M.Sc. Mathematics
Semester–I

Abstract Algebra

Course Code: MAL-6111

L	T	P	C
4	0	0	4

At the end of the Abstract Algebra, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Explain** basic notions of Groups, subgroups, Lagrange theorem, quotient groups	Understand
2.	**Extend** structure of finitely generated abelian groups.	Understand
3.	**Illustrate** Rings, formal power series, prime ideals, isomorphism theorems, Integral domains.	Understand
4.	**Discuss** field of fractions; primes and irreducibles, irreducibility criteria; product of rings, Chinese remainder theorem.	Create
5.	**Tell** separable and inseparable extensions, fundamental theorem of Galois theory; solvability by radicals.	Remember

Unit I

Groups, subgroups, Lagrange theorem, quotient groups, isomorphism theorems; cyclic groups, dihedral groups, symmetric groups, alternating groups; simple groups, simplicity of alternating groups.

Unit II

Group action, Sylow theorems and applications; free abelian groups, structure of finitely generated abelian groups; Solvable and nilpotent groups, composition series, Jordan-Holder theorem.

Unit III

Rings, examples: polynomial rings, formal power series, matrix rings, group rings; prime ideals, maximal ideals, quotient rings, isomorphism theorems;Integral domains, PID, UFD, Euclidean domains, division rings, field of fractions; primes and irreducibles, irreducibility criteria; product of rings, Chinese remainder theorem.

Unit IV

Field extension, algebraic extension, algebraic closure, straight edge and compass constructions, splitting fields, separable and inseparable extensions, fundamental theorem of Galois theory; solvability by radicals.

Books Recommended/Suggested Reading:

1. *Herstein I. N.; Topics in Algebra, Wiley Eastern.*
2. *Bhattacharya P. B., Jain S. K. and Nagpal S. R.; Basic Abstract Algebra, Cambridge University Press.*
3. *Gallian J. A.; Contemporary Abstract Algebra, Thomson Press.*
4. *Sahai Vivek and Bist Vikas; Algebra, Narosa Publishing House.*
5. *Malik D. S., Mordeson J. N. and Sen M. K.; Fundamentals of Abstract Algebra, McGraw-Hill.*
6. *Khanna V. K. and Bhambri S. K.; A Course in Abstract Algebra, Vikas Publishing House*.

M.Sc. Mathematics
Semester–I

Classical Mechanics

Course Code: MAL-6112

L	T	P	C
4	0	0	4

At the end of the Classical Mechanics, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Solve** Lagrangian and Hamiltonian of the system.	Apply
2.	**Understand and solve** the problems using various canonical transformations**.**	Understand
3.	**Explain** two body central force problem.	Understand
4.	**Define** and **Make use of** tensors	Remember

Unit I

General idea of Newtonian physics; Mechanics of a particle, mechanics of a system of particles, constraints, generalized coordinates, D'Alembert's principle and Lagranges equations, applications of Lagrangian formulation, 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, Generalized momenta, cyclic co-ordinates.

Unit II

Equation of canonical transformation, examples of canonical transformation, Poisson and Lagrange brackets and their invariance under canonical transformation. Jacobi's Identity, Poisson's Theorem. Equations of motion infinitesimal canonical transformation in the poisson bracket formulation. Hamilton Jacobi Method, Generating functions.

Unit III

Two body central force problem: bound state, reduction of two-body problem to one body problem. Motion in a central force field, Thevirial theorem, The inverse square law of force, The motion in central force in the Kepler problem. Concept of small oscillations, eigen value equation, simple application (CO_2), Normal coordinates and modes.

Unit IV

Elementary idea of tensors: co-variant, contra variant and mixed tensor, addition, subtraction, multiplication and characterization of tensors, quotient law. Four dimensional representation of the Lorentz transformations, covariance of the laws of nature, four vectors; velocity momentum, force and their transformation, equation of motion of a point particle in four vector form, relativistic Lagrangian and Hamiltonian of a charged particle in an em field.

Books Recommended/Suggested Reading:

1. *Goldstein H.; Classical mechanics, 2nd edition, Narosa Publishing House.*
2. *Rana N.C. and Joag P. S.; Classical Mechanics, McGraw-Hill Education.*
3. *Gupta K. C.; Classical Mechanics, Wiley Publication.*
4. *Moller, M.C.; Theory of relativity, Oxford University.*

M.Sc. Mathematics
Semester–I

Partial Differential Equations

Course Code: MAL-6113

L	T	P	C
4	0	0	4

At the end of the Partial Differential Equations, student will be able to

COs No.	Course Outcomes(COs)	Cognitive Level
1	**Define** Linear and semi-linear equations	Remember
2	**Explain** wave equation in one space dimension, classical and weak solutions	Understand
3	**Recall** the rank of a given matrix and, from that, the dimension of the solution space of the corresponding system of homogeneous linear equations	Remember
4	**Extend** Laplace equation, fundamental solutions, maximum principles and mean value formulas	Understand
5	**Apply** Some special methods for finding solutions: Similarity solutions, Hopf-Cole transformation.	Apply

Unit I
Linear and semi-linear equations, Cauchy problem, Method of characteristics. Cauchy-Kowalewsky theorem, Holmgren's Uniqueness Theorem.

Unit II
Classification of second order equations, wave equation in one space dimension, classical and weak solutions, Duhamel's principle.

Unit III
Laplace equation, fundamental solutions, maximum principles and mean value formulas, Properties of harmonic functions, Green's function, Energy methods, Perron's method, Parabolic equations in one space dimension, fundamental solution, maximum principle, existence and uniqueness theorems.

Unit IV
Wave equation, Solutions by spherical means, Non-Homogeneous Problems, Duhamel's principle, Energy Methods. Nonlinear first order PDE's: Complete integrals, Envelopes and singular solutions. Some special methods for finding solutions: Similarity solutions, Hopf-Cole transformation.

Books Recommended/Suggested Reading:

1. *Evans L. C.; Partial Differential Equations, Graduate Studies in Mathematics.*
2. *Jurgen Jost; Partial Differential Equations, Graduate Text in Mathematics, Springer Verlag Heidelberg.*
3. *Robert C. Mcowen; Partial Differential Equations: Methods and Applications, Pearson Education Inc.*
4. *John Fritz, Partial Differential Equations, Sringer-Verlag.*
5. *Sneddon I. N.; Elements of Partial Differential Equations, McGraw-Hill.*
6. *Raisinghania M. D.; Ordinary and Partial Differential Equations, S. Chand & Sons*.

M.Sc. Mathematics
Semester–I

Real Analysis

Course Code: MAL-6114	**L**	**T**	**P**	**C**
	4	**0**	**0**	**4**

At the end of the Real Analysis, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Discuss** Elementary set theory, Countable and Uncountable sets.	Create
2.	**Extend** Metric spaces to Fixed Points, Baire's Category Theorem, Compactness, Connectedness.	Understand
3.	**Memorize** Equicontinuity, Arzelà-Ascoli Theorem, Dini's Theorem, Stone-Weierstrass Theorems	Remember
4.	**Explain** Linear transformations, Differentiation, Inverse function theorem.	Understand

Unit-I
Elementary set theory, Countable and Uncountable sets, Real number system and its order completeness.

Unit-II
Metric spaces, Continuous and uniformly continuous functions, Homeomorphism and isometry, Completeness, Fixed Points, Baire's Category Theorem, Totally bounded metrics, Compactness, Connectedness.

Unit-III
Sequences and series of functions, Pointwise and uniform convergence of sequences of functions, Equicontinuity, Arzelà-Ascoli Theorem, Dini's Theorem, Stone-Weierstrass Theorems (Lattice and algebra versions).

Unit-IV
Functions of several variables, Linear transformations, Differentiation, Inverse function theorem, Implicit Function theorem, Derivatives of higher order.

Books Recommended/Suggested Reading:

1. *Walter Rudin; Principles of Mathematical Analysis, McGraw-Hill International.*
2. *Narayan Shanti and Raisinghania M. D.; Elements of Real Analysis, S. Chand Publications.*
3. *Malik S. C. and Arora Savita; Mathematical Analysis, New Age International Publication.*
4. *Mapa S. K.; Introduction to Real Analysis, Levant Books.*
5. *Bartle R. G. and Sherbert D. R.; Introduction to Real Analysis, Wiley Edition.*

M.Sc. Mathematics
Semester–I

Technique of Applied Mathematics

Course Code: MAL-6115	**L**	**T**	**P**	**C**
	4	**0**	**0**	**4**

At the end of the Technique of Applied Mathematics, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Define** trajectories, Pfaffian differential equations, 1st order partial differential equations.	Remember
2.	**Explain** jacobies method, canonical forms, separation of variables method, Monge's method.	Understand
3.	**Illustrate** the concept of Linear equations with regular singular points, Euler equations and series solutions	Understand
4.	**Utilize** Volterre's integral equations and Fredholm's integral equations, Fourier and Laplace transforms in many applications of D.E	Apply
5.	**Discuss** One dimensional Green's function, generalized function, green's function in higher dimensions	Create

Unit-I
Equation of the form dx/P=dy/Q=dz/R, Orthogonal trajectories, Pfaffian differential equations, 1st order partial differential equations, Charpits method and some special methods, jacobies method, second order partial differential equations with constant and variable coefficient, canonical forms, separation of variables method, Monge's method.

Unit-II
Linear equation with variable coefficients, the wronskian and linear independence, reduction of the order of homogeneous and non-homogeneous equations, homogeneous equation with analytic coefficients; Linear equations with regular singular points, Euler equations and series solutions, Existence and uniqueness of solution of 1st order equations, exact equations, Picards method of successive approximations, existence and uniqueness of solution to system.

Unit-III
Basic concepts and solutions of Integral equations, Volterre's integral equations and Fredholm's integral equations, Fourier and Laplace transforms with applications to ordinary, partial differential equations and integral equations.

Unit-IV
Orthogonal Co-ordinate systems, separations of variables, A Strum-Liouville problems, series solutions of boundary value problems; green functions, Non-homogeneous boundary value problems, One dimensional Green's function, generalized function, green's function in higher dimensions, problems in unbounded regions.

Books Recommended/Suggested Reading:

1. *Sneddon I. N.; Elements of Partial Differential Equations, Tata McGraw-Hill.*
2. *Raisinghania M. D.; Ordinary and Partial Differential Equations, S. Chand & Sons.*
3. *Raisinghania M. D.; Advanced Differential Equations, S. Chand & Sons.*
4. *Ross S. L.; Differential Equations, Wiley Edition.*
5. *Raisinghania M. D.; Integral Equations and Boundary Value Problems, S. Chand & Sons.*
6. *Wazwaz Abdul-Majid; A First Course in Integral Equations, World Scientific.*

M.Sc. Mathematics
Semester–II

Complex Analysis

Course Code: MAL-6211

L	T	P	C
4	0	0	4

At the end of the Complex Analysis, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Define** Field of complex numbers, complex plane, polar representation, stereographic projection.	Remember
2.	**Illustrate** basic knowledge about pair of Contour integrals, power series representation of an analytic function	Understand
3.	**Explain** Cauchy's theorem, Cauchy integral formula, Open mapping theorem.	Understand
4.	**Identify** Isolated singularities.	Apply

Unit I

Field of complex numbers, complex plane, polar representation, stereographic projection. Analytic functions, Cauchy-Riemann equation, harmonic conjugates, power series, MÖbius transforms.

Unit II

Contour integrals, power series representation of an analytic function, zeros of an analytic function, Liouville's theorem and applications.

Unit III

Index of a closed curve, Cauchy's theorem, Cauchy integral formula, Open mapping theorem, Goursat's theorem.

Unit IV

Isolated singularities, Laurent Series, Residue theorem and application to real integrals. Meromorphic functions, Argument principle and Rouche's theorem. Maximum modulus principle and Schwarz's Lemma.

Books Recommended/Suggested Reading:

1. *Ahlfors L. V.; Complex Analysis, McGraw-Hill Education.*
2. *Goyal and Gupta; Functions of a Complex Variable, Pragati Prakashan.*
3. *Sharma J. N.; Functions of a Complex Variable, Krishna Prakashan.*
4. *Brown J. W. and Churchill R. V.; Complex Variables and Applications, McGraw-Hill Education.*
5. *Kasana H. S.; Complex Variables: Theory and Applications, Prentice Hall India Learning.*

M.Sc. Mathematics
Semester–II

Topology

Course Code: MAL-6212

L	T	P	C
4	0	0	4

At the end of the Topology, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Explain** Topological spaces, Basis and Sub-basis for a Topology, Subspace Topology.	Understand
2.	**Extend** Connectedness and Compactness to Connected subspaces of the real line and Sequential compactness.	Understand
3.	**Tell** the Tychonoff theorem, characterizations of compact metric spaces. Countability Axioms.	Remember
4.	**Illustrate** Hausdorff, Regular and Normal spaces	Understand

Unit I

Topological spaces: Definitions and Examples, Basis and Sub-basis for a Topology, limit points, closure, interior; Continuous functions, Homeomorphisms; Subspace Topology, Metric Topology, Product & Box Topology, Order Topology; Quotient spaces.

Unit II

Connectedness and Compactness: Connectedness, Path connectedness; Connected subspaces of the real line; Components and local connectedness; Compact spaces, Limit point compactness, Sequential compactness.

Unit III

Local compactness, One point compactification; Tychonoff theorem, characterizations of compact metric spaces. Countability Axioms: First countable spaces, Second countable spaces, Separable spaces, Lindeloff spaces.

Unit IV

Separation Axioms: Hausdorff, Regular and Normal spaces; Urysohn's lemma; Uryohn's Metrization theorem; Tietze extension theorem. Completely metrizable spaces, Baire's category theorem and Function Spaces.

Books Recommended/Suggested Reading:

1. *Munkres J. R.; Topology, Pearson Education India.*
2. *Simmons G.; Introduction to Topology and Modern Analysis, McGraw-Hill Education.*
3. *Sharma J. N. and Chauhan J. P.; Topology (General and Algebraic), Krishna Publication.*
4. *Krantz S. G.; Essentials of Topology with Applications, CRC Press.*
5. *Joshi K. D.; Introduction to General Topology, New Age International Publishers.*

M.Sc. Mathematics
Semester–II

Mathematical Programming

Course Code: MAL-6213

L	T	P	C
4	0	0	4

At the end of the Mathematical Programming, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Explain** basic concepts of Linear programs	Understand
2.	**Extend** the concept of Linear programs to geometry of linear programs, basic feasible solution, simplex method, variants of simplex method.	Understand
3.	**Illustrate** idea of Duality and its principles.	Understand
4.	**Outline** the Transportation problems, assignment problems, network maximum flow problems.	Understand
5.	**Discuss** Non-linear programming, KKT optimality conditions, Wolfe method, applications of quadratic programs	Create

Unit I

Linear programs formulation through examples from engineering / business decision making problems, preliminary theory and geometry of linear programs, basic feasible solution, simplex method, variants of simplex method, like two phase method and revised simplex method.

Unit II

Duality and its principles, interpretation of dual variables, dual simplex method, primal-dual method; linear integer programs, their applications in real decision making problems, cutting plane and branch and bound methods,

Unit III

Transportation problems, assignment problems, network maximum flow problems; complexity of simplex method, ellipsoid method, Karmarkar's interior point method.

Unit IV

Non-linear programming, Lagrange multipliers, Farkas lemma, constraint qualification, KKT optimality conditions, sufficiency of KKT under convexity; quadratic programs, Wolfe method, applications of quadratic programs in some domains like portfolio optimization and support vector machines, etc.

Books Recommended/Suggested Reading:

1. *Sinha S. M.; Mathematical Programming-Theory and Methods, Elsevier.*
2. *Minoux M.; Mathematical Programming-Theory and Algorithms, Wiley-Blackwell.*
3. *Bradley S. P.; Applied Mathematical Programming, Addison-Wesley.*
4. *Hillier F. S. and Lieberman G. J.; Introduction to Operations Research, McGraw-Hill.*
5. *Walker R. C.; Introduction to Linear Programming, Prentice Hall.*

M.Sc. Mathematics
Semester–II

Numerical Analysis

Course Code: MAL-6214	**L**	**T**	**P**	**C**
	4	**0**	**0**	**4**

At the end of the Numerical Analysis, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Define** Interpolation: Lagrange Interpolation Newton's divided difference interpolation. Finite differences.	Remember
2.	**Explain** Numerical differentiation and Numerical Integration	Understand
3.	**Illustrate** Solution of Nonlinear equations: Fixed point iteration, bisection, Secant, Regula Falsi, Newton-Raphson methods.	Understand
4.	**Extend** Solution of linear systems: Direct methods, Gauss elimination, LU and Cholesky factorizations.	Understand
5.	**Solve** the System of nonlinear equation, Eigen-Value problems.	Apply

Unit I

Numerical Algorithms and errors, Floating point systems, Round off error accumulations. Interpolation: Lagrange Interpolation Newton's divided difference interpolation. Finite differences. Hermite Interpolation. Cubic splines.

Unit II

Numerical differentiation. Numerical Integration: Newton cotes formulas, Gaussian Quadrature composite quadrature formulas Approximation: Least squares approximation, minimum maximum error techniques. Legendre and Chebyshev polynomials.

Unit III

Solution of Nonlinear equations: Fixed point iteration, bisection, Secant, Regula Falsi, Newton-Raphson methods. Solution of linear systems: Direct methods, Gauss elimination, LU and Cholesky factorizations. Iterative methods – Jacobi, Gauss- Seidel and SOR methods.

Unit IV

System of nonlinear equation, Eigen-Value problems: Power and Inverse power method. Numerical Solution of ODE. Taylor series, Euler and Runge-Kutta methods.

Books Recommended/Suggested Reading:

1. *Ranganatham S., Prasad M. V. S. S. N. and Ramesh Babu V.; Numerical Analysis, S. Chand.*
2. *Sastry S. S.; Introductory Methods of Numerical Analysis, PHI Learning Pvt. Ltd.*
3. *Hildebrand F. B.; Introduction to Numerical Analysis, McGraw-Hill Education.*
4. *Gupta R. S.; Elements of Numerical Analysis, Algebra, Cambridge University Press.*
5. *Conte S. and Deboor C.; Elementary Numerical Analysis, McGraw-Hill Education.*

M.Sc. Mathematics
Semester–III

Linear Algebra

Course Code: MAL-7111

L	T	P	C
4	0	0	4

At the end of the Linear Algebra, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1	**Recall** existence-uniqueness of solutions of a system of linear equations.	Remember
2	**Find** Eigenvalues, eigenvectors	Remember
3	**Define** Inner product spaces over R (real numbers) and C (complex numbers)	Remember
4	**Explain** Adjoint of a linear operator, unitary and normal operators.	Understand

Unit I

Revision of existence-uniqueness of solutions of a system of linear equations, elementary row operations, row-reduced echelon matrices. Vector spaces, span of a subset, bases and dimension, quotient spaces, direct sums.

Unit II

Linear transformations, rank-nullity, matrix representation of a linear transformation, algebra of linear transformations, dual space, transpose of a linear transformation. Eigenvalues, eigenvectors, annihilating polynomials, Cayley-Hamilton theorem, invariant subspaces, triangulable and diagonalizable linear operators.

Unit III

Simultaneous triangulation and diagonalization, Primary decomposition theorem, Jordan decomposition. Inner product spaces over R (real numbers) and C (complex numbers), Gram-Schmidt orthogonalization process, orthogonal projection, best approximation.

Unit IV

Adjoint of a linear operator, unitary and normal operators, spectral theory of normal operators. Bilinear forms, symmetric and skew-symmetric bilinear forms.

Books Recommended/Suggested Reading:

1. *Hoffman K. M. and Kunze R.; Linear Algebra, Pearson.*
2. *Lipschutz S. and Lipson M. L.; Schaum's Outline Series: Linear Algebra, McGraw-Hill.*
3. *Strang G.; Introduction to Linear Algebra, Wellesley Cambridge Press.*
4. *Friedberg S. H., Insel A. J. and Spence L. E.;Linear Algebra, Pearson.*
5. *Kumaresan S.; Linear Algebra-A Geometric Approach, PHI Learning Pvt. Ltd..*

M.Sc. Mathematics
Semester–III

Mathematical Statistics

Course Code: MAL-7112

L	T	P	C
4	0	0	4

At the end of the Mathematical Statistics, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1	**Recall** Probability definition, conditional probability, Bayes theorem.	Remember
2	**Define** Specific discrete and continuous distributions.	Remember
3	**Discuss** joint, marginal and conditional distributions.	Create
4	**Explain** Sampling distributions - Chi-sq, Student's t, F.	Understand
5	**Illustrate** theory of estimation, maximum likelihood test, testing of hypothesis.	Understand

Unit I

Probability definition, conditional probability, Bayes theorem, random variables, expectation and variance.

Unit II

Specific discrete and continuous distributions, e.g. uniform, Binomial, Poisson, geometric, Pascal, hypergeometric, exponential, normal, gamma, beta, moment generating function, Poisson process.

Unit III

Chebyshev's inequality, bivariate and multivariate distributions, joint, marginal and conditional distributions, order statistics, law of large numbers, central limit theorem.

Unit IV

Sampling distributions - Chi-sq, Student's t, F, theory of estimation, maximum likelihood test, testing of hypothesis, nonparametric analysis, test of goodness of fit.

Books Recommended/Suggested Reading:

1. *Gupta S. C. and Kapoor V. K.; Fundamentals of Mathematical Statistics, S. Chand and Sons.*
2. *Hogg R. V., Mckean J. and Craig A. T.; Introduction to Mathematical Statistics, Pearson.*
3. *Miller I. and Miller M.; John E. Freund's Mathematical Statistics with Applications, Pearson.*
4. *Rohatgi V. K. and Saleh A. K. Md. E.; An Introduction to Probability and Statistics, Wiley.*
5. *Kapoor J. N. and Saxena H. C.; Fundamentals of Mathematical Statistics, S. Chand and Sons.*

M.Sc. Mathematics
Semester–III

Functional Analysis

Course Code: MAL-7113	**L**	**T**	**P**	**C**
	4	**0**	**0**	**4**

At the end of the Functional Analysis, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Recall** Normed linear spaces, Banach spaces and their examples.	Remember
2.	**Describe** Hahn Banach theorems, Uniform boundedness principle, open mapping theorem.	Evaluate
3.	**Recognize** Characterization of the dual of certain Banach spaces.	Analyze
4.	**Compute** Geometry of Banach spaces and Geometry of Hilbert spaces	Evaluate
5.	**Express** Basic operator theory - Adjoint of an operator, self-adjoint operators, normal and unitary operators.	Evaluate

Unit I

Normed linear spaces, Banach spaces and their examples, quotient spaces, bounded linear operators, finite dimensional Banach spaces, Lp Spaces, Lp spaces as examples for Banach spaces.

Unit II

Hahn Banach theorems, Uniform boundedness principle, open mapping theorem, closed graph theorem, transpose of an operator Characterization of the dual of certain Banach spaces.

Unit III

Geometry of Banach spaces - Weak and weak* convergence, Geometry of Hilbert spaces - Inner product spaces and its properties, Hilbert spaces and examples, best approximation in Hilbert spaces, orthogonal complements, orthonormal basis, dual of a Hilbert space.

Unit IV

Basic operator theory - Adjoint of an operator, self-adjoint operators, normal and unitary operators, projections Compact operators, examples and properties, spectral theorem for the compact self-adjoint operator.

Books Recommended/Suggested Reading:

1. *Rudin W.; Functional Analysis, McGraw-Hill Education.*
2. *Kreyszig E.; Introductory Functional Analysis with Applications, Wiley.*
3. *Limaye B. V.; Functional Analysis, New Age International Publishers.*
4. *Somasundaram D.; A First Course in Functional Analysis, Narosa Publishing House.*
5. *Choudhary B. and Nanda S.; Functional Analysis with Applications, New Age International Publishers.*

M.Sc. Mathematics
Semester–IV

Fluid Mechanics

Course Code: MAL-7211	**L**	**T**	**P**	**C**
	4	**0**	**0**	**4**

At the end of the Fluid Mechanics, student will be able to

COs No.	**Course Outcomes (COs)**	**Cognitive Level**
1	**Recall** pipe and channel flow laminar flow.	Remember
2	**Define** Flow past an object; boundary layer and separation.	Remember
3	**Explain** equations of motion; dynamical scaling, sample viscous flows.	Understand
4	**Illustrate** inviscid flows and flow in rotating fluids	Understand

Unit I

Description of principles of flow phenomena: pipe and channel flow laminar flow, transition, turbulence.

Unit II

Flow past an object; boundary layer, wake, separation, vortices, drag, convection in horizontal layers.

Unit III

Transition from periodic to chaotic behaviour; equations of motion; dynamical scaling, sample viscous flows.

Unit IV

Inviscid flows. Flow in rotating fluids; hydrodynamic stability.

Books Recommended/Suggested Reading:

1. *White F. M.; Fluid Mechanics, McGraw-Hill Education.*
2. *Cengel Y. and Cimbala J.; Fluid Mechanics, McGraw-Hill Education.*
3. *Morrison F. A.; An Introduction to Fluid Mechanics, Cambridge University Press.*
4. *Rathakrishnan E.; Fluid Mechanics-An Introduction, PHI Learning Pvt. Ltd.*
5. *Raisinghania M. D.; Fluid Dynamics, S. Chand and Sons.*

M.Sc. Mathematics
Program Electives

Programming in Scilab

Course Code: MAL- 6221	**L**	**T**	**P**	**C**
	3	**0**	**1**	**4**

At the end of the Programming in Scilab, student will be able to

COs No.	**Course Outcomes(COs)**	**Cognitive Level**
1.	**Explain** the functions of console, The editor, Batch Processing; Creating Real variables.	Understand
2.	**Understand** the main features of the MATLAB/SCILAB program development environment to enable their usage in the higher learning.	Understand
3.	**Interpret** and visualize simple mathematical functions and operations thereon using plots/display.	Evaluate
4.	**Analyze** the program for correctness and determine/estimate/predict the output and verify it under simulation environment using MATLAB/SCILAB tools.	Analyze

Unit I

Overview of Scilab; How to get started with Scilab, Getting help from Scilab demonstrations and macros, The console, The editor, Batch Processing; Creating Real variables, Elementary mathematical functions, Booleans, Complex numbers, Integrals, Floating Points, Strings, Dynamic variables.

Unit II

Matrices; Create matrices of real variables, Accessing elements of matrices, Matrices are dynamic, Elementwise operations; Conjugate transpose and non-conjugate transpose, Multiplication of two vectors, Comparing two real matrices, Issues with floating point integers, More on elementary functions, Higher level linear algebra features.

Unit III

Looping and branching; The if, select, for and while statements; The break and continue statements; Functions, Functions libraries, Managing output arguments; Levels in the call stack, The return statement, Debugging functions with pause.

Unit IV

Plotting, 2D plot, Counter plots; Titles, axes and legends; Export; Solving ordinary differential equations using Scilab.

Books Recommended/Suggested Reading:

1. *Michael Baudin from Scilab Consortium-2010; Introduction to Scilab Chapters 1 to 8 (Book freely downloadable in internet).*
2. *An open source document; Plotting using Scilab, www.openeering.com.*
3. *Campbell S. L., Chanceller J. P. and Nikoukhah R.; Modelling and Simulation in Scilab.*
4. *Rietsch E.; An introduction to Scilab from a Matlab user's point of view.*

M.Sc. Mathematics
Program Electives

Research Methodology

Course Code: MAL-7121	**L**	**T**	**P**	**C**
	3	**0**	**0**	**3**

At the end of the Research Methodology, student will be able to

COs No.	Course Outcomes(COs)	Cognitive Level
1.	**Explain** knowledge of research processes (reading, evaluating, and developing)	Understand
2.	**Understand** various sources of information for literature review and data collection	Understand
3.	**Identify**, explain, compare, and prepare the key elements of a research proposal/report.	Apply
4.	**Extend** an understanding of the ethical dimensions of conducting applied research.	Understand

Unit I

Meaning, Objectives and Characteristics of research, Research methods Vs Methodology, Types of research, Descriptive Vs. Analytical, Applied Vs. Fundamental, Quantitative Vs. Qualitative, Conceptual Vs. Empirical, Research process, Criteria of good research, Developing a research plan, Defining the research problem, Selecting the problem, Necessity of defining the problem, Techniques involved in defining the problem, Importance of literature review in defining a problem, Survey of literature, Primary and secondary sources, Reviews, treatise, monographs patents, web as a source, searching the web, Identifying gap areas from literature review, Development of working hypothesis.

Unit II

Research design and methods, Research design, Basic Principles, Need of research design, Features of good design, Important concepts relating to research design, Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models, Developing a research plan, Exploration, Description, Diagnosis, and Experimentation, Determining experimental and sample designs. Sampling design, Steps in sampling design, Characteristics of a good sample design, Types of sample designs, Measurement and scaling techniques, Methods of data collection, Collection of primary data, Data collection instruments.

Unit III

Testing of hypotheses, Basic concepts, Procedure for hypotheses testing flow diagram for hypotheses testing, Data analysis with Statistical Packages, Correlation and Regression, Important parametric test, Chi-square test, Analysis of variance and Covariance.

Unit IV

Interpretation and report writing, Techniques of interpretation, Structure and components of scientific reports, Different steps in the preparation, Layout, structure and language of the report, Illustrations and tables, Types of report, Technical reports and thesis.

Books Recommended/Suggested Reading:

1. *Kothari C. R.; Research Methodology: Methods and Techniques, New Age International Publishers.*
2. *Sinha S. C. and Dhiman A. K.; Research Methodology, EssEss Publications.*
3. *Anderson T. W.; An Introduction to Multivariate Statistical Analysis, Wiley*.
4. *Garg B. L., Karadia R., Agarwal F. and Agarwal U. K.; An Introduction to Research Methodology, RBSA Publishers*.

M.Sc. Mathematics
Program Electives

Advanced Number Theory

Course Code: MAL-7122

L	T	P	C
3	0	0	3

At the end of the Advanced Number Theory, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Explain** basic notions of Divisibility, prime numbers, Bertrand's theorem, Congruences.	Understand
2.	**Extend** the study of linear and system of linear congruences.	Understand
3.	**Illustrate** approximations and applications to linear and Pell's equations.	Understand
4.	**Discuss** prime Number theorem, Diophantine equations, special cases of the Fermat equation.	Create

Unit I

Divisibility, prime numbers, Bertrand's theorem, Congruences, complete & reduced residue systems, theorems of Fermat, Euler, Wilson & Wolstenholme.

Unit II

Solutions of general congruences, study of linear and system of linear congruences, Chinese Remainder theorem, study of quadratic congruences, Quadratic, Cubic& Biquadratic Reciprocity laws, binary and ternary quadratic forms.

Unit III

Continued fractions, Diophantine approximations and applications to linear and Pell's equations, Arithmetical functions, properties, rate of growth, Distribution of primes, Dirichlet's theorem on primes in arithmetic progression.

Unit IV

Prime Number theorem, Diophantine equations, special cases of the Fermat equation, introduction to classic and modern techniques.

Books Recommended/Suggested Reading:

1. *Andrews G. E.; Number Theory, Dover Publications Inc.*
2. *Cohn H.; Advanced Number Theory, Dover Publications Inc.*
3. *Silverman J. H.; A Friendly Introduction to Number Theory, Pearson.*
4. *Ash R. B.; A Course in Algebraic Number Theory, Dover Publications Inc.*
5. *Tenenbaum G.; Introduction to Analytic and Probabilistic Number Theory, Cambridge University Press.*

M.Sc. Mathematics
Program Electives

Differential Geometry

Course Code: MAL-7221

L	T	P	C
3	0	0	3

At the end of the Differential Geometry, student will be able to

COs No.	Course Outcomes (COs)	Cognitive Level
1.	**Recall** Curves in plane and space, arc-length, reparametrization, curvature of a plane curve.	Remember
2.	**Describe** Surfaces, smooth surfaces and examples, surfaces of revolution, tangent space, derivatives.	Evaluate
3.	**Recognize** the first fundamental form and the second fundamental form.	Analyze
4.	**Express** parallel transport, geodesics and their examples	Evaluate

Unit I

Curves in plane and space, arc-length, reparametrization, curvature of a plane cure, curvature and torsion of a space curve Simple closed curves, isoperimetric inequality, Four-vertex theorem.

Unit II

Surfaces, smooth surfaces and examples, level surfaces, quadric surfaces, surfaces of revolution, ruled surfaces smooth maps, tangent space, derivatives, orientability of surfaces The first fundamental form, lengths of curves on surfaces, isometries, conformal mappings, equiareal maps.

Unit III

The second fundamental form, Gauss and Weingarten maps, normal and geodesic curvatures, Gaussian and mean curvatures, principal curvatures Surfaces of constant Gaussian curvature, surfaces of constant mean curvature, flat surfaces.

Unit IV

Parallel transport, geodesics and their examples, properties, geodesic equations, geodesics as shortest paths, Gauss and Codazzi-Minardi equations, Theorema Egregium Gauss-Bonnet Theorem. Introduction to hyperbolic and spherical geometry.

Books Recommended/Suggested Reading:

1. *Khan Q.; Differential Geometry of Manifolds, PHI Learning Pvt. Ltd.*
2. *Mittal and Agarwal; Differential Geometry, Krishna Prakashan.*
3. *Kreyszig E.; Differential Geometry, Dover Publications Inc.*
4. *Somasundaram D.; Differential Geometry: A First Course, Alpha Science.*
5. *Dube K. K.; Differential Geometry and Tensors, I. K. International Publishing House Pvt. Ltd.*

M.Sc. Mathematics
Program Electives

Graph Theory

Course Code: MAL-7222

L	T	P	C
3	0	0	3

At the end of the Graph Theory, student will be able to

COs No.	Course Outcomes(COs)	Cognitive Level
1.	**Define** basic concepts of graph and trees	Remember
2.	**Explain** Paths and Distance in Graphs	Understand
3.	**Apply** the method to find center and median of a graph	Apply
4	**Recall** the Factorizations: maximum matching in bipartite graphs, maximum matching in general graphs	Remember
5.	**Extend** Networks to the Max-flow min-cut theorem and Menger's theorem	Understand

Unit I

Introduction to Graphs: Definition and basic concepts; Trees: characterizations, counting of minimum spanning tree.

Unit II

Paths and Distance in Graphs: Basic Definitions, center and median of a graph, activity digraph and critical path; Eulerian Graphs: Definition and Characterization; Hamiltonian Graphs: Necessary and sufficient conditions, Planar Graphs: properties, dual, genus of a graph.

Unit III

Graph Coloring: vertex coloring, chromatic polynomials, edge coloring, planar graph coloring; Matching and Factorizations: maximum matching in bipartite graphs, maximum matching in general graphs, Hall's marriage theorem, factorization.

Unit IV

Networks: The Max-flow min-cut theorem, connectivity and edge connectivity, Menger's theorem; Graph and Matrices.

Books Recommended/Suggested Reading:

1. *West D. B.; Introduction to Graph Theory, Pearson.*
2. *Deo Narsingh; Graph Theory with Applications to Engineering and Computer Science, PHI Learning Pvt. Ltd.*
3. *Harary F.; Graph Theory, Narosa Publishing House.*
4. *Trudeau R. J.; Introduction to Graph Theory, Zaccheus Entertainment.*
5. *Choudum S. A.; A First Course in Graph Theory, Laxmi Publications.*

M.Sc. Mathematics
Program Electives

Tensor Analysis

Course Code: MAL-7223	**L**	**T**	**P**	**C**
	3	**0**	**0**	**3**

At the end of the Tensor Analysis, student will be able to

COs No.	Course Outcomes(COs)	Cognitive Level
1.	**Define** the concept of tensor variables and difference from scalar or vector variables.	Remember
2.	**Derive** differentiable manifolds of dimension n, tangent spaces, transformation of coordinates.	Understand
3.	**Discuss** Riemannian metric, Lie derivative and commutation formulae for Lie differential operator	Create
4.	**Illustrate** motion, affine motion, projective motion in a Riemannian space and graphs.	Understand

Unit I

n-dimensional real vector space, contravariant vectors, dual vector space, covariant vectors, tensor product, second order tensors, tensors of type (r, s), symmetry and skew symmetry of tensors, fundamental algebraic operations, inner product, quotient law of tensors.

Unit II

Differentiable manifolds of dimension n, tangent spaces, transformation of coordinates, transformation laws for contravariant (tangent), covariant (cotangent) vectors and tensors of higher order, connection, covariant differentiation and curvature tensor, parallelism.

Unit III

Riemannian metric, Christoffel symbols, curvature tensor with respect to Christoffel symbols, differential operators, geodesics, Riemann curvature tensor, Lie derivative, Lie derivatives of scalars, vectors, tensors and linear connections, commutation formulae for Lie differential operator and covariant differential operator.

Unit IV

Motion, affine motion, projective motion in a Riemannian space, curvature collineation, conformal and homothetic transformations. Introduction to Graphs: Definition and basic concepts; Trees: characterizations, counting of minimum spanning tree.

Books Recommended/Suggested Reading:

1. *Mishra R. S.; A Course in Tensors with Applications to Riemannian Geometry, Pothishala Pvt. Ltd. Allahabad.*
2. *Yano K.; The Theory of Lie Derivatives and its Applications, North-Holland Publishing Company, Amsterdam.*
3. *Weatherburn C. E.; An Introduction to Riemannian Geometry and the Tensor Calculus, Cambridge University Press.*
4. *Matthew S. S.; Principles and Applications of Tensor Analysis, W. Sons Indianapolis.*

M.Sc. Mathematics
Program Electives

Introduction to Game Theory

Course Code: MAL-7224	**L**	**T**	**P**	**C**
	3	**0**	**0**	**3**

At the end of the Introduction to Game Theory, student will be able to

COs No.	Course Outcomes(COs)	Cognitive Level
1.	**Define** the concept of Game Trees, Choice Functions and Strategies, Choice Subtrees,	Remember
2.	**Study** the matrix Games and Linear Programming, Simplex Algorithm	Understand
3.	**Discuss** imputations and their Dominance, The Core of a game, Strategic Equivalence	Create
4.	**Illustrate** N-Person Non-Zero Sum Games with continuum of strategies.	Understand

Unit I

Game Trees, Choice Functions and Strategies, Choice Subtrees, Equilibrium N-tuples Strategies, Normal Forms, Non-cooperative games, Nash Equilibrium and its computation, The von Neumann Minimax Theorem.

Unit II

Mixed strategies, Best Response Strategies, Matrix Games and Linear Programming, Simplex Algorithm, Avoiding cycles and Achieving Feasibility, Dual-Simplex Algorithm, Duality Theorem, 2x2 Bimatrix Games.

Unit III

Nonlinear Programming Methods for Non-zero Sum Two-Person Games, Coalitions and Characteristic Functions, Imputations and their Dominance, The Core of a game, StrategicEquivalence, Stable Sets of Imputations, Shapley Values.

Unit IV

N-Person Non-Zero Sum Games with continuum of strategies – Duels, Auctions, Nash Model with Security Point, Threats, Evolution, Stable Strategies, Population Games, Bayesian Games.

Books Recommended/Suggested Reading:

1. *Durlauf S. N. and Blume L. E.; Game Theory, Palgrave Macmillan.*
2. *Barron E. N.; Game Theory: An Introduction, Wiley.*
3. *Osborne M. J. and Rubinstein A.; A Course in Game Theory, PHI Learning Pvt. Ltd.*
4. *Binmore K.; Game Theory-A Very Short Introduction, Oxford University Press.*
5. *Tadelis S.; Game Theory-An Introduction, Princeton University Press.*