PUNJABI UNIVERSITY, PATIALA

OUTLINES OF TESTS,

SYLLABI AND COURSES OF READING

FOR

M.Sc. (Mathematics)-II

2021-22 & 2022-23

PUNJABI UNIVERSITY, PATIALA

Third Semester

LIST OF ELECTIVES (Any five of the followings)

		CREDITS
MM 601:	DIFFERENTIABLE MANIFOLDS	6
MM 602:	FIELD THEORY	6
MM 603:	DIFFERENTIAL EQUATIONS II	6
MM 604:	CATEGORY THEORY I	6
MM 605:	NUMERICAL ANALYSIS	6
MM 606:	COMPLEX ANALYSIS II	6
MM 607:	CLASSICAL MECHANICS * (It can be opted only if MM 507 had not been opted in semester-II)	6
MM 608:	ALGEBRAIC TOPOLOGY	6
MM 609:	OPTIMIZATION TECHNIQUES-I	6
MM 610:	FUZZY SETS AND APPLICATIONS	6
MM 611:	SOLID MECHANICS	6
MM 612:	FUNCTIONAL ANALYSIS* (It can be opted only if MM 506 had not been opted in semester-II)	6

Fourth Semester

LIST OF ELECTIVES (Any five of the followings)

		CREDITS
MM 701:	HOMOLOGY THEORY	6
MM 702:	THEORY OF LINEAR OPERATORS	6
MM 703:	LIE GROUPS AND COMPLEX MANIFOLDS(Prerequisite: Differentiable Manifolds)	6
MM 704:	CATEGORY THEORY – II (Prerequisite: Category Theory – I)	6
MM 705:	OPTIMIZATION TECHNIQUES-II	6
MM 706:	HOMOLOGICAL ALGEBRA (Prerequisite: Category Theory – I)	6
MM 707:	FINITE ELEMENT METHODS	6
MM 708:	FLUID MECHANICS	6
MM 709:	ALGEBRAIC CODING THEORY	6
MM 710:	COMMUTATIVE ALGEBRA	6
MM 711:	OPERATIONS RESEARCH	6
MM 712:	WAVELETS	6
MM 713:	NON LINEAR PROGRAMMING	6
MM 714:	COMPUTATIONAL TECHNIQUES	6
MM 715:	MATHEMATICS OF FINANCE	6
MM 716:	MATHEMATICAL METHODS	6
MM 717:	ANALYTIC NUMBER THEORY	6

MM 601: DIFFERENTIABLE MANIFOLDS

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: 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.

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 & Sons, New York, 1963.

MM 602: 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. David S. Dummit, Richard M Foote: *Abstract Algebra*, John Wiley & Sons, 2004.
3. M. Artin: *Algebra*, Prentice Hall of India, New Delhi, 1994.

MM 603: Differential Equations –II

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 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, familyof equipotential surface.Interior and exterior Dirichlet boundary value problem for Laplaceequation, separation ofvariables, axial symmetry, Kelvin's inversion theorem.Green's function for Laplace equation.Dirichlet'sproblem for semi-infinite space and for a sphere.Copson'stheorem (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*, TataMcGraw-Hill. 1991.
3. I.N. Sneddon:*Elements of Partial Differential Equations*, Tata McGraw-Hill. 1957.

MM 604: CATEGORY THEORY - I

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: 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, 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, stone duality, 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. Emily Reihl: *Category Theory in Context*, Dover Modern Math Originals Emily Reihl, Dover Publications, 2016.

MM 605 : NUMERICAL ANALYSIS

L	T	P
4	0	4

University Exam(Theory): 40
Internal Assessment(Theory): 20
University Exam(Practical): 30
Internal Assessment(Practical): 10

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 7.5 marks and Section C will be of 10 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, modifiedEuler method, and Runge-Kutta method (up to fourth order), predictor corrector method. Stability andconvergence of Runge-Kutta and predictor corrector methods.
Parabolic Equation: 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, Dirichlet and Neumann boundary conditions. Treatment of curved boundaries, solution byA.D.I. method.
Hyperbolic equations: Solution by finite difference methods on rectangular and characteristics gridsand their stability.

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.

MM 606: COMPLEX ANALYSIS–II

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: The course will continue the study of complex analysis and introduce more advance methods like the Greens functions, MittagLeflers 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, analyticcontinuation by power series method.natural boundary.Schwarz reflection principle.Monodromy theorem.Mittag-Leffler's theorem (only in the case when the set of isolatedsingularities admits the point at infinity alone as an accumulation point). Cauchy's method ofexpansion of meromorphic functions. Partial fraction decomposition of cosec z, representationof 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 minimum principles, Harmonic functionson a disc,Harnack's inequality and theorem,sub-harmonic andsuper-harmonic functions,Dirichletproblem,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. ZeevNihari: *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*, NoordhoffInternational Publishing, Leyden, 1960 (Sections 4.11.1 and 4.11.2 only).
3. J. B. Conway: *Functions of One Complex Variable*, Springer, Vertag-InternationalStudent,Narosa Publishing House, 1980 (Chap.X only).
4. E. T. Copson: *Theory of Functions of a Complex Variable*, OxfordUniversity Press, 1935 (Chap. IV (4.60, 4.61, 4.62)Chap. VII (excl. Section 7.7)Chap.VIII (Section 8.4)).

MM 607: CLASSICAL MECHANICS

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: 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'sprinciple and Lagrange'sequations, velocity dependent potentials and the dissipation function, simple applications ofthel agrangianformulation.

Variational Principles and Lagrange's Equations: Hamilton's principle, derivation ofl agrange'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.

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 Coriolisforce.

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

MM 608: 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 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, theBorsuk - 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.

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

MM 609: OPTIMIZATION TECHNIQUES-I

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 IPP method, Gomory's mixed-integer method, branch and bound method.

Dynamic Programming: Introduction, the recursive equation approach, dynamic programming algorithm, solution of discrete DPP.

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 & Strategies: Definition & 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, NewDelhi, 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 & Business Media,2013.
4. G.Hadley: *Linear Algebra*, Addison-Willey, 7th Edition 1977.

MM 610: FUZZY SETS AND APPLICATIONS

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 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, a-cuts, properties of a-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, binaryfuzzy Relations, Binary relations on single set, equivalence, compatibility and orderingrelations, 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.

MM611: SOLID MECHANICS

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 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 oftensor, isotropic tensors of different orders and relation between them, symmetric and skewsymmetric tensors, tensor invariants, deviatoric tensors, eigen-values and eigen-vectors of atensor.

Tensor analysis: Scalar, vector, tensor functions, comma notation, gradient, divergence and curlof 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 andinvariance, general infinitesimal deformation, Saint-Venants equations of compatibilty, finitedeformations.

Analysis of Stress: Stress tensor, equations of equilibrium, transformation of co-ordinates, stressquadric of Cauchy, principal stress and invariants, maximum normal and shear stresses (relevant portion of Chap. 1 & 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 and isotropic elastic solid, strain energy function and its connection with Hooke's law, uniqueness of solution. Beltrami-Michellcompatibilty 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, generalsolution of bi-harmonic equation, stresses and displacements in terms of complex potentials, thestructure of functions of $\varphi(z)$ and $\psi(z)$. First and second boundary-value problems in planeelasticity.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:*ATreatise 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. Shanti Narayan:*Text Book of Cartesian Tensor*, S. Chand & 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.

MM 612: FUNCTIONAL ANALYSIS

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. 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. Siddiqi, AbulHasan: *Applied Functional Analysis: Numerical Methods, Wavelet Methods and Image Processing*, CRC Press, 2003.
4. Balmohan V. Limaye: *Linear Functional Analysis for Scientists and Engineers*, Springer, Singapore, 2016.
5. B. Béla: *Linear analysis*, Cambridge University Press, 1990.

Semester-IV

MM 701: HOMOLOGY THEORY

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: 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 asingular simplex, the boundary of a p −chain.

Cycles & Homology: The group $Zp(E; G)$, thehomology 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, thehomotopy theorem,the excision theorem, the barycentric subdivision operator B,theaxiomatic 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, theoriented 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-chaincomplex 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 MM 608 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, 1st Edition, 2001.

MM 702: 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 ofbounded linear operator,properties of resolvant and spectrum, spectral mapping theorem

forpolynomials, 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 linearoperators with respect to solvability of operator equations,Fredholm-type theorems,Fredholmalternative theorems.Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space, positiveoperators,monotone sequence theorem for bounded self-adjoint operators on a complex Hilbertspace,square roots of positive operators,spectral family of a bounded self-adjoint linearoperator and its properties, spectral theorem.

Pedagogy: Same as for Functional Analysis of previous year.

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.

MM 703 - LIE GROUPS AND COMPLEX MANIFOLDS

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.

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.

MM 704: CATEGORY THEORY –II

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, stone duality (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 adjointfunctor theorem.

Monads and Algebras: The triangle identities, monads and adjoints, algebras for a monad, the Eilnberg- Moore category and the Kliesli category, comonad and co-algebras (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).

Pedagogy: Same as for MM 604.

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

MM 705: OPTIMIZATION TECHNIQUES –II

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: Continuing the study of MM 609, this course introduces more advanced methods of programming and introduces decision theory and simulation.

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 quadraticprogramming, problems using linear complementary method.
Separable Programming: Introduction, reduction of separable programming to linear programmingproblem, separable programming algorithm.
Goal Programming: Introduction, formulation of linear goal programming, graphical & simplexmethod for goal programming.

Section-B

Geometric Programming: Introduction, constrained & unconstrained geometric programmingproblem, complementary geometric programming.
Dynamic Programming: Introduction, nature of dynamic programming (DP), solution of discrete DPP, application of DP in linear 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 & disadvantages, event type, Monte-Carlo simulation,application to inventory, queueing, capital budgeting, financial planning, maintenance, jobsequencing, networks.

Pedagogy: Same as for MM 609.

BOOKS RECOMMENDED:

1. KantiSwarup, 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 andApplications*, Springer, Science and Business Media, 2013.
4. S.D.Sharma: *Operation Research*,KedarnathRamnath and Co., Meerut, 2002.
5. Hamdy A. Taha: *Operations Research:An Introduction*, Pearson Parentice Hall, New Delhi,2007.

MM 706: HOMOLOGICAL ALGEBRA

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 homotopictranslations (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 amodule, augmentation translation and augmentation homomorphism, acyclic right and acyclic 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 ofresolutions of sequences, functors of complexes, associated translations, Functors of twocomplexes, 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 6.4of Northcott).

Torsion and Extension Functors: Connected sequences of functors, connected right and leftsequences of covariant and contravariantfunctors, homomorphism and isomorphism as a natural equivalence between connected sequences of functors, torsion functorstorn, basic properties oftorsion functors, extension functorsand basic properties of extension functors (R.R. Sections 6.5 to 7.4of 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 AlgebraMonographs and Surveys in Pure and Applied Mathematics*, 130 Chapman and Hall/CRC, 2003.

MM 707: FINITE ELEMENT METHODS

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, variationalformulation of boundary value problems, equivalence of Galerkin and Ritz methods.Applications to solving simple problems of ordinary differentialequations.

SECTION-B

Linear, quadratic and higher order elements in one dimensional and assembly, solution ofassembled 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.

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 FiniteElement Analysis*, John Wiley, 2002.
4. Thomas J.R. Hughes:*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.

MM 708: FLUID MECHANICS

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, sphericalobstacle 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, Twodimensional dipole, superposition, Joukowski's transformation, Milne Thomson circle theorem,
Blasius theorem, drag and lift.
Source and Vortex Filaments, Vortex Pair, Rows of Vortices, Kármán 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 astraight 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.

MM 709: ALGEBRAIC CODING THEORY

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 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, 1stSouth Asian Edition, 2004 (Sec. 1.5 of Chap. 1).
3. R. Hill:*Introduction to Error Correcting Codes*, Oxford University Press, Reprint: 1986, 2009.

MM 710: COMMUTATIVE ALGEBRA

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 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, localproperties.

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. 1-5).
2. David S. Dummit, M. Foote: *Abstract Algebra*, Wiley India, 2nd Edition, 2008.
3. B. Singh: *Basic Commutative Algebra*, Board Scientific Publishing, 2011.

MM 711: OPERATIONS RESEARCH

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), multi item deterministic inventory models: Models III(a), III(b) III(c), introduction to stochastic inventory models.

SECTION-B

Replacement & 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 MM609.

BOOKS RECOMMENDED:

1. KantiSwarup, P. K. Gupta, Man Mohan: *Operations Research*, Sultan Chand and Sons, New Delhi, 2010.
2. C. Mohan and 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*, KedarnathRamnath& Co., Meerut., 2002.
5. Hamdy A. Taha: *Operations Research: An Introduction*, Pearson Parentice Hall, New Delhi,2007.

MM 712: 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 partialdifferential equations.Classification and joint time frequency analysis of signals, definition, examplesandbasic properties of Gabor transforms, frames and frame operators, Zak transforms: definition andbasic 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.

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.

MM 713: Non Linear Programming

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 & examples of non-linear programming, its formulation,unconstrained problems, constrained problems with equality and inequality constraints, Fritz-Johnand 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 & 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, Sherali, D Hanif, C.M.Shetty:*Nonlinear Programming: Theory and Algorithm*, John Wiley, 2nd Edition, 1993.
2. C. Mohan,Kusum 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*, PrenticeHall, Englewood Cliffs,1976.

MM 714: COMPUTATIONAL TECHNIQUES

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-Birkhoffinterpolation 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, piecewisepolynomial 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. Carl de 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. Larry L. Schumaker:*Spline Functions: Basic Theory*, Cambridge Mathematical Library, 3rd Edition, 2007.

MM 715: MATHEMATICS OF FINANCE

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. MarekCapiski, Tomasz Zastawniak:*Mathematics for Finance: An Introduction to Financial Engineering*, Springer, 2003.

MM 716: MATHEMATICAL METHODS

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 teaches integral equations and variational methods.

SECTION –A

Linear integral equations of first and second kind, Abel's problem, relation between lineardifferential equation and Volterra's equation, non-linear and singular equations, solution bysuccessive substitutions, Volterra's equation, iterated and reciprocal functions, Volterra'ssolution 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, geodesies, the brachistochrone, minimum surface of revolution, brachistochrone from a given curve to a fixedpoint, 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. Robert Weinstock:*Calculus of Variations*, McGraw-Hill, London, 1974.
5. L.B. Chambers:*Integral Equations*, International Text Book Co, 1976.

MM 717: ANALYTIC NUMBER 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: 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 inMathematics, New York, 2000.