits and Analogues of Kepler's laws in general relativity. Advance of perihelion of a planet. Bending of light rays in a gravitational field. Variational red-shift of spectral lines. Radar echo delay. Energy momentum tensor of a perfect fluid. Schwarzschild external solution, Boundary conditions. Energy momentum tensor of a Electromagnetic field. Einstein-Maxwell equations. Riessner-Nordstrom solution. **Marks: 20**

**References:**

1. **H Stephani**, General Relativity, Ian Introduction to the theory of Gravitational field, Cambridge University Press.
2. **BF Shutz**, A first Course in General Relativity, Cambridge University Press.
3. **R Adlev, M Bazin and M Scjiffer**, Introduction to General Relativity, McGraw Hill Inc.

4. **S Weinberg**, Gravitation and Cosmology: Principles and Applications of General theory of Relativity, John Wiley & Sons Inc.
5. **RK Sachs and H Wu**, General Relativity for Mathematicians, Springer Verlag.
6. **JV Narlikar**, General Relativity and Cosmology, Macmillan and Co.
7. **JV Narlikar**, Introduction to Cosmology, Cambridge University Press.
8. **LD Landau and FM Lifshitz**, The Classical theory of fields, Pregmon Press.

## **OPERATIONS RESEARCH-I**

**MAT-3065(B)**

**Full Marks: 100**

**Objectives and Outcome:** The objective of this course is to explore various important areas of Operations research and Mathematical programming algorithms to solve real life problems.

**Unit I:** Operations research and its scope, features of Operations research, Operations research Methodology, Structure of Mathematical model. Linear programming, Convex sets and their properties, Simplex method, Duality in linear programming and Sensitivity analysis. **Mark: 30**

**Unit II:** Integer programming, Gomory's all integer Cutting plane algorithm, Branch and Bound Technique, Applications of zero one integer programming, Dual Simplex method, Goal programming, Parametric linear programming. **Mark: 30**

**Unit III:** Dynamic programming, Game theory-Two person zero sum games, The maxima and minima principles, algorithm for determining a saddle point, Games with mixed strategies, Algebraic method for solving  $m$  by  $n$  games, Graphical solution, and solution by linear programming. **Mark: 20**

### **References:**

1. **HA Taha**, Operations research: an introduction (Eighth edition), PHI New Delhi, 2006.
2. **F S Hiller and Gerald J**, Introduction to operations research, Leiberman, McGraw Hills.
3. **PK Gupta and Manmohan**, Operations research: Kanti Swarup, sultan Chand & Sons.
4. **JK Sharma**, Operations research: Theory and applications by, Trinity 2017.
5. **HS Kasana and KD Kumar**, Introductory operations research: Theory and Applications, Springer Verlag.

## **CRYPTOLOGY-I**

**MAT-3065(C)**

**Full Marks: 100**

**Objective and outcome:** Information Security or Cryptology is an area which is of paramount importance not only for strategic and tactical military and paramilitary forces applications but also for our day to day life uses like e-commerce, e-governance, e-voting, etc. The one who studies this subject will enjoy the encryption & decryption techniques.

**Unit I:** Algebra & Number Theory: Integers & residues; Chinese Remainder Theorem, Miller Rabin Primality Test, Fermat's theorem, Euler's Theorem, Fast Deterministic Tests. **Marks: 30**

**Unit II:** Symmetric Key Encryption: Stream Ciphers, Block Ciphers, Data Encryption Standard, Advanced Encryption Standard, Modes of Operation of Hash Functions; Construction of Hash Function, Probabilistic Signatures, and Discrete Logarithm. **Marks: 30**

**Unit III:** Concept of Public-key Cryptography; the RSA Cryptosystem; Key Generation Scheme; Encryption, Decryption, Signature Verification, Key Length, Factoring Problem Security of RSA, Attacks. **Marks: 20**

**References:**

1. **William Stallings:** Cryptography & Network security (Principles & practice), Pearson Education, revised 3rd edition, 2003.
2. **Hans Delfs and Helmut Knebl:** Introduction to cryptography, (Principles & Applications), Springer verlag, revised 3rd Edition, 2002.
3. **David M Burton :** Elementary Number Theory, Tata McGraw Hill Educational Pvt. Ltd., New Delhi, Sevent Reprint, 2009.
4. Abraham Robinson: Numbers & Ideals; Yale University, Reprinted, 1965.

**THEORY OF LINEAR OPERATORS –I**

**MAT-3065(D)**

**Marks-100**

**Unit-I** Spectral theory of linear operators in normed spaces: Eigen values of an operator, spectrum, resolvent set, spectral properties of bounded linear operators, Approximate eigen values and its properties, Spectral mapping theorem for polynomials. **Marks: 30**

**Unit-II** Compact linear operators on normed spaces, spectral properties of compact linear operators, Finite dimensional linear operators, compactness of product of linear operators,  $\varepsilon$ -net, totally boundedness, separable. **Marks: 30**

**Unit-III** Closed linear operators, Linear operators permitting closure (closure of an operator), Densely defined linear operators, Adjoint of a linear operator, Hermitian operator, Symmetric operator, Normal and Unitary operators. **Marks: 20**

**References:**

1. **E Kreyszig,** Introductory Functional Analysis with applications, John- Wiley & Sons.
2. **PR Halmos,** Introduction to Hilbert space and the Theory of Spectral Multiplicity, Second Edition, Chelsea Publishing Co. N.Y. 1957.
3. **N Dunford and JT Schwartz,** Linear operators-3 parts, Interscience Wiley, New York.
4. **G Bachman and L Narici,** Functional Analysis, Academic Press, New York, 1966.
5. **NI Akhiezer and IM Glazman,** Theory of Linear operators in Hilbert Spaces, Frederick Unger Pub. Co. N. Y. Vol. I (1961), Vol. II, 1963.



## IV-SEMESTER

### NUMBER THEORY

MAT-4015

Full Marks: 100

**Unit-I:** Divisibility, g.c.d, Euclidean Algorithm, Fundamental theorem of Arithmetic, Congruences, Chinese Remainder Theorem, Fermat's Little Theorem, Wilson's Theorem, Euler's Theorem, Arithmetic functions  $\Phi(n)$ ,  $d(n)$ ,  $\sigma(n)$ ,  $\mu(n)$ , Dirichlet product of arithmetic functions, Mobius Inversion formula. **Marks: 30**

**Unit-II:** Primitive roots and indices, Quadratic residues, Legendre symbol, Euler's criterion, Gauss Lemma, Quadratic reciprocity Law, Jacobi symbol. **Marks: 30**

**Unit-III:** Representation of an integer as sum of two and four squares, Continued fraction, Approximation of real by rational, Pell's equation. **Marks: 20**

#### References:

1. **David M Burton**, Elementary Number Theory, Tata McGraw Hill, 2007.
2. **GH Hardy and EM Wright**, An introduction to theory of Numbers, Oxford University Press, 2008.
3. **SG Telang** (edt. MG Nadkarni and JS Dani), Number Theory, Tata McGraw Hill, 2002.
4. **GA Jones and JM Jones**, Elementary Number Theory, Springer Verlag, London, 2005.
5. **Thomas Koshy**, Elementary number theory with applications, Harcourt science & Technology Co.

### MECHANICS

MAT-4025

Full Marks: 100

**Unit-I** Generalized co-ordinates, Holonomic and non-holonomic systems, Scleronomic and Rheonomic system, De Alembert's Principle, Lagrange's equation, Hamilton's Principle, Lagrange's Principle from Hamilton's Principle, Extension of Hamilton's Principle to non conservative and non holonomic systems. **Marks: 30**

**Unit-II** Calculus of variation, Shortest distance, Minimum surface of revolution, Geodesic, Fundamental lemma of calculus of variation. Euler's equation for one dependent function and its generalization to n independent functions, Hamilton's equation of motion, Conservation theorem and physical significance of Hamiltonian, Derivation of Hamilton's equation from variational principle, Principle of least action. **Marks: 30**

**Unit-III** Equation of canonical transformation, Integral invariance of Poincare, Lagrange and Poisson Brackets, Condition of canonical character of a transformation in terms of Lagrange Brackets and Poisson Brackets, Invariance of Lagrange and Poisson Brackets under canonical transformation, Constants of motion and symmetry properties, Gravitation, Attraction and Potential of rod, disc, spherical shell and sphere. **Marks: 20**

## References:

1. **H Goldstein**, Classical Mechanics, Wesley Publication Massachusetts.
2. **F Grantmacher**, Lectures in Analytical Mechanics, MIR Publication.
3. **IM Gelfand and SV Fomin**, Calculus of Variation, Prentice Hall of India.
4. **SL Loney**, An Elementary Treatise on Statics, Kalyani Publishers, New Delhi.
5. **AS Ramsey**, Newtonian Gravitation, Cambridge University Press.
6. **TWB Kibble**, Classical Mechanics, Orient Longman, London.
7. **Gregory**, Classical Mechanics, Cambridge University Press.

## ALGEBRAIC TOPOLOGY

**MAT-4035**

**Full Marks: 100**

**Unit-I** Topological spaces: Continuity and topological spaces, Topological Spaces, Metric Spaces, Closed Sets, Hausdorff Spaces, Subspace topologies, Continuous functions between topological spaces, a criterion for continuity, Homeomorphisms, Product topologies, Identification Maps and Quotient topologies, Compact topological spaces, Lebesgue Lemma and Uniform Continuity, Connected topological Spaces.

**Marks: 30**

**Unit-II** Homotopy: Instruction and definitions, properties of Homotopic Mappings, Relative Homotopy, Contractible spaces, Homotopy Type, Retractions, Path-Definition, Path connected Spaces, Equivalent paths.

**Marks: 30**

**Unit-III** Fundamental Group: Formation of a group, Isomorphism of Fundamental Groups, Homomorphism of Fundamental Groups, Induced Homomorphism, Simply connected Topological Spaces, Brouwer's fixed point Theorem, Fundamental Theorem of algebra.

**Marks: 20**

## References:

1. **JR Munkres**, Topology-A first Course, PHI
2. **BK Lahiri**, A First Course in Algebraic Topology, Narosa
3. **D Wilkins**, Course-421-Algebraic Topology, Lecture Notes, 2008-09 Sec. 1 & 2
4. **A Hatcher**, Algebraic Topology, CUP
5. **EH Spainer**, Algebraic Topology, McGraw Hill NY
6. **Chatterjee, Ganguly and Ghosh**, A Text Book of Topology, Asian.

## ALGEBRAIC NUMBER THEORY

**MAT-4045**

**Full Marks: 100**

**UNIT -1:** Algebraic number, Number fields, Conjugates, Discriminant, Algebraic Integers, Ring of Integers, Integral Basis, Discriminant of Number Field, Monogenic Number Field, Calculation of Ring of Integers in cubic cases.

**Marks: 30**

**UNIT-II:** Integral Closure, Prime Ideals, Dedekind domain, Ideal in Dedekind domain, Factorization into prime ideals, Norm of an ideal, Fractional ideals, Decomposition number, Ramification index, Factoring primes in quadratic and monogenic fields. **Marks: 30**

**UNIT-III:** Class group, Class number, Minkowski translation theorem, Minkowski convex body theorem, Minkowski linear forms theorem, Finiteness of ideal class group and class number. **Marks: 20**

**References:**

1. **K Ireland and M Rosen**, A classical introduction to Modern Number Theory, Springer Verlag, New York, 1990.
2. **S Lang**, Algebraic Number Theory, Springer Verlag, New York, 1999.
3. **DA Marcus**, Number fields, Springer Verlag, New York Inc 1987.
4. **IN Stewart and DO Tall**, Algebraic Number Theory, Chapman and Hall, London 1987.
5. **Saban Alaca and Kenneth S Williams**, Introductory Algebraic Number Theory, Cambridge University Press, 2004.

**COMMUTATIVE ALGEBRA:**

**MAT-4055**

**Full Marks-100**

**Unit-I: Rings and modules:** Nilradical, Jacobson Radical, Extension and Contraction, Exact sequences, Tensor product of modules and algebras, Rings and modules of fractions; Local properties and contracted ideals in the rings of fractions. **Marks: 30**

**Unit-II: Primary Decomposition:** Primary decomposition, Chain Condition, Noetherian rings, Artin rings. **Marks: 30**

**Unit-III: Integral Dependence and Valuation:** Integral dependence, The going up theorem, Integrally closed integral domain, The going down theorem, Valuation rings, Discrete valuation rings, Dedekind domains, Completions; Topologies and Completions; Filtrations; Graded rings and modules. **Marks: 20**

**References:**

1. **MF Atiya & IG McDonald**, Introduction to Commutative Algebra, Addition-Wesley.
2. **O Zariski & P Samuel**, Commutative Algebra I-II, Van Nostrand.
3. **NS Gopalkrishnan**, Commutative Algebra, Oxonian Press, New Delhi.
4. **RY Sharp**, Steps in Commutative Algebra, Cambridge University Press.

**GENERAL RELATIVITY AND COSMOLOGY-II      MAT-4065(A)      Full Marks: 100**

**Unit I:** Mach's principle, Einstein modified field equations with cosmological term. Static Cosmological model of Einstein and De-Sitter, their derivation, properties and comparison with the actual universe. **Marks: 30**

**Unit II:** Hubble's law, Cosmological principles, Weyl's postulate. Derivation of Robertson-Walker metric. Hubble and deceleration parameters. Redshift. Redshift versus distance relation. Angular size versus redshift relation and source counts in Robertson-Walker space time. **Marks: 30**

**Unit III:** Friedmann models, Fundamental equations of dynamical cosmology. Critical density. Closed and open Universe. Age of the Universe. Matter dominated era of the universe. Einstein-de-Sitter model. Particle and event horizons. Eddington-Lamaitre models with I-term. Perfect cosmological principle. Steady state cosmology. **Marks: 20**

**References:**

1. **H Stephani**, General Relativity: An Introduction to the theory of gravitational field, Cambridge University Press.
2. **AS Eddington**, Mathematical Theory of Relativity, Cambridge University Press.
3. **JV Narlikar**, General Relativity and Cosmology, Macmillan and Co. India Ltd.
4. **R Adlev, M Bazin & M Schiffer**, Introduction to general relativity, McGraw Hill Inc.
5. **BF Shutz**, a first course in general relativity, Cambridge University Press.
6. **S Weinberg**, Gravitation and Cosmology: Principles and applications of the general theory of relativity, Hohn Wiley & Sons. Inc.
7. **JV Narlikar**, Introduction to Cosmology, Cambridge University Press.
8. **RK Sachs and H Wu**, General Relativity for Mathematicians, Springer Verlag.
9. **LD Landu and EM Lifshitz**, The Classical Theory of Fields, Pergamon Press.
10. **JL Synge**, Relativity: The general theory, North Holland Pub. Company.

**OPERATIONS RESEARCH-II      MAT-4065(B)      Full Marks: 100**

**Objectives and Outcome:** The objective of this course is to explore various important areas of Operations research and Mathematical programming algorithms to solve real life problems.

**Unit I:** Non-linear Programming, Convex function, Concave function, Pseudo convex function, Quasiconvex function, Quasiconcave function, Lagrangian method, Kuhn Tucker theory, Quadratic programming- Beale's method, Wolfe's method. **Mark: 30**

**Unit II:** Deterministic Inventory Control Models, Economic lot size models, Deterministic models with shortages, Probabilistic Inventory Control models. **Mark: 30**

**Unit III:** Monte-Carlo simulation, Network routing problems, Minimal spanning tree problem, Shortest route problems. **Mark: 20**

**References:**

1. **HA Taha**, Operations Research: An Introduction (Eighth edition) PHI Publications.
2. **FS Hiller and GJ Lieberman**, Introduction to Research, McGraw Hills Publication, International Edition, Industrial Engineering series, 1995.
3. **Kanti Swarup, PK Gupta and Man Mohan**, Operation Research: Sultan Chand & Sons, New Delhi, 2008.
4. **JK Sharma**, Operations Research: Theory and applications by Trinity 2017.
5. **HS Kasana and KD Kumar**, Introduction to Operations Research: Theory and Applications Springer, 2011.

**CRYPTOLOGY-II**

**MAT-4065(C)**

**Full Marks: 100**

**Unit I:** Cryptographic Protocols; Key-exchange and Authentication, Diffie-Hellman Key Agreement, Key Exchange and Mutual Authentication; The Rabin Cipher, Phil Zimmermann on PGP, Mc Eliece Cryptosystem. **Marks: 30**

**Unit II:** Elliptic Curve Cryptography; Simplified Elliptic Curve Cryptography, Efficiency of Algorithms, Addition on Elliptic Curves, Koblitz Curves, Integer Factorization and Discrete Logarithm Problems, NIST Primes, Pollard's Rho Attacks, ECC2K-130 & Iteration Function, ECC Vs RSA. **Marks: 30**

**Unit III:** Probabilities & Information Theory; Finite Probability Spaces and Random Variables, The Weak Law of Large Numbers, Distance Measures, IP Security, Web Security, Secure E-Transactions. **Marks: 20**

**References:**

1. **William Stallings**: Cryptography & Network security (Principles & practice), Pearson Education, revised 3rd edition [2003].
2. **Hans Delfs, Helmut Knebl**: Introduction to cryptography; (Principles & Applications), Springer Verlag, revised 3rd Edition, 2002.
3. **Stinson Douglass**: Cryptography: Theory and Practice, CRC Press [1995].
4. **Darrel Hankerson**, Alfred Menezes, Scott Vanstone, Guide to Elliptic Curve Cryptography, Springer-Verlag, New York (2004).
5. **Vandenay S**, A Classical Introduction to Cryptography (Applications for Communications Security); Springer (India) Pvt. Ltd. Akash Deep Building, Barakhamba Road, New Delhi (2009).

**Unit-I:** Spectral measure, Spectral Integrals, Regular spectral measures, Real and Complex measures  
Complex spectral Integrals, Description of the spectral subspaces, and characterization of Spectral  
subspaces. The Spectral theorem for bounded Normal operators. **Marks: 30**

**Unit-II:** Spectral properties of bounded self-adjoint linear operators, Positive operators, Projection  
operators, product of projections, Monotone sequence theorem for bounded self adjoint operators on a  
complex Hilbert space. **Marks: 30**

**Unit-III:** Unbounded linear operators and their Hilbert-Adjoint operators, Characterization of resolvent of  
an unbounded self-adjoint operator, Spectrum of a self-adjoint unbounded linear operator, Spectral  
theorem for unitary and self-adjoint linear operators, Cayley's transformation of an unbounded self-  
adjoint operator, Multiplication operators and Differentiation operators. **Marks: 30**

**References:**

1. **E Kreyszig**, Introductory Functional Analysis with applications, John-Wiley & Sons, New York.
2. **PR Halmos**, Introduction to Hilbert Space and the Theory of Spectral Multiplicity, Second Edition, Chelsea Publishing Co. N.Y. 1957.
3. **N Dunford and JT Schwartz**, Linear operators 3 parts, Inter-science Wiley, New York, 1958-71.
4. **G Bachman and L Narici**, Functional Analysis, Academic Press, New York, 1966.
5. **NL Akhiezer and IM Glazman**, Theory of Linear Operators in Hilbert Spaces, Frederick Unger Pub. Co. N. Y. Vol. I (1961), Vol. II (1963).
6. **PR Halmos**, A Hilbert Problem Book, D. Van Nostrand Company Inc., 1967.

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