PUNJABI UNIVERSITY, PATIALA

OUTLINES OF TESTS,

SYLLABI AND COURSES OF READING

FOR

M.Sc. (Mathematics) Part-II

2022-23 and 2023-24

PUNJABI UNIVERSITY, PATIALA

Third Semester

LIST OF ELECTIVES-I (Any Five of the following)

Code	Title of Paper/Subject	Hrs/ Week	Credit	Max Cont. Asmt.	Marks Univ Exam	Total
MATM2101T	Differentiable Manifolds	6	6	30	70	100
MATM2102T	Field Theory	6	6	30	70	100
MATM2103T	Differential Equations –II	6	6	30	70	100
MATM2104T	Category Theory - I	6	6	30	70	100
MATM2105T	Complex Analysis – II	6	6	30	70	100
MATM2106T	Classical Mechanics (If AMCM1207T has not been opted in Semester-II)	6	6	30	70	100
MATM2107T	Algebraic Topology	6	6	30	70	100
MATM2108T	Optimization Techniques-I	6	6	30	70	100
MATM2109T	Fuzzy Sets And Applications	6	6	30	70	100
MATM2110T	Solid Mechanics	6	6	30	70	100
MATM2111T	Functional Analysis (If AMCM1206T has not been opted in Semester-II)	6	6	30	70	100
MATM2112T	Numerical Analysis	6	6	30	70	100

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Fourth Semester

LIST OF ELECTIVES-III (Any Five of the following)

Code	Title of Paper/Subject	Hrs/ Week	Credit	Max Cont. Asmt.	Marks Univ Exam	Total
MATM2201T	Homology Theory	6	6	30	70	100
MATM2202T	Theory of Linear Operators	6	6	30	70	100
MATM2203T	Lie Groups and Complex Manifolds (Prerequisite: MATH2101T)	6	6	30	70	100
MATM2204T	Category Theory - II	6	6	30	70	100
MATM2205T	Optimization Techniques-II	6	6	30	70	100
MATM2206T	Homological Algebra	6	6	30	70	100
MATM2207T	Finite Element Methods	6	6	30	70	100
MATM2208T	Fluid Mechanics	6	6	30	70	100
MATM2209T	Algebraic Coding Theory	6	6	30	70	100
MATM2210T	Commutative Algebra	6	6	30	70	100
MATM2211T	Operations Research	6	6	30	70	100
MATM2212T	Wavelets	6	6	30	70	100
MATM2213T	Non Linear Programming	6	6	30	70	100
MATM2214T	Mathematics Of Finance	6	6	30	70	100
MATM2215T	Mathematical Methods	6	6	30	70	100
MATM2216T	Analytic Number Theory	6	6	30	70	100
MATM2217T	Computational Techniques	6	6	30	70	100
MATM2218T	Computer Algebra System	6	6	10	40	50
MATM2218L	Software Lab (Computer Algebra System)	4	2	20	30	50
MATM2219T	Advanced Functional Analysis	6	6	30	70	100

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MATM2101T: DIFFERENTIABLE MANIFOLDS

Course Outcomes:
To study complicated structures in terms of relatively well understood properties of simpler spaces
To acquire the thorough knowledge of the concept of Riemannian manifolds having wide applications in various fields of mathematics
Understanding the theory of various differential geometric structures on manifolds and arrange the results on submanifolds of Riemannian manifolds with certain structures
To deal with the theory of tensors and to construct differentiable mappings on the tensor product spaces
To define various differentiable mappings and connections on the structure of manifolds leading to formation of some important differential geometric tools.

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total: 100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The aim of this paper is to study the theory of differentiable manifolds and the structure of sub-manifolds. It introduces and elaborates the concept of Riemannian manifolds having wide applications in various fields of mathematics.

SECTION-A

Differentiable Manifolds, examples of differentiable manifolds, the local coordinate approach, differentiable maps on manifolds, tangent vectors and tangent space, different approaches to tangent vectors, Cotangent space. Vector Fields, Lie-bracket of vector fields. Jacobian map, pull back map, integral curves. Tensors, exterior product, forms, exterior derivative, contraction, Lie-derivative. Affine connection, difference tensor, covariant derivative of tensors.

SECTION-B

Torsion tensor and curvature tensor of a connection, properties of torsion and curvature tensor, Bianchi's identities, the Riemannian metric, Riemannian manifolds, fundamental theorem of Riemannian geometry, Riemannian connection, Christoffel symbols, Riemannian curvature tensor and its properties. Sectional curvature, theorem of Schur, sub-manifolds and hyper-surfaces, normal, induced connection, Gauss and Weingarten formulae and their applications.

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Pedagogy: The teacher should lay emphasis on the extensive study of the basic properties instrumental in developing the theory of Riemannian manifolds having wide applications in the further research in this area.

BOOKS RECOMMENDED:

1. Y. Matsushima: *Differentiable Manifolds*, Marcel Dekker, Inc. New York, 1972.
2. K. Yano, M. Kon: *Structures on Manifolds*, World. Scientific Publishing Co. Pvt. Ltd., 1984.
3. U.C. De: *Differential Geometry of Manifolds*, Alpha Science Int. Ltd., Oxford, U.K., 2007.
4. J.M. Lee: Introduction to Riemannian Manifolds, Springer International Publishing 2nd edition, 2018.
5. K. Nomizu, S. Kobayashi: *Foundations of Differential Geometry,* Vol. I, Inter-science Publishers, John Wiley and Sons, New York, 1963.

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MATM2102T: FIELD THEORY

Course Outcomes:
Ability to test whether a given polynomial is irreducible or not
Understanding of the basic notions of Field theory like Normal Extensions, Separable Extensions etc
Ability to find splitting field of a given polynomial
To calculate Galois group of certain polynomials
To apply the Galois correspondence to solve problems of Field theory

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course will introduce the basic ideas of field theory, leading to the Galois theory and its applications in solving some of the classical problems.

SECTION –A

Fields, examples, algebraic and transcendental elements, irreducible polynomials. Gauss lemma, Eisenstein's criterion, adjunction of roots, Kronecker's theorem, algebraic extensions, algebraically closed fields. Splitting fields, normal extensions, multiple roots, finite fields, separable extensions, perfect fields, primitive elements, Lagrange's theorem on primitive elements.

SECTION – B

Automorphism groups and fixed fields, Galois extensions, fundamental theorem of Galois theory, fundamental theorem of algebra, roots of unity and cyclotomic polynomials. Cyclic extension, polynomials solvable by radicals, symmetric functions, cyclotomic extension, quintic equation and solvability by radicals, ruler and compass construction.

Pedagogy: It is expected that the teacher will lay emphasis on how the modern field theoretic methods help us to find relatively easier solutions to the problems of algebraic and geometric constructions.

BOOKS RECOMMENDED:

1. P.B. Bhattacharya, S.K. Jain, S.R. Nagpal: *Basic Abstract Algebra*, 2nd Edition, Cambridge University Press, 2002 (Chapters 15-18).
2. D. S. Dummit, Richard M Foote: *Abstract Algebra*, John Wiley and Sons, 2004.
3. M. Artin: *Algebra*, Prentice Hall of India, New Delhi, 1994.

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MATM2103T: Differential Equations –II

Course Outcomes:	
CO1	Analyse the existence of solutions of first order differential equations for complex system.
CO2	Derive the family of Equipotential surface and prove Kelvin inversion theorem.
CO3	Understand the uniqueness and continuation of solutions of first order differential equations for complex system.
CO4	Understand the Maximum and minimum solution of first order differential equations for complex system.
CO5	Formulate and solve initial and boundary value problems for the Laplace equations in polar, spherical and cylindrical coordinates

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5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total: 100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course will continue the study of differential equations started in the previous year and will introduce more advance techniques like the Green's functions and the symmetry methods.

SECTION-A

Existence and uniqueness of solutions of first order differential equations for complex systems, maximum and minimum solution, Caratheodory theorem. Continuation of solution, uniqueness of solutions and successive approximations, variation of solutions.

SECTION-B

Partial Differential Equations: Occurrence and elementary solution of Laplace equation, family of equipotential surface. Interior and exterior Dirichlet boundary value problem for Laplace equation, separation of variables, axial symmetry, Kelvin's inversion theorem. Green's function for Laplace equation, Dirichlet's problem for semi-infinite space and for a sphere, Copson's theorem (Statement only).

Pedagogy: Same as for Differential Equations – I.

BOOKS RECOMMENDED:

1. E. Coddington, N. Levinson: *Theory of Ordinary Differential Equations,* Tata McGraw-Hill, India, 1955.
2. G.F. Simmons: *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, 1991.
3. I.N. Sneddon: *Elements of Partial Differential Equations*, Tata McGraw-Hill, 1957.

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MATM2104T: CATEGORY THEORY - I

Course Outcomes:	
CO1	The central concepts of Functors, Natural Transformations and its numerous applications enable the student to see the link between seemingly different concepts.
CO2	Can establish the importance of universal properties and the study of various mathematical structures through their universal mapping properties via commutative diagrams.
CO3	Study of categorical limits and co-limits and its use to bring concepts like pullbacks, products and equalizers under a common structure.
CO4	Prepares the groundwork for a deeper study of adjunctions and monads.

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The objective of the course is to introduce the modern way of looking at the mathematical objects and their universal properties with the help of categories, functors and natural transformations. The student after completing the course will be ready to tackle the more advance methods of adjunctions and monads.

SECTION – A

Categories: Introduction with functions of sets. Definition and examples of categories: Sets, Pos, Rel, Mon, groups, Top, Dis(X), finite category, the category of modules, the concept of functor and the category Cat, functors of several variables. Isomorphism constructions: Product of two categories, the dual Category, the arrow category, the slice and co-slice category. The category of graphs. Free Monoids and their UMP.
Abstract Structures: Epi and mono, initial and terminal objects, generalized elements, sections and retractions, product diagrams and their universal mapping property, uniqueness up to isomorphism, examples of products: Hom-sets, covariant representable functors, functors preserving binary product.

SECTION –B

Duality: The duality principle, co-products, examples in sets, Mon, Top, co-product of monoids, of abelian groups and co-product in the category of abelian Groups. Equalizers,

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equalizers as a monic, co-equalizers, co-equalizers as an epic. Co-equalizer diagram for a monoid.

Limits and Co-limits: Sub-objects, pullbacks, properties of pullbacks, pullback as a functor, limits, cone to a diagram, limit for a diagram, co-cones and co-limits. Preservation of limits, contra variant functor, direct limit of groups. Functors creating limits and co-limits.

Naturality: Exponential in a category, Cartesian closed categories, category of categories, representable Structure, Ultrafilters in Boolean Algebra, naturality, examples of natural transformations.

Pedagogy: The teacher should lay emphasis on the unifying nature of category theory and stress the importance of universal properties in defining and building up models of different mathematical objects.

BOOKS RECOMMENDED:

1. S. Awodey: *Category Theory*, Oxford Logic Guides, 49, Oxford University Press, 2007(Chap.1 to 3 Excluding Example 6 of Sec 2.6 and Chap. 5 and Sections 6.1, 6.2 and Chap. 7, Sections 7.1 to 7.5).
2. S. Mac Lane: *Categories for the Working Mathematician*, Springer Verlag, New York, Volume 5, 1971.
3. E.Reihl: *Category Theory in Context,* Dover Modern Math Originals Emily Reihl, Dover Publications, 2016.

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MATM2105T: COMPLEX ANALYSIS–II

Course Outcomes:
Introduce the analyticity of complex functions and study their applications.
Evaluate complex integrals using Cauchy residue and Cauchy integral theorems.
Determine and classify the zeros and singularities of the complex functions
Learn the uniqueness of conformal transformation
Establish the capacity for mathematical reasoning through analysing, proving and explaining concepts from complex analysis

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Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total: 100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The course will continue the study of complex analysis and introduce more advance methods like the Greens functions, Mittag-Leflers expansion, Monodromy theorem and the Harmonic methods.

SECTION-A

Normal families of analytic functions. Montel's theorem, Hurwitz's theorem, Riemann mapping theorem, Univalent functions. Distoration and growth theorems for the class S of normalized univalent functions, Koebe 1/4 theorem, Bieberbach conjecture (statement only), Littlewood's inequality for the class S, coefficient inequalities for functions in S in case of real coefficients only. Principle of analytic continuation, the general definition of an analytic function, analytic continuation by power series method, natural boundary, Schwarz reflection principle, Monodromy theorem, Mittag-Leffler's theorem (only in the case when the set of isolated singularities admits the point at infinity alone as an accumulation point), Cauchy's method of expansion of meromorphic functions, Partial fraction decomposition of cosec Z, representation of an integral function as an infinite product, infinite product for sin z.

SECTION-B

The factorization of integral functions, Weierstrass theorem regarding construction of an integral function with prescribed zeros, the minimum modules of an integral function, Hadamard's three circle theorem, the order of an integral function, integral functions of finite order with no zeros,

Jensen's inequality, exponent of convergence, Borel's theorem on canonical products, Hadmard's factorization theorem, basic properties of harmonic functions, maximum and

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minimum principles, Harmonic functions on a disc, Harnack's inequality and theorem, sub-harmonic and super-harmonic functions, Dirichlet problem, Green's function.

Pedagogy: The teacher will build on the previous knowledge of students and gradually introduce more and more advanced techniques.

BOOKS RECOMMENDED:

1. Z. Nihari: *Conformal Mapping*, Courier Corporation, 2012 (Chap. III (section 5), Chap. IV, Chap. V (pages173-178, 209-220)).
2. G. Sansone, J. Gerretsen, *Lectures on the Theory of Functions of a Complex Variable*, Noordhoff International Publishing, Leyden, 1960 (Sections 4.11.1 and 4.11.2 only).
3. J. B. Conway: *Functions of One Complex Variable*, Springer, Vertag-International Student, Narosa Publishing House, 1980 (Chap. X only).
4. E. T. Copson: *Theory of Functions of a Complex Variable*, Oxford University Press, 1935(Chap. IV (4.60, 4.61, 4.62) Chap. VII (excl. Section 7.7) Chap. VIII (Section 8.4)).

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MATM2106T: CLASSICAL MECHANICS-I

Course Outcomes:	
CO1	Determine the Lagrangian and Hamiltonian functions for a physical systems
CO2	Derive and solve the equations of motion from these functions
CO3	Determine the moments of inertia of a rigid body.
CO4	Identify symmetries and to derive the corresponding conservation laws
CO5	Perform calculations using relativistic kinematics and conservation laws

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The subject of classical mechanics is a perfect example of the power of mathematics to solve real physical problems and this course introduces the students to the Lagrangian version of classical mechanics which is indispensable for any study of quantum mechanical methods.

SECTION-A

Basic Principles: Mechanics of a particle and a system of particles, constraints, generalized Co-ordinates, holonomic and non-holonomic constraints. D'Alembert's principle and Lagrange's equations, velocity dependent potentials and the dissipation function, simple applications of the Lagrangian formulation.

Variational Principles and Lagrange's Equations: Hamilton's principle, derivation of Lagrange's equations from Hamilton's principle, extension of Hamilton's principle to non-holonomic systems.

Conservation Theorems and Symmetry Properties: Cyclic co-ordinates, canonical momentum and its conservation, the generalized force, and angular momentum conservation theorem.

The Two-Body Central Force Problem: Reduction to the equivalent one-body problem, equation of motion, equivalent one dimensional problem and classification of orbits, The virial theorem, conditions for closed orbits, Bertrand's theorem.

SECTION –B

The Kepler Problem: Inverse square law of force, the motion in time in the Kepler problem, Kepler's laws, Kepler's equation, the Laplace-Runge-Lenz vector.

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Scattering in a Central Force Field: Cross section of scattering, Rutherford scattering cross section, total scattering cross section, transformation of the scattering problem to laboratory co-ordinates.

The Kinematics of Rigid Body Motion: The independent co-ordinates of rigid body, transformation matrix, Euler angles, Cayley-Klein parameters and related quantities, Euler's theorem on the motion of rigid bodies, finite rotations, infinitesimal rotations, the Coriolis force.

Pedagogy: The instructor should lay emphasis on those techniques which naturally lend themselves to their quantum mechanical interpretations to enable the student to more naturally transform from the classical to the quantum.

BOOKS RECOMMENDED:

1. H. Goldstein: *Classical mechanics*, Addison-Wesley, 3rd Edition, 2002.
2. D. Kleppner, R. Kolenlow: *An Introduction to Mechanics,* Cambridge University Press, 2014.

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MATM2107T: ALGEBRAIC TOPOLOGY

Course Outcomes:	
CO1	Able to find algebraic invariants that classify topological spaces up to homeomorphism.
CO2	Enables in the construction and use of functors from some category of topological spaces into an algebraic category.
CO3	Can have the idea of attaching an algebraic structure with a given topological space and to prove that if the topological spaces are homeomorphic then their associated algebraic structure must be isomorphic.
CO4	Able to solve the associated algebraic problem than the original topological one.
CO5	Through the concepts like homotopy, the fundamental group and the covering spaces can establishes a close link between topology and algebra.
CO6	Knowledge of concept of categories and functors.

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Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course introduces algebraic methods for the solutions of topological problems and builds the basic machinery of the Fundamental Group and the covering spaces.

SECTION-A

The Fundamental group: Homotopy of paths, Homotopy classes, the fundamental group, change of base point, topological invariance, covering spaces, the fundamental group of the circle. Retractions and fixed points, no retraction theorem, the fundamental theorem of algebra, the Borsuk - Ulam theorem, the bisection theorem, deformation retracts and homotopy type, homotopy invariance.

SECTION-B

Direct sums of abelian groups, free products of groups, uniqueness of free products, least normal subgroup, free groups, generators and relations, the Seifert-Van Kampen theorem, also classical version, the fundamental group of a wedge of circles.

Classification of covering spaces: Equivalence of covering spaces, the general lifting lemma, theuniversal covering space, covering transformation, existence of covering spaces.

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Pedagogy: The instructor should stress the limited applicability of the general topological methods and hence justify the algebraic methods for the solutions of topological problems. At the same time the categorical nature of the subject should be stressed.

BOOKS RECOMMENDED:

1. J. R. Munkres: *Topology*, Pearson Prentice Hall, 2nd Edition, 2000 (Chap. 9 (51-58), Chap. 11(67-71), Chap. 13 (79-82)).
2. J. J. Rotman: *An Introduction to Algebraic Topology,* Graduate Texts in Mathematics Volume 119, Springer Verlag, New York, 1988.
3. A. Hatcher: *Algebraic Topology,* Cambridge University Press. First Edition 2001.

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MATM2108T: OPTIMIZATION TECHNIQUES-I

Course Outcomes: After studying this course students will be able to	
CO1	Formulate a real life problem as a linear programming model in general, standard and canonical forms
CO2	Sketch a graphical representation of a two-dimensional linear programming model given in general, standard or canonical form
CO3	Use various variants of the Simplex method to solve small size linear programming models manually
CO4	Analyse the effect of changes in the given LPP model and finding solution using concepts 0f post optimal analysis and duality theory.
CO5	Find optimal solutions of many other problems like assignment, transportation, travelling salesman etc.
CO6	Understand dynamic programming algorithms and its applications in problem solving.
CO7	Understand the concept of game, minimax-maximin principle, dominance property and solving a game problem through linear programming problem.

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessments: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C. Use of non-programmable scientific calculators is allowed.

SECTION-A

Review of Linear Programming: Simplex method, Big-M method, two phase method and duality.
Sensitivity Analysis: Discrete changes in the cost vector, requirement vector and co-efficient matrix, addition of a new variable, deletion of a variable, addition of new constraint, deletion of a constraint.
Integer Programming: Introduction, Gomory's all LPP method, Gomory's mixed-integer method, branch and bound method.
Dynamic Programming: Introduction, the recursive equation approach, dynamic programming algorithm, solution of discrete DPP.

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SECTION-B

Transportation Problem: Introduction, mathematical formulation of the problem, initial basic feasible solution using North-West corner method, least cost method and Vogel's approximation method, optimal solution using MODI method, degeneracy in transportation problems, some exceptional cases in transportation problems.
Assignment Problems: Introduction, mathematical formulation of an assignment problem, assignment algorithm, unbalanced assignment problems, travelling salesman problem.
Games and Strategies: Definition and characteristics of games, two person zero sum games, maximin and minimax principle, games without saddle points, mixed strategies, graphical method for solving 2 ×2 games, concept of dominance, reducing the game problem to LPP, limitations.

BOOKS RECOMMENDED:

1. K. Swarup, P. K. Gupta, M. Mohan: *Operations Research*, Sultan Chand and Sons, New Delhi, 2010.
2. C. Mohan, K. Deep: *Optimization Techniques*, New Age International, 2009.
3. H.S. Kasana, K.D. Kumar: *Introductory Operations Research: Theory and Applications,* Springer, Science and Business Media, 2013.
4. G. Hadley: *Linear Algebra*, Addison-Willey, 7th Edition 1977.

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MATM2109T: FUZZY SETS AND APPLICATIONS

Course Outcomes:	
CO1	To be able to distinguish between the crisp set and fuzzy set concepts through the learned differences between the crisp set characteristic function and the fuzzy set membership function.
CO2	To be able to draw a parallelism between crisp set operations and fuzzy set operations through the use of characteristic and membership functions respectively.
CO3	Become aware of the use of fuzzy inference systems in the design of intelligent or humanistic systems.

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Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course introduces Fuzzy Techniques to the students. The techniques have found many applications in sciences to solve problems with limit and incomplete information.

SECTION-A

Classical Sets and Fuzzy Sets: Overview of classical sets, membership function, α-cuts, properties of α-cuts, decomposition theorems, extension principle.

Operations on Fuzzy Sets: Compliment, intersections, unions, combinations of operations, aggregation operations.

Fuzzy Arithmetic: Fuzzy numbers, linguistic variables, arithmetic operations on intervals and numbers, lattice of fuzzy numbers, fuzzy equations.

Fuzzy Relations: Crisp and fuzzy relations, projections and cylindrical extensions, binary fuzzy Relations, Binary relations on single set, equivalence, compatibility and ordering relations, morphisms, fuzzy relation equations.

SECTION-B

Possibility Theory: Fuzzy Measures, evidence and possibility theory, possibility versus probability theory.

Fuzzy Logic: Classical logic, multivalued logics, fuzzy propositions, fuzzy qualifiers, linguistic hedges.

Uncertainty based Information: Information and uncertainty, non-specificity of fuzzy and crisp sets, fuzziness of fuzzy sets, applications of fuzzy logic.

Pedagogy: The need for fuzzy techniques should be stressed throughout.

BOOKS RECOMMENDED:

1. G.J. Klir, T.A. Folyger: *Fuzzy Sets: Uncertainty and Information*, Prentice Hall of India, 1988.
2. G.J. Klir, B. Yuan: *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice Hall of India, 1995.
3. H. J. Zimmermann: *Fuzzy Set Theory and its Applications*, Allied Publishers, 1991.
4. C. Mohan: *An Introduction to Fuzzy Set Theory and Fuzzy Logic*, M. V. Learning Publishers, New Delhi (INDIA) and London (UK), 2015.

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MATM2110T: SOLID MECHANICS

Course Outcomes: After studying this course the students will be able to	
CO1	Understand the meaning of tensor and its basic properties, gradient, divergence and curl of a vector tensor field
CO2	Determine the Stresses and Strain developed in a body due to loading and find the different types of Stresses/strains in the body
CO3	Develop governing equations for isotropic or anisotropic elastic solids
CO4	Find the solution for the two dimensional problems

L T P
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Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The course introduces Tensor Methods and uses them to formulate the problems of Mechanics of the Solids.

SECTION-A

Tensor Algebra: Co-ordinate transformation, Cartesian tensor of different order, properties of tensor, isotropic tensors of different orders and relation between them, symmetric and skew symmetric tensors, tensor invariants, deviatoric tensors, eigen-values and eigen-vectors of a tensor.

Tensor analysis: Scalar, vector, tensor functions, comma notation, gradient, divergence and curl of a vector/tensor field. (Relevant portions of Chap. 2 and 3 of book by D.S. Chandrasekharaiah and L. Debnath).

Analysis of strain: Affine transformation, infinitesimal affine deformation, geometrical interpretation of the components of strain, strain quadric of Cauchy. Principal, strains and invariance, general infinitesimal deformation, Saint-Venants equations of compatibility, finite deformations.

Analysis of Stress: Stress tensor, equations of equilibrium, transformation of co-ordinates, stress quadric of Cauchy, principal stress and invariants, maximum normal and shear stresses (relevant portion of Chap. 1 and 2 of book by I.S. Sokolnikoff).

SECTION-B

Equations of Elasticity: Generalized Hooks law, anisotropic medium, homogeneous isotropic media, elasticity, moduli for isotropic media, equilibrium and dynamic equations, for anisotropic elastic solid, strain energy function and its connection with Hooke's law, uniqueness of solution. Beltrami-Michell compatibilty equations, Saint-Venant's principle (relevant portion of Chap. 3 of book by I.S. Sokonikoff).

Two dimensional problems: Plane stress, generalized plane stress, airy stress function, general solution of bi-harmonic equation, stresses and displacements in terms of complex potentials, the structure of functions of $\varphi(z)$ and $\psi(z)$. First and second boundary-value problems in plane elasticity. Existence and uniqueness of the solutions (Section 65-74 of I.S. Sokolnikoff).

BOOKS RECOMMENDED:

1. I.S. Sokolnikoff: *Mathematical Theory of Elasticity*, Tata McGraw-Hill, New Delhi, 1977.
2. A.E.H. Love: *A Treatise on the Mathematical theory of Elasticity*, Dover Publications, New York, 2013.
3. Y.C. Fung: *Foundations of Solid Mechanics*, Prentice Hall, New Delhi, 1965.
4. D.S. Chandrasekharaiah, L. Debnath: *Continuum Mechanics*, Academic Press, 1994.
5. S. Narayan: *Text Book of Cartesian Tensor*, S. Chand and Co., 1950.
6. S. Timeshenki, N. Goodier: *Theory of Elasticity*, McGraw-Hill, New York, 1970.
7. I.H. Shames: *Introduction to Solid Mechanics*, Prentice Hall, New Delhi, 1971.

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MATM2111T: FUNCTIONAL ANALYSIS

Course Outcomes:	
CO1	Understand and apply fundamental theorems Hahn-Banach theorem in Normed linear spaces and its applications, uniform boundedness principle, open mapping theorem, closed graph theorem.
CO2	Understand Hilbert spaces including orthogonality, orthonormal sets, Bessel's inequality, Parseval's theorem.
CO3	Use and derive basic definitions and theorems of functional analysis
CO4	Differentiate between Banach Space and Hilbert Space
CO5	Apply contraction and approximation theory in differential equations and integral equations.

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total: 100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections: A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus. Section C will consist of one compulsory question having ten short questions covering the entire syllabus uniformly. Each question in sections A and B will be of 10 marks each and section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each sections A and B and compulsory question of section C.

SECTION-A

Normed linear spaces, banach spaces, examples of banach spaces and subspaces. Continuity of linear maps, equivalent norms. Normed spaces of bounded linear maps, bounded linear functional. Hahn-Banach theorem in linear spaces and its applications. Hahn-Banach theorem in normed linear spaces and its applications. Uniform boundedness principle, open mapping theorem, projections on banach spaces, closed graph theorem.

SECTION-B

The conjugate of an operator. Dual spaces of L_p and $C[a,b]$, reflexivity. Hilbert spaces, examples, orthogonality, orthonormal sets, Bessel's inequality, Parseval's theorem. The conjugate space of a Hilbert spaces, adjoint operator, self-adjoint operator, normal and unitary operators. Projection operators. Spectrum of an operator, Spectral Theorem, Banach fixed point theorem, Brower's fixed point theorem, Schauder fixed point theorem, Picards theorem, applications of fixed point theorem in differential equations and integral equations.

BOOKS RECOMMENDED:

1. G. Bachman, L. Narici: *Functional Analysis*, Dover, Mineola, New York, Revised Edition, 2000.
2. E. Kreyszig: *Introductory Functional Analysis with Applications,* Wiley, New York, 1978.
3. A. H.Siddiqi: *Applied Functional Analysis: Numerical Methods, Wavelet Methods and Image Processing*, CRC Press, 2003.
4. V. L.Balmohan: *Linear Functional Analysis for Scientists and Engineers*, Springer, Singapore, 2016.
5. B. Béla: *Linear analysis*, Cambridge University Press, 1990.

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MATM2112T: Numerical Analysis

Course Outcomes: After studying this course students will be able to	
CO1	Understand the concept of single step and multistep methods for solving Initial and Boundary Value problems
CO2	Analyze the convergence , truncation error and stability of the single and multistep methods
CO3	Develop an efficient numerical scheme for solving boundary value problems based finite difference approach (explicit and implicit method) arising in science and engineering
CO4	Carry out stability analysis and truncation error in various finite difference schemes

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total: 100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C. Use of Non-Programmable Scientific Calculators is allowed.

SECTION – A

Solution of Differential Equations : Taylor's series. Euler's method, improved Euler method, modified Euler method, and Runge-Kutta method (Up to fourth order), predictor corrector method. Stability ad convergence of Runge-Kutta and predictor corrector methods.

Parabolic Equations : Explicit and implicit schemes for solution of one-dimensional equations. Crank-Nicolson, Dufort-Frankel schemes for one-dimension equations. Discussion of their compatibility, stability and convergence. Peaceman-Rachford A.D.I. scheme for two dimensional equations.

SECTION – B

Elliptic Equation: Finite difference replacement and reduction to block tri-diagonal form and its solution. Diriehlet and neumann boundary conditions. Treatment of curved boundaries, solution by A.D.I. method.

Hyperbolic equations: Solution by finite difference methods on rectangular and characteristics grids and their stability.

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BOOKS RECOMMENDED:

1. G.D. Smith: *Numerical Solution of Partial Differential Equations*, Oxford Univ. Press, 1982.
2. R.S. Gupta: *Elements of Numerical Analysis*, Macmillan India Ltd., 2009.
3. A.R. Mitchell: *Computational Methods in Partial Differential Equations*, John Wiley, 1975.
4. C.E. Forberg: *Introduction to Numerical Analysis*, Addision-Wesley, Reading, Massachusetts, 1969.
5. C.F. Gerald: *Applied Numerical Analysis*, Addision-Wesley, Reading, Massachusetts, 1970.
6. M.K. Jain: *Numerical solutions of Differential Equations*, John Wiley, 1984.
7. L. Collatz: *Numerical Treatment of Differential Equations*, Springer - Verlag, Berlin, 1966.

MATM2201T: HOMOLOGY THEORY

Course Outcomes:	
CO1	Deep knowledge of algebraic structures associated with a topological space.
CO2	Homology groups lead to the singular and simplicial homology
CO3	Enables the student to compute some homology groups.

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: Continuing the study of Topology this course introduces the Singular and Simplicial Homology and enables the students to grasp these techniques to compute homological groups of a simplicial pair for instance.

SECTION – A

Singular Homology Theory: Euclidean Simplexes, linear Maps, singular p-simplex, the group $Cp\ (E; G)$, induced homomorphism on chains, the boundary operator d, the boundary of a singular simplex, the boundary of a p $-$chain.

Cycles and Homology: The group $Zp(E;\ G)$, the homology groups $Hp(E; G)$, $Hp(E, F; G)$, induced homomorphism on relative homology groups, the dimension theorem, the exactness theorem, exact sequence, the boundary homomorphism and the exactness of the singular homology sequences (R.R.: Sec 1-1 to 1-9 of Wallace).

Singular and Simplicial Homology: Homotopic maps of pairs, the prism operator P, the homotopy theorem, the excision theorem, the barycentric subdivision operator B, the axiomatic approach, simplicial complexes, traingulable space, triangulation, the direct sum theorem, the direct sum theorem for complexes (R.R.: Sec 1-10 to 2-4 of Wallace).

SECTION – B

Simplicial Homology: Homology groups of cells and spheres, orientation, homology groups of a simplicial pair, formal description of simplicial homology; the oriented chain group, the oriented boundary operator, the oriented simplicial homology group, simplicial map, cell complexes, canonical basis, the Betti group Bp and the torsion group Tp (R.R.: Sec 2-5 to 2-10 of Wallace).

Chain Complexes: Singular chain complex, oriented simplicial chain complex, the group Kp of p $-$chains of a chain complex, the group Kp of co-chains, co-boundary operator, the co-

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chain complex and the p[th] Co-homology group $Hp(K)$, chain homomorphism, induced homomorphism on homology and co-homology groups, chain homotopy and the algebraic homotopy theorem. (R.R.: Sec 3-1 to 3-6 of Wallace).

Pedagogy: The course is a natural successor of AMC 308 and such has the same pedagogy as that course.

BOOKS RECOMMENDED:

1. A.H. Wallace: *Algebraic Topology and Co-Homology,* Courier Corporation, 2007.
2. J.J. Rotman: *AnIntroduction to Algebraic Topology Graduate Text in Mathematics,* Springer, Verlag, New York, Volume 119, 1988.
3. A. Hatcher: *Algebraic Topology*, Cambridge University Press, 1[st] Edition, 2001.

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MATM2202T: THEORY OF LINEAR OPERATORS

Course Outcomes:	
CO1	Understand spectral theory in Normed linear spaces,bounded linear operator, spectral mapping theorem for polynomials, elementary theory of banach algebras..
CO2	Undersatand spectral properties of compact linear operators on normed space bounded self-adjoint linear operators on a complex Hilbert space.
CO3	Differentiate between Banach Space and Hilbert Space
CO4	Apply spectral techniques for the study of the theory of linear operators.

L	T	P	
5	1	0	

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The aim of this course is to introduce Spectral Techniques for the study of the Theory of Linear Operators.

SECTION-A

Spectral theory in normed linear spaces, resolvant set and spectrum, spectral properties of bounded linear operator, properties of resolvant and spectrum, spectral mapping theorem for polynomials, spectral radius of bounded linear operator on a complex Banach space. Elementary theory of banach algebras, resolvant set and spectrum, invertible elements, resolvant equation, general properties of compact linear operators.

SECTION-B

Spectral properties of compact linear operators on normed space, behaviour of compact linear operators with respect to solvability of operator equations, Fredholm-type theorems, Fredholm alternative theorems. Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space, positive operators, monotone sequence theorem for bounded self-adjoint operators on a complex Hilbert space, square roots of positive operators, spectral family of a bounded self-adjoint linear operator and its properties, spectral theorem.

BOOKS RECOMMENDED:

1. E. Kreyszic: *Introductory Functional Analysis with Applications,* Wiley, New York, 1978.
2. Balmohan V. Limaye: *Linear Functional Analysis for Scientists and Engineers,* Springer, Singapore, 2016.

MATM2203T: LIE GROUPS AND COMPLEX MANIFOLDS

Course Outcomes:	
CO1	To acquire the knowledge of the theory of Lie groups which is based on the study of differential geometry and differential topology
CO2	To define connections on the structure of complex manifolds leading to the development of new spaces
CO3	To implement the metric induced on the submanifolds for the construction of structural equations
CO4	To understand the concept of complex manifolds and complex differential forms based on unitary space which is instrumental in further research in this field
CO5	To apply the theory of differentiable manifolds and Lie groups, which is one of the cornerstones of the edifice of modern mathematics, in various spheres of study

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This paper aims to study the theory of Lie algebras and various types of complex manifolds extensively.

SECTION-A

Lie groups and lie algebras, product of two lie-groups, one parameter subgroups and exponential maps, examples of lie groups, homomorphism and isomorphism, lie transformation groups, general linear groups. Sub-manifolds, induced connection and the associated second fundamental form, curvature tensor field of the sub-manifold, the normal vector along with the linear connections, the Gauss and Weingarten formulae, the equations of Gauss and Mainardi-Codazzi.

SECTION-B

Almost Complex manifolds, Nijenhuis tensor, contravariant and covariant almost analytic vector fields, F-connection, Hermitian metric, almost Hermitian manifolds, linear connections in an almost Hermitian manifolds, Hermitian manifolds with their characterizations, the fundamental 2-form phi, Kählerian metric, almost Kähler manifolds, Kähler manifold, constant holomorphic sectional curvature, complex space form.

Pedagogy: The teacher should lay emphasis on the study of structure of sub-manifolds and of the differentiable manifolds based on C^nwhich is of great use for further research in this field.

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BOOKS RECOMMENDED:

1. K. Yano, M. Kon:*Structures on Manifolds*, World Scientific Publishing Co. Pvt. Ltd., 1984.
2. Y. Matsushima:*Differentiable Manifolds*, Marcel Dekker, Inc. New York, 1972.
3. U.C. De, A.A. Shaikh: *Complex Manifolds with Contact Manifolds*, Narosa Publishing House, New Delhi, 2009.
4. K. Nomizu, S. Kobayashi: *Foundations of Differential Geometry*, ,Interscience Publishers, John Wiley & Sons, New York, Vol. 2, 1969.
5. B. Hall: *Lie Groups, Lie Algebras and Representations: An Elementary Introduction,* Springer, Graduate Texts in Mathematics, 2nd Edition, 2015.

MATM2204T: CATEGORY THEORY –II

Course Outcomes:	
CO1	Knowledge of the fundamental concepts of categorical adjunctions and monads.
CO2	Can establish the unity of all mathematical concepts as different instances of adjoints
CO3	Development of the machinery of Elinberg Moore Category and Kliesli construction for the study of relationship between adjoints and monads.
CO4	Yoneda lemma also finds many applications in the course.

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course continues the study of category theory and achieves the aim of the study of adjunctions and monads. The famous Yoneda lemma finds numerous applications in the course.

SECTION-A

Equivalence: The functor category $Fun(C, D)$ and natural isomorphism (R.R.: Sections 6.1, 6.2 and 7.1 to 7.5 of Awodey), exponentials of categories, the bifunctor lemma, Cat is Cartesian closed, functor categories, equivalence of categories. Examples of Equivalence: Setsfin and Ordfin, pointed set and partial maps, slice categories and indexed families, (R.R 7.6 to 7.9 of Awodey).

Categories of Diagrams: Set-valued functor categories, the Yoneda embedding, the Yoneda lemma, applications of the Yoneda lemma, limits, co-limits and exponentials in categories of diagrams, $Hom(X, GP)$ and $Hom(X, x, P, Q)$ (R.R.: Sections 8.1 to 8.7 of Awodey).

SECTION-B

Adjoints: Adjunction between categories, left and right adjoints, hom-set definition of adjoints. examples of adjoints, uniqueness up to isomorphism, order adjoints and interior operation in topology as an order adjoint. Preservation of limits (co-limits) by right (left) adjoints. UMP of the Yoneda embedding and Kan extensions, the adjoint functor theorem.

Monads and Algebras: The triangle identities, monads and adjoints, algebras for a monad, the Elinberg- Moore category (R.R: Chap. 9, Sections 9.1 to 9.4, 9.6 AFT from Section 9.8 and Chap. 10: Sections 10.1 to 10.4 of Awodey).

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BOOKS RECOMMENDED:

1. S. Awodey: *Category Theory*, Oxford Logic Guides, 49, Oxford University Press, 2007.
2. E. Reihl: *Category Theory in Context*, Dover Modern Math Originals, 2006.
3. S. Mac Lane: *Categories for the Working Mathematician*, Springer Verlag, New York, Volume 5, 1971.

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MATM2205T: OPTIMIZATION TECHNIQUES –II

Course Outcomes: After studying this course students will be able to	
CO1	Understand some advanced level concept in optimization.
CO2	Use Methods for solving quadratic programming, Goal programming, Separable programming and linear complementary method.
CO3	Get acquainted with applications of geometric programming in electrical circuit design, finance industry and Statistics.
CO4	Understand constrained and unconstrained geometric programming problem.
CO5	Use decision theory and the related concepts in solving various problems
CO6	Study the Simulation and its application to different types of problems like queueing, inventory, budgeting etc

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C. Use of non-programmable scientific calculators is allowed.

SECTION-A

Quadratic Programming: Wolfe's modified simplex method, Beale's method for quadratic programming, separable, convex programming.

Linear Complimentary Problem: Lemke's complementary pivoting algorithm, solution of quadratic programming, problems using linear complementary method.

Separable Programming: Introduction, reduction of separable programming to linear programming problem, separable programming algorithm.

Goal Programming: Introduction, formulation of linear goal programming, graphical and simplex method for goal programming.

SECTION-B

Geometric Programming: Introduction, constrained and unconstrained geometric programming problem, complementary geometric programming.

Decision Theory: Introduction and components of decision theory, EMV, EOL, decision making under uncertainty, decision making under utilities, decision making under risk.

Simulation: Introduction, advantages and disadvantages, event–type, Monte-Carlo simulation, application to inventory, queueing, capital budgeting, financial planning, maintenance, job sequencing, networks.

BOOKS RECOMMENDED:

1. K. Swarup, P. K. Gupta, Man Mohan: *Operations Research*, Sultan Chand and Sons, New Delhi, 2010.
2. C. Mohan, Kusum Deep: *Optimization Techniques*, New Age International, 2009.
3. H. S. Kasana, K.D. Kumar: *Introductory Operations Research: Theory and Applications*, Springer, Science and Business Media, 2013.
4. S.D. Sharma: *Operation Research*, Kedar nath Ramnath and Co., Meerut, 2002.
5. H. A. Taha: *Operations Research*: *An Introduction*, Pearson Prentice Hall, New Delhi, 2007.

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MATM2206T: HOMOLOGICAL ALGEBRA

Course Outcomes:	
CO1	Knowledge of homology functors in the more general algebraic setting.
CO2	The categorical concepts having natural applications in the study of homology and algebraic topology
CO3	Proficiency in setting up the homology functors, derived functors and the special ext and tor functor
CO4	Can apply knowledge of functors in algebraic topology.

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam:70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course is a natural application of categorical methods to algebraic structures which arise in the study of homology and algebraic topology. The aim of the course is to make the student well conversant with homology, torsion and extension functors.

SECTION-A

Homology functors: Diagrams over a ring, translations of diagrams, translation category, split exact sequence, images and kernel as functors, Homology functors, the connecting homomorphism, complexes, boundary homomorphism, differentiation homomorphism, homology modules, right and left complexes, exact homology sequence and homotopic translations (R.R.: Chapter 4 of Northcott).

Projective and injective modules: Projective modules, injective modules, an existence theorem for injective modules, complexes over a modules, right and left complexes over a module, augmentation translation and augmentation homomorphism, a cyclic right and a cyclic left complexes over a module, projective and injective resolutions of a module, properties of resolutions of a module (R.R: Sections 5.1 to 5.5).

SECTION-B

Derived Functors: Projective and injective resolutions of an exact sequence, properties of resolutions of sequences, functors of complexes, associated translations, Functors of two complexes, right-derived functors, the defining systems and the connecting homomorphism, the functor R0T, left-derived functors, the functor L0T (R.R.: Sections 5.6 to 6.4 of Northcott).

Torsion and Extension Functors: Connected sequences of functors, connected right and left sequences of covariant and contravariant functors, homomorphism and isomorphism as a natural equivalence between connected sequences of functors, torsion functors torn, basic properties of torsion functors, extension functors and basic properties of extension functors (R.R. Sections 6.5 to 7.4 of Northcott).

Pedagogy: The instructor should emphasize the topology problems which these algebraic methods enable to simplify and solve.

BOOKS RECOMMENDED:

1. D. G. Northcott: *An introduction to Homological Algebra*, Cambridge University Press, 1960.
2. Charles A. Weibel: *An Introduction to Homological Algebra*, Cambridge Studies in Advanced Mathematics 38, Cambridge University Press, 1995.
3. J.J. Rotman: *An Introduction to Homological Algebra,* Springer, Universitext, 2008.
4. L.R. Vermani: *An Elementary Approach to Homological Algebra Monographs and Surveys in Pure and Applied Mathematics,* 130 Chapman and Hall/CRC, 2003.

MATM2207T: FINITE ELEMENT METHOD

Course Outcomes:	
CO1	Understand the concept of finite element methods and their effectiveness as compared to finite difference methods
CO2	Formulate the boundary value problem
CO3	Solve simple ordinary differential equations using FEM
CO4	Determine stresses and strains in a body using FEM
CO5	Solve two dimensional partial differential equations under different geometric conditions

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The course introduces finite element methods and their variational formulation.

SECTION-A

Introduction to finite element methods, comparison with finite difference methods, methods of weighted residuals, collocations, least squares and Galerkin's method, variational formulation of boundary value problems, equivalence of Galerkin and Ritz methods. Applications to solving simple problems of ordinary differential equations.

SECTION-B

Linear, quadratic and higher order elements in one dimensional and assembly, solution of assembled system, simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly discretization with curved boundaries, interpolation functions, numerical integration, and modeling considerations, solution of two dimensional partial differential equations under different geometric conditions.

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Pedagogy: Variational Principles should be stressed.

BOOKS RECOMMENDED:

1. J.N. Reddy: *Introduction to the Finite Element Methods*, Tata McGraw-Hill, 2003.
2. K.J. Bathe: *Finite Element Procedures*, Prentice-Hall, 2001.
3. R.D. Cook, D.S. Malkus, M.E. Plesha: *Concepts and Applications of Finite Element Analysis*, John Wiley, 2002.
4. J. R. H. Thomas: *The Finite Element Method: Linear Static and Dynamic, Finite Element Analysis,* Courier Corporation, 2012.
5. George R. Buchanan: *Finite Element Analysis*, Schaum's Outline, 1994.

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MATM2208T: FLUID MECHANICS

Course Outcomes:	
CO1	Understand the basic principles of fluid mechanics, such as Lagrangian and Eulerian approach, conservation of mass .
CO2	Understand the application of Euler and Bernoulli's equations and the conservation of mass to determine velocity and acceleration for incompressible and inviscid fluid.
CO3	Analyse the concept of rotational and irrotational flow, stream functions, velocity potential, sink, source, vortex etc.
CO4	Understand the simple fluid flow problems (flow between parallel plates, flow through pipe etc.) with Navier - Stoke's equation of motion.

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The aim of the course is to introduce basic equations of fluid dynamics like, the Navier-Stokes equation. To study drag and drift after developing the basic theory of irrotational non-viscous compressible flow.

SECTION-A

Equations of Fluid Mechanics: Real and continuous fluids, differentiation following the motion, equation of continuity, stream function, stream lines, pressure, Euler's equation of motion., Bernoulli's theorem, steady irrotational non-viscous compressible flow, vorticity, circulation, Kelvin's theorem on constancy of circulation, kinetic energy.
Three-dimensional problems: Laplace's equation, three dimensional sources and dipoles, spherical obstacle in a uniform steam, moving sphere, images.

SECTION-B

Application of Complex Variable Method: Conjugate functions in plane, complex potential and incompressible flow in two dimensions, uniform stream, source and sink, Vortex, Two dimensional dipole, superposition, Joukowski's transformation, Milne Thomson circle theorem, Blasius theorem, drag and lift.

Source and Vortex Filaments, Vortex Pair, Rows of Vortices, Kàrmàn Cortex Street, Viscous flow: Navier-Stokes equations, dissipation of energy, diffusion of vorticity in an incompressible fluid, condition of no slip, steady flow between two parallel infinite flat plates, steady flow through a straight circular pipe (Poiseuille Flow).

Pedagogy: Basic Physical Principles should lead to the theory of Fluid Dynamics.

BOOKS RECOMMENDED:

1. D. E. Rutherford: *Fluid Dynamics*, Oliver and B., 1971.
2. F. Chorlton: *Fluid Dynamics*, C.B.S. Publishers, Delhi, 1985.

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MATM2209T: ALGEBRAIC CODING THEORY

Course Outcomes:	
CO1	To do arithmetic in Finite fields, Linear Algebra over Finite Fields
CO2	To find Minimal polynomials with the help of Cyclotomic cosets
CO3	Understanding of Linear codes , their basis and distance
CO4	Encoding and Decoding of Linear Codes;
CO5	The Main Coding Theory Problem and certain bounds

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This is the course which introduces the applications of finite field methods to the problems of the coding theory.

SECTION-A

Error detecting and error correcting codes, maximum likelihood decoding, hamming distance, finite fields, minimal polynomials, linear codes, encoding with a linear code, generator matrix and parity check matrix, dual codes, syndrome decoding.

SECTION-B

ISBN codes, new codes from old, sphere covering bound, sphere packing bound, Gilbert-Varshamov bound, perfect codes, hamming Codes, Golay codes, simplex codes, singleton bound and MDS codes, Plotkin bound, Griesmer bound, Reed-Muller codes, linear programming bounds.

Pedagogy: Necessity of different types of coding, their usefulness and limitations should be stressed.

BOOKS RECOMMENDED:

1. S. Ling, C. Xing: *Coding Theory*, Cambridge University Press, 1st Edition, 2004 (Chap. 2-5).
2. W. C. Huffman, V. Pless: *Fundamentals of Error Correcting Codes*, Cambridge University Press, 1st South Asian Edition, 2004 (Sec. 1.5 of Chap. 1).
3. R. Hill: *Introduction to Error Correcting Codes*, Oxford University Press, Reprint: 1986, 2009.

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MATM2210T: COMMUTATIVE ALGEBRA

Course Outcomes:	
CO1	Understanding of the basic terminology used to understand commutative algebra
CO2	To know exact sequences, construction of Tensor product and exactness of Hom and Tor Functor
CO3	Understanding of Localization of rings, modules and will be able to see the correspondence between ideals of rings and localized rings
CO4	To know Primary ideals and two theorems regarding decomposition of ideals as product of Primary Ideals
CO5	To understand Integral Dependence of rings, Going up and Going down theorems.

L	T	P	
5	1	0	University Exam: 70
			Internal Assessment: 30

Time Allowed: 3 hours — Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course introduces basic techniques of commutative algebra and discusses the behavior of prime ideals under localization.

SECTION-A

Nil radical and Jacobson radical of ring, operation on ideals, extension and contraction of ideals, the prime spectrum of ring, Zairiski topology, exact sequence of modules, tensor product of modules, restriction and extension of scalars, exactness property of tensor product, flat modules, tensor product of algebras. Rings and modules of fractions, local properties.

SECTION-B

Extended and contracted ideals in rings of fractions. Primary ideals, decomposable ideals, first uniqueness theorem, isolated prime ideals, second uniqueness theorem, behavior of primary ideals under localization, integral dependence, integrally closed integral domains, integral A-algebra, going-up theorem, going-down theorem, valuation rings.

Pedagogy: Previous knowledge of students should naturally be developed for the study of the problems of commutative algebra.

BOOKS RECOMMENDED:

1. M.F. Atiyah, L.G. MacDonald: *Introduction to Commutative Algebra,* Addison-Wesley Publishing, 1969 (Chap. 1-4).
2. D. S. Dummit, M. Foote: *Abstract Algebra*, Wiley India, 2nd Edition, 2008.
3. B. Singh: *Basic Commutative Algebra*, Board Scientific Publishing, 2011.

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MATM2211T: OPERATIONS RESEARCH

Course Outcomes: After studying this course the students will be able to	
CO1	Understand basic characteristic features of a queuing system and acquire skills in analyzing queuing models
CO2	Apply models studied in queuing to solve real life problems
CO3	Comprehend the dynamics of inventory management's principles, concepts, and techniques as they relate to the entire supply chain (customer demand, distribution, and product transformation processes)
CO4	Study the models for replacement of machines which degenerates with time with/without considering any change in value of money
CO5	Understand operations research situations that can be conveniently modeled and solved as network problems through a variety of network optimization algorithms

L	T	P	University Exam: 70
5	1	0	Internal Assessment: 30

Time Allowed: 3 hours — Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks. Use of non-programmable calculator is allowed.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This very practical and useful subject introduces the students to queuing problems, inventory models, network analysis and project management.

SECTION-A

Queueing Problems: Characteristics of queueing system, distribution in queueing systems, Poisson arrivals and exponential service time, transient and steady state, probabilistic queueing models (Model I $(M/M/1)(\infty/FCFS)$, Model II A (General Erlang queueing model), Model II $B(M/M/1):(\infty/SIRO)$, Model III $(M/M/1):(N/FCFS)$, Model IV $(M/M/S):(\infty/FCFS)$, Model V $(M/M/S);(N/FCFS)$, Model VI A $(M/Ek/1):(\infty/FCFS)$, Model VIB $(M/Ek/1):(1/FCFS)$, measures and their solutions.

Inventory Models: Introduction, costs involved in inventory problems, variables in inventory problems, classification of inventory models, deterministic inventory model, (DIM), basic economic order quantity, (EOQ) models with no shortages: Model I(a), I(b), I(c). DIM with shortages: Model II(a), II(b), II(c), multiitem deterministic inventory models: Models III(a), III(b) III(c), introduction to stochastic inventory models.

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SECTION-B

Replacement and Maintenance Problems: Replacement policy when money value changes and does not change with time, group replacement of item that fails suddenly, the general renewal process.

Network Analysis: Introduction to networks, minimal spanning tree problem, shortest path problem, Dijkastra's algorithm, Floyd's algorithm, maximum flow problem.

Project Management: Critical path method, critical path computations, optimal scheduling by CPM, project cost analysis, PERT, distinction between CPM and PERT.

Pedagogy: Same as for AMC 309.

BOOKS RECOMMENDED:

1. K. Swarup, P. K. Gupta, Man Mohan: *Operations Research*, Sultan Chand and Sons, New Delhi, 2010.
2. C. Mohan, Kusum Deep: *Optimization Techniques*, New Age International, 2009.
3. H.S. Kasana, K.D. Kumar: *Introductory Operations Research: Theory and Applications*, Springer, Science and Business Media, 2013.
4. S.D. Sharma: *Operation Research*, Kedar nath Ramnath and Co., Meerut., 2002.
5. H. A. Taha: *Operations Research; An Introduction*, Pearson Prentice Hall, New Delhi, 2007.

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MATM2212T: WAVELETS

Course Outcomes:	
CO1	Expand a function in Haar wavelets
CO2	Construct Meyer wavelets to a given function
CO3	Find Daubechies wavelet series to a given function
CO4	Analyse two or more dimensional problems using wavelets

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total: 100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The course introduces the theory of wavelets which has many applications in communication and fundamental physical theory. It has important applications in image processing, thereby connecting this field with computer science as well.

SECTION-A

Fourier transforms and its basic properties, Poisson's summation formula, Gibb's phenomenon, Heisenberg uncertainty principle, applications of Fourier transforms to ordinary and partial differential equations. Classification and joint time frequency analysis of signals, definition, examples and basic properties of Gabor transforms, frames and frame operators, Zak transforms: definition and basic properties.

SECTION-B

Discrete and discrete- time and continuous wavelet transforms, scaling functions, multi-resolution analysis (MRA), wavelet functions, Parseval's theorem and examples of wavelet expansion. Wavelet transforms for partial differential equations: general procedure, error estimation by wavelet basis, introduction to signal and image processing, representation of signals by frames.

Pedagogy: The pure mathematical knowledge of students like Fourier Analysis should be put to practical use in this course.

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BOOKS RECOMMENDED:

1. C. S. Burrus, R. A. Gopinath, H. Guo: *Introduction to Wavelets and Wavelet Transforms*, Prentice Hall, 1997.
2. C.K. Chui: *An Introduction to Wavelets*, Academic Press, 1992.
3. Loknath Debnath: *Wavelet Transforms and Their Applications*, Springer, Birkhauser, 2nd Edition, 2015.
4. Abul Hasan Siddiqi: *Applied Functional Analysis: Numerical Methods, Wavelet Methods and Image Processing,* Marcel Decker, New York, 2004.

Navpreet Singh

MATM2213T: Non Linear Programming

Course Outcomes:	
CO1	Understand the concept of non linear optimization problems and its formulation
CO2	Formulate unconstrained problems, constrained problems with equality and inequality constraints
CO3	Solve one dimensional unconstrained non linear optimization problems
CO4	Solve multidimensional non linear optimization problems

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

SECTION –A

Non-linear Programming: Definition and examples of non-linear programming, its formulation, unconstrained problems, constrained problems with equality and inequality constraints, Fritz-John and Kuhn-Tucker optimality conditions, saddle point, Lagrange's method of solution.

Direct Search Methods: Solution of unconstrained non-linear optimization problems. One-Dimensional Problems: dichotomous search, Fibonacci search, golden-section search, Rosen Brock search method, methods requiring function to be differentiable: bisection method, method of false position, Newton-Raphson method, quadratic interpolation method, cubic interpolation method.

Direct Search Methods for multidimensional optimization problems: Evolutionary search method, simplex search method.

SECTION-B

Gradient search based methods for Multidimensional nonlinear optimization problems: Unconstrained problems: Hooke and Jeeves method, Steepest Descent method, Newton-Raphson method, Marquardt's method. Conjugate direction methods: Concept of conjugate directions, basic conjugate-direction method, method of Fletcher-Reeves, Partan method.

Constrained optimization Problems: Solution through Kuhn-Tucker conditions, penalty function method (interior penalty function method and exterior penalty function method).
Methods of feasible directions: Zoutendijk method, Gradient Projection method, Wolfe's reduced gradients method.

BOOKS RECOMMENDED:

1. M.S. Bazaraa, D. H. Sherali, C.M.Shetty: *Nonlinear Programming: Theory and Algorithm*, John Wiley, 2nd Edition, 1993.
2. C. Mohan, K. Deep: *Optimization Techniques*, New Age International, 2009.
3. D.M. Simmons: *Non-Linear Programming for Operations Research*, Prentice Hall, 1975.
4. M. Avriel: *Non-linear Programming: Analysis and Methods,* Prentice Hall, Englewood Cliffs, 1976.

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MATM2214T: MATHEMATICS OF FINANCE

Course Outcomes:	
CO1	The students will study different market models using basic notions and assumptions.
CO2	Students will learn to manage risk with options.
CO3	Students will learn about periodic compounding, continuous compounding and will be able to compare the various compounding methods.
CO4	In this subject techniques will be learnt to apply the different models to the dynamics of stock prices.
CO5	Some particular models like Binomial tree model, Trinomial tree model and continuous time limit will be taught to the students so that they can manage the risks.

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt two questions each from the sections A and B of the question paper and the entire section C.

Objective: Different market models are studied and applied to the dynamics of stock prices.

SECTION-A

A simple market model, basic notions and assumptions, no arbitrage principle, one-step binomial model, risk and return, forward contracts, call and put options, managing risk with options. Risk-free assets, time value of money, simple interest, periodic compounding, streams of payments, continuous compounding, how to compare compounding methods, money market, zero-coupon bonds, coupon bonds, money market account.

SECTION-B

Risky assets, dynamics of stock prices, return, expected return, binomial tree model, risk-neutral probability, martingale property, other models, trinomial tree model and continuous-time limit.

Discrete time market model, stock and money market models, investment strategies, the principle of no arbitrage, application to the binomial tree model, fundamental theorem of asset pricing.

BOOKS RECOMMENDED:

1. R.J. Williams: *Introduction to Mathematics of Finance*, AMS, 2006.
2. M.Capiski, T.Zastawniak: *Mathematics for Finance: An Introduction to Financial Engineering,* Springer, 2003.

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MATM2215T: MATHEMATICAL METHODS

Course Outcomes:	
CO1	Understand the relation between linear differential equation and Volterra's equation and convert one type into another.
CO2	Apply to analyze the safety and stability of the dam during an earthquake.
CO3	Understand the difference between Volterra and Fredholm integral equations, first kind and second kind.
CO4	Understand the fundamental concepts of the space of admissible variations for fixed points.
CO5	Give the Solution to the brachistochrone and isoperimetric problem

L T P — University Exam: 70
5 1 0 — Internal Assessment: 30
Time Allowed: 3 hours — Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: This course teaches integral equations and variational methods.

SECTION –A

Linear integral equations of first and second kind, Abel's problem, relation between linear differential equation and Volterra's equation, non-linear and singular equations, solution by successive substitutions, Volterra's equation, iterated and reciprocal functions, Volterra's solution of Fredholm's equation. Fredholm's equation as limit of finite system of linear equations, Hadamard's theorem, convergence proof, Fredholm's two fundamental relations, Fredholm's solution of integral equation when $D(x) = 0$, Fredholm's solution of Dirichlet's problem and Neumann's problem, lemmas on iterations of symmetric kernel, Schwarz's inequality and its applications.

SECTION –B

Simple variational problems, necessary condition for an extremum, Euler's equation, end point problem, variational derivative, invariance of Euler's equation, fixed end point problem for unknown functions, Variational problem in parametric form, functionals depending on higher order derivatives. Euler-Lagrange equation, first integral of Euler-Lagrange equation, geodesics, the brachistochrone, minimum surface of revolution, brachistochrone from a given curve to a fixed point, Snell's law, Fermat's principle and calculus of variations.

BOOKS RECOMMENDED:

1. F.B. Hildebrand: *Method of Applied Mathematics,* Prentice Hall, India, 1965.
2. I.M. Gelfand, S.V. Fomin: *Calculus of Variations*, Prentice Hall, India, 1961.
3. W.W. Lovitt: *Linear Integral Equations*, Tata McGraw-Hill, India, 1950.
4. R. Weinstock: *Calculus of Variations*, McGraw-Hill, London, 1974.
5. L.B. Chambers: *Integral Equations,* International Text Book Co, 1976.

MATM2216T: ANALYTIC NUMBER THEORY

Course Outcomes:	
CO1	Can handle multiplicative functions.
CO2	Can deal with Dirichlet series as functions of a complex variable,
CO3	To prove the Prime Number Theorem and simple variants.
CO4	To study number theory by using analytic tools (inequalities, limits, calculus, etc) .
CO5	To solve problems about the integers and the distribution of prime numbers by using analysis.

L	T	P	
5	1	0	University Exam: 70
			Internal Assessment: 30

Time Allowed: 3 hours — Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Objective: The aim of this course is the study of arithmetical functions.

SECTION –A

Arithmetical Functions: Mobius function, Euler's totient function, mangoldt function, Liouville's function, the divisor functions, relation connecting $\varphi$and μ, product formula for $\varphi(n)$, Dirichlet product of arithmetical functions, Dirichlet inverses and Mobius inversion formula, multiplicative functions, Dirichlet multiplication, the inverse of a completely multiplicative function, generalized convolutions.

Averages of Arithmetical Functions: The big oh notation, asymptotic equality of functions, Euler's summation formula, elementary asymptotic formulas, average order of $d(n), \varphi(n), \sigma_\alpha(n), \mu(n), \Lambda(n)$, the partial sums of a Dirichlet product, applications to $\mu(n)$and$\Lambda(n)$, Legendre's identity.

SECTION –B

Some elementary theorems on the distribution of prime numbers: Chebyshev's functions $\psi(x)$ and $\theta(x)$, relation connecting $\theta(x)$ and $\Pi(x)$, Abel's identity, equivalent forms of Prime number theorem, inequalities for $\Pi(n)$ and P_n , Shapiro's Tauberian theorem, applications of Shapiro's theorem, asymptotic formula for the partial sums $\sum_{p\leq x}\frac{1}{p}$. Elementary properties of groups, characters of finite abelian groups, the character group, orthogonality relations for characters, Dirichlet characters, Dirichlet's theorem for primes of the form $4n-1$ and $4n+1$, Dirichlet's theorem in primes on arithmetical progression, distribution of primes in arithmetical progression.

Pedagogy: The course should be taught as a direct application of mathematical analysis.

BOOKS RECOMMENDED:

1. T.M. Apostol: *Introduction to Analytic Number Theory*, Springer, Science and Business Media, 1998.
2. M. Ram Murti: *Problems in Analytical Number Theory*, Springer, Graduate Text in Mathematics, New York, 2000.

Head
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MATM2217T:: COMPUTATIONAL TECHNIQUES

Course Outcomes:	
CO1	Compute piecewise cubic and Hermite polynomials
CO2	Understand the Hermite-Birkhoff interpolation problem
CO3	Use of different types of Spline functions and their properties
CO4	Find the solution of various problems using Green's function and Tchebycheffian spline functions

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C. Use of non-programmable scientific calculators is allowed.

Objective: The course introduces numerical techniques in the solutions of some of the most important and frequently occurring equations in nature including advanced methods like splines.

SECTION-A

Introduction to Hermite interpolation and computation of piecewise cubic, Hermite polynomials, piecewise Hermite interpolation and computation of piecewise Hermite polynomials, Hermite-Birkhoff interpolation problem, Runge example. Piecewise cubic Bessel interpolation, basic properties of splines, construction of local basis, $B-$splines. Equally spaced knots, perfect $B-$splines, dual basis, zero properties, sign properties of green's function, derivatives, piecewise polynomial representation.

SECTION-B

Piecewise constants and linear function, direct theorems in intermediate spaces, lower bounds, $N-$Widths periodic splines, natural splines, g-splines, monosplines, discrete splines, Green's function, Tchebycheffian spline functions.

BOOKS RECOMMENDED:

1. C.D. Boor: *A Practical Guide to Splines*, Springer, Applied mathematical Science, 1st Edition, 1978.
2. P.M. Prenter: *Splines and Variational Methods*, Dover Publications, 2008.
3. L. L.Schumaker: *Spline Functions: Basic Theory*, Cambridge Mathematical Library, 3rd Edition, 2007.

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MATM2218T: COMPUTER ALGEBRA SYSTEM

CourseOutcomes:	
CO1	The student will be able to learn about Computer Algebra.
CO2	The students will have concept clarity of the subjects like Basic Algebra and Basic Calculus.
CO3	The students will learn about Rational Function plotting: 2D and 3D
CO4	Students will be told about construction of groups, homomorphisms and isomorphisms.
CO5	The students will learn to write programs for elementary problems in Group theory.
CO6	The students will be able to have understanding of other Algebriac subjects using GAP.

L	T	P
5	1	0

Time Allowed: 3 hours

University Exam: 40
Internal Assessment: 10
Total: 50

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 6 marks and Section C will be of 16 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C.

Section A

Meaning of Computer Algebra System, Examples, Common Features of Computer Algebra Systems, a glimpse of Jupyter notebooks, using Jupter notebooks as a calculator.

Saga Math: Basic interface, Basic Algebra and Calculus is SagaMath(Polynomial Equations, Differentiation,Differential Equations). Numerical solutions using SagaMath.
Polynomial rings is SageMath in one and more variable with coefficients in reals. complex and finite fields, ideals and quotienting, Cyclotomic polynomials, Rational Functions Plotting (both 2D and 3D).
Structures using SageMath: Binary trees. POSETs.
Linear Algebra with SageMath: Matriees and pieces of materies. Echelon forms, Solving system of linear equations, vector spaces, conturuction of subspaces cigenvalues and eigenvectors
Number Fields in SageMath: Constuction calculation of discriminant and different automorphisms.

SECTION- B

GAP : Basic interface, contruction of groups. Small Groups library, iterating over a group, character table of group using GAP, Constructing homomorphisms and isomorhisms.

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Writing programs for elementary problems in group theory (verifying Sylow theory determining all simple groups up to an order, finding orders of all elements in a group, construction of Rubik's cube group).

Other algebraic objects using GAP: Polynomials and their factorization, Garussian integers vector spaces, field extensions, finite fields.

BOOKS RECOMMENDED:

1. Sage reference Manual : https://doc.sagemath.org/
2. Sang-Gu-Lee et al. Linear Algebra with Sage, Bigbook, 11, 2015.
3. Ribert A. Beezer, Sage Quick Reference: https://wiki.sagemath.org/quickref.
4. J.G. Rainbolt and J.A. Gallian, Abstract Algebra with GAP, 7th Edition, 2010.

MATM2218L: SOFTWARE LAB (COMPUTER ALGEBRA SYSTEM)

L T P
0 0 4
Time Allowed: 3 hours

University Exam: 30
Internal Assessment: 20
Total: 50

This laboratory course will mainly comprise of exercises on what is learnt under the paper," Computer Algebra System".

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⑤

MATM2219T:: ADVANCED FUNCTIONAL ANALYSIS

Course Outcomes:	
CO1	To introduce the Sobolev spaces
CO2	To introduce the applications of functional analysis on differential equations
CO3	To introduce the concept of weak convergence
CO4	To introduce the students to distributions
CO5	To define the application of Functional analysis on finite elements

L T P
5 1 0
Time Allowed: 3 hours

University Exam: 70
Internal Assessment: 30
Total:100

INSTRUCTIONS FOR THE PAPER-SETTER

The question paper will consist of three sections A, B and C. Sections A and B will have four questions each from the respective sections of the syllabus and Section C will consist of one compulsory question having ten short answer type questions covering the entire syllabus uniformly. Each question in Sections A and B will be of 10 marks and Section C will be of 30 marks.

INSTRUCTIONS FOR THE CANDIDATES

Candidates are required to attempt five questions in all selecting two questions from each of the Section A and B and compulsory question of Section C. Use of non-programmable scientific calculators is allowed.

Objective: The course introduces numerical techniques in the solutions of some of the most important and frequently occurring equations in nature including advanced methods like splines.

SECTION-A

Test function spaces, distributions, calculus on distributions and basic examples. Localization, supports and singular support of distributions. Convolutions. Fourier transform, tempered distributions and Paley-Weiner Theorems. Fundamental solutions and Malgrange-Ehrenpreis Theorem. Definition and basic properties of Sobolev spaces. Approximation by smooth functions, traces and extension theorems.

SECTION-B

Sobolev inequalities and Compactness theorems. Dual spaces, fractional order spaces, Tracer Theory Abstract variational problem and Second-order elliptic equations, weak solutions, existence of weak solutions, L2-regularity theory, maximum principles and eigen-value problem, Basics of finite element method.

BOOKS RECOMMENDED:

1. S. Kesvan: Topics in Applied Functional Analysis. Wiley Eastern Limited.

2. Eberhard Zeidler: Applied Functional Analysis: Applications to Mathematical Physics. Applied Mathematical Sciences 108, Springer Verlag.

3. A.H. Siddiqui: Applied Functional Analysis: Numerical methods, Wavelet methods and Image Processing. Marcel Decker, Inc.

4. Walter Rudin: Functional Analysis. McGraw Hill

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