DAV UNIVERSITY JALANDHAR

Course Scheme & Syllabus
For
M.Sc. (Hons.) Mathematics
(Program ID-37)
(As per Choice Based Credit System)

1st to 4th SEMESTER
Examinations 2015–2016 Session Onwards
Syllabi Applicable For Admissions in 2015

M.Sc. (HONS) MATHEMATICS

Semester 1

S.No	Paper Code	Course Type	Course Title	L	T	P	Cr
1	MTH 531	Core	Real Analysis	4	0	0	4
2	MTH 532	Core	Algebra-I	4	0	0	4
3	MTH 533	Core	Linear Algebra	4	0	0	4
4	MTH 534	Core	Differential Equations	4	0	0	4
5	MTH 535	Core	Classical Mechanics and Calculus of Variation	4	0	0	4
6	Interdisciplinary Course-I						4
Total							24

L: Lectures T: Tutorial P: Practical Cr: Credits

M.Sc. (HONS)MATHEMATICS

Semester 2

S.No	Paper Code	Course Type	Course Title	L	T	P	Cr
1	MTH 536	Core	Complex Analysis	4	0	0	4
2	MTH 537	Core	Theory of Measure and Integration	4	0	0	4
3	MTH 538	Core	Algebra-II	4	0	0	4
4	MTH 539	Core	Differential Geometry	4	0	0	4
5	MTH 540	Core	Probability and Statistics	4	0	0	4
6	MTH 541	Core	Numerical Analysis	4	0	0	4
7	MTH 542	Core	Computational Lab-I	0	0	4	2
Total							26

L: Lectures T: Tutorial P: Practical Cr: Credits

M.Sc. (HONS) MATHEMATICS

Semester 3

S.No.	Paper Code	Course Type	Course Title	L	T	P	Cr
1	MTH 631	Core	Topology	4	0	0	4
2	MTH 632	Core	Mathematical Methods	4	0	0	4
3	MTH 633	Core	Operational Research	4	0	0	4
4	MTH 634	Core	Computational Lab-II	0	0	4	2
5	Interdisciplinary Course-II						4
6	Department Elective-I						4
	Total						22
Departmental Elective-I							
7	MTH 636	Elective	Fluid Mechanics-I	4	0	0	4
8	MTH 637	Elective	Discrete Mathematics	4	0	0	4
9	MTH 638	Elective	Finite Element Analysis	4	0	0	4
10	MTH 639	Elective	Fuzzy Sets and Fuzzy Logic	4	0	0	4
11	MTH 640	Elective	Advance Complex Analysis	4	0	0	4
12	MTH 641	Elective	Advance theory of Partial Differential Equations and Sobolev spaces	4	0	0	4

L: Lectures T: Tutorial P: Practical Cr: Credits

M.Sc. (HONS) MATHEMATICS

Semester 4

S.No.	Paper Code	Course Type	Course Title	L	T	P	Cr
1	MTH 642	Core	Functional Analysis	4	0	0	4
2	MTH 643	Core	Number Theory	4	0	0	4
3	MTH 644	Departmental Elective	Project**				8
4	Departmental Elective						4
5	Departmental Elective						4
	Total						24
Departmental Elective (Choose any Two courses)							
6	MTH 645	Elective	Differential Geometry of Manifolds	4	0	0	4
7	MTH 646	Elective	Advanced Numerical Analysis	4	0	0	4
8	MTH 647	Elective	Wavelet Analysis	4	0	0	4
9	MTH 648	Elective	Fluid Mechanics-II	4	0	0	4
10	MTH 649	Elective	Special Functions	4	0	0	4
11	MTH 650	Elective	Algebraic Topology	4	0	0	4
12	MTH 651	Elective	Commutative Algebra	4	0	0	4
13	MTH 652	Elective	Continuum Mechanics	4	0	0	4
14	MTH 653	Elective	Advanced Operational Research	4	0	0	4

L: Lectures T: Tutorial P: Practical Cr: Credits

**** Those students who do not opt for project have to pass two department elective subjects from the list of departmental elective provided below third and fourth semester.**

Course Title: Real Analysis
Paper Code: MTH 531

L	T	P	Credits
4	0	0	4

Objective:

The aim of this course is to make the students learn fundamental concepts of metric spaces, Riemann-Stieltjes integral as a generalization of Riemann Integral, the calculus of several variables and basic theorems.

UNIT-I **14 Hours**

Basic Topology: Finite, countable and uncountable sets, metric spaces, compact sets, perfect sets, connected sets.
Sequences and series: Convergent sequences, sub sequences, Cauchy sequences (in metric spaces), completion of a metric space, absolute convergence, addition and multiplication of series, rearrangements of series of real and complex numbers.

UNIT-II **13 Hours**

Continuity: Limits of functions (in metric spaces), continuous functions, continuity and compactness, continuity and connectedness, monotonic functions.
The Riemann-Stieltjes integral: Definition and existence of the Riemann-Stieltjes integral, properties of the integral, integration of vector-valued functions, rectifiable curves.

UNIT-III **13 Hours**

Sequences and series of functions: Problem of interchange of limit processes for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Equicontinuous families of functions, Stone Weierstrass Theorem.

UNIT-IV **14 Hours**

Differentiation: Differentiation of vector-valued functions.
Functions of several variables: The space of linear transformations on R^n to R^m as a metric space. Differentiation of a vector-valued function of several variables. The Inverse function theorem. The implicit function theorem.

Reference Books:

1. Rudin, W. *Principles of Mathematical Analysis, 3rd Edition*. New Delhi: McGraw-Hill Inc., 2013.
2. Royden, H. L., and P. M. Fitzpatrick. *Real Analysis, 4th Edition.* New Delhi: Pearson, 2010.
3. Apostol, Tom. *Mathematical Analysis –A modern approach to Advanced Calculus*. New Delhi: Narosa Publishing House, 1957.

Course Title: Algebra-I
Paper Code: MTH 532

L	T	P	Credits
4	0	0	4

Objective:
This course provides the foundation required for more advanced studies in Algebra. The aim is also to develop necessary prerequisites for the course MTH 538.

UNIT-I **14 Hours**

Review of basic property of Groups: Subgroups and cosets, cyclic groups, normal subgroups and quotient groups, Isomorphism theorems. Dihedral groups. Symmetric groups and their congruency classes.

UNIT-II **12 Hours**

Simple groups and their examples, simplicity of A_n ($n\geq5$). Normal and Subnormal Series, Derived Series, Composition Series and Solvable Groups.

UNIT-III **14 Hours**

Cauchy Theorem, Sylow's Theorems and their applications, Converse of Lagrange Theorem, Direct Products, Finite Abelian Groups, Invariants of a finite abelian groups, Groups of order p^2, pq. Fundamental Theorem on Finitely generated Abelian Groups.

UNIT-IV **12 Hours**

Review of Rings, Ring Homomorphism, Ideals, and Algebra of Ideals, Maximal and prime ideals, Ideals in quotient rings, Field of Quotient of Integral domain.

Reference Books:

1. Bhattacharya, P. B., S. K. Jain, and S. R. Nagpaul, *Basic Abstract Algebra*, *2nd Edition.* U.K.: Cambridge University Press, 2004.
2. Herstein, I. N. *Topics in Algebra, 2nd Edition*. New Delhi: Wiley, 2006.
3. Singh, Surjeet, and Q. Zameeruddin, *Modern Algebra*, *7th Edition*. New Delhi: Vikas Publishing House, 1993.
4. Dummit, David. S., and Richard M. Foote, *Abstract Algebra, 2nd Edition*. New Delhi: Wiley, 2008.

Course Title: Linear Algebra
Paper Code: MTH 533

L	T	P	Credits
4	0	0	4

Objective:
The concepts and techniques from linear algebra are of fundamental importance in many scientific disciplines. The main objective is to introduce basic notions in linear algebra that are often used in mathematics and other sciences. The emphasis will be to combine the abstract concepts with examples in order to intensify the understanding of the subject.

UNIT-I **13 Hours**

Vector Spaces, Subspaces, Linear dependence, Basis and Dimensions, Algebra of Linear Transformation, Algebra of Matrices, Row rank, Column rank and their equality, System of Linear Equations.

UNIT-II **14 Hours**

Eigen values and Eigenvectors, Characteristic and minimal polynomials, companion matrix, Cayley Hamilton Theorem, Matrix representation of Linear Transformation, Change of Basis, Canonical forms, Diagonal forms, triangular forms, Rational and Canonical Jordan Forms.

UNIT-III **14 Hours**

Eigen spaces and similarity, Linear functional, Dual Spaces and dual basis, the double dual, Inner Product Spaces, Norms and Distances, Orthonormal basis, The Gram-Schmidt Orthogonalization, Orthogonal complements.

UNIT-IV **13 Hours**

The Adjoint of a Linear operator on an inner product space, Normal and self-Adjoint Operators, Unitary and Normal Operators, Spectral Theorem, Bilinear and Quadratic forms.

Reference Books:

1. Lipschutz, S., and M. Lipson. *Linear Algebra*, *3rd Edition*. New Delhi: Tata McGraw Hill, 2011.
2. Hoffman, K., and R. Kunze. *Linear algebra*, *2nd Edition.* New Delhi: Prentice Hall, 1971.
3. Axler, S. *Linear Algebra Done Right*, *2nd Edition*. New York: Springer Verlag, 2004.
4. Lang, S. *Undergraduate Texts in Mathematics, 3rd Edition*. New York: Springer-Verlag, 2004

Course Title: Differential Equation
Paper Code: MTH 534

L	T	P	Credits
4	0	0	4

Objective:
The objective of this course is to equip the students with knowledge of some advanced concepts related to differential equations and to understand some basic approach to mathematical oriented differential equation.

UNIT-I **14 Hours**
Review of fundamental of Ordinary differential equations. Wronskian, Concept of existence and uniqueness for the solution of the equation $\frac{dy}{dx} = f(x, y)$ with examples. A theorem on convergence of solution of a family of initial value problem. The method of successive approximation, general properties of solution of linear differential equation of order *n***,** Adjoint and self-adjoint equations. Total differential equations.

UNIT-II **15 Hours**
Simultaneous differential equations. Linear second and higher order differential equations. Solutions of homogeneous and non-homogeneous equations. Method of variation of parameters. Orthogonality of functions, Sturm Liouville's boundary value problems, Abel identity, Sturm comparison and separation theorems. Orthogonality of Eigen vectors and reality of Eigen values. Green function to solve boundary value problems.

UNIT-III **13 Hours**
First Order linear and quasi Partial differential equations, method of Lagrange's, Integral surface through a given curve, Surface orthogonal to given system of surfaces. Nonlinear Partial differential equations of first order, Cauchy problem for first order PDE's. Charpit's Method.

UNIT-IV **14 Hours**
Partial differential equations of the 2^{nd} order. Linear Partial differential equations with constant coefficients. Second order Partial differential equations with variable coefficients and their classification. Non-linear Partial differential equations of second order, Monge's method. Solution of Laplace, Wave and diffusion equations by method of separation of variables. Classifications of partial differential equations and canonical forms.

References Books:

1. Raisinghania, M. D. *Advanced Differential Equations*. New Delhi: S. Chand & Company Ltd. 2001.
2. Piaggio, H. T. H. *Differential Equations*. New Delhi: CBS Publisher, 2004.
3. George, F Simmons. *Differential equations with applications and historical notes*. New Delhi: Tata McGraw Hill, 1974.
4. Sneddon, I. N. *Elements of Partial Differential Equations*. New Delhi: Tata McGraw Hill 1957.
5. Ross, S. L. *Differential Equation*s. New Delhi: John Wiley and Sons 2004.

Course Title: Classical Mechanics and Calculus Of Variations
Paper Code: MTH 535

L	T	P	Credits
4	0	0	4

Objective:
The objective of this paper is to introduce the concept of variation of functionals and variational techniques. Dynamics of rigid bodies, Lagrangian and Hamiltonian equations for dynamical systems are also introduced at large.

UNIT-I **12 Hours**
Functional, variation of a functional and its properties, Euler's equation and its different forms, Motivational problems of calculus of variation- Shortest distance in a plane, Minimum surface of revolution, Brachistochrone problem, Geodesics, Isoperimetric problems, Functionals involving several dependent variable and higher order derivatives, Variational problems with moving boundaries.

UNIT-II **11 Hours**
Approximate solutions of Boundary Value Problems- Rayleigh-Ritz method, Galerkin's method, Generalised coordinates, Constraints, Holonomic and non-holonomic systems, Generalised velocity, Generalised potential, Generalised force, Principle of virtual work, D'Alembert's principle, Lagrange's equation and its applications.

UNIT-III **11 Hours**
Hamiltonian principle, Derivation of Lagrange's equations from Hamilton's principle, Cyclic co-ordinates, Principle of least action and its applications, Legendre transformation, Hamilton's canonical equation of motion, Routhian function.

UNIT-IV **12 Hours**
Central force, Equivalent one-body problem, Motion in a central force field, Kepler's Law of planetary motion, Moments and product of inertia, Theorems of perpendicular and parallel axis, Angular momentum of a rigid body about a fixed point and about fixed principal axes, Euler's dynamical equations for motion of rigid body.

Reference Books:

1. Goldstein H., C. Poole, and J. Safko. *Classical Mechanics, 3rd edition*. New Delhi: Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Reprint 2008.
2. Chorlton F. *Text book of Dynamics, 2nd edition*. New Delhi: CBS Pub. & Distribution Pvt. Ltd., Reprint 2002.
3. Synge, J. L., and B. A. Griffth. *Principles of mechanics*, 2nd edition. McGraw Hill Book Company, 1947.
4. Elsgolts, L. *Differential Equations and the Calculus of Variations*. Miami: University Press of the Pacific, Reprint 2003.
5. Fox, C. *An Introduction to the Calculus of Variation*. New York: Dover Publications,
6. Reprint 1987.

L	T	P	Credits
4	0	0	4

Course Title: Complex Analysis
Paper Code: MTH 536

Objective:
The objective of the course is to provide foundation for other related branches of Mathematics. Most of the topics covered are widely applicable in Applied Mathematics and Engineering.

UNIT-I **14 Hours**

Complex plane, geometric representation of complex numbers, joint equation of circle and straight line, stereographic projection and the spherical representation of the extended complex plane. Function of Complex variables, continuity and differentiability, Analytic functions, Conjugate function, Harmonic function, Cauchy Riemann equations (Cartesian and Polar form). Construction of analytic functions. Power series, exponential and trigonometric functions, arg z, log z, and their continuous branches.

UNIT-II **13 Hours**

Complex line integral, Cauchy's theorem, Cauchy's integral formula and its generalized form. Cauchy's inequality. Poisson's integral formula, Morera's theorem. Liouville's theorem, conformal transformation, bilinear transformation, critical points, fixed points, Cross ratio problems.

UNIT-III **14 Hours**

Power series, Taylor's theorem, Laurent's theorem, Maximum modulus theorem (Principle), Schwarz's Lemma, poles and zeroes of meromorphic functions, Fundamental theorem of Algebra and Rouche's theorem.

UNIT-IV **13 Hours**

Zeros, Singularities, Residue at a pole and at infinity. Cauchy's Residue theorem, Jordan's lemma. Integration round Unit Circle. Evaluation of Integrals and integrations of many valued functions.

Reference Books:

1. Copson, E. T. *Theory of functions of complex variables*. U.K.: Oxford University Press, 1970.
2. Ahlfors, L. V. *Complex Analysis 2nd Edition*. New Delhi: McGraw Hill, 1966.
3. Narayan, Shanti, and Mittal, P. K. *Theory of functions of a Complex variable*. New Delhi: Sultan Chand, 2007.
4. Conway, J. B. *Functions of one complex variable*. New York: Springer Verlang, 1978.

Course Title: Theory of Measure and Integration
Paper Code: MTH 537

L	T	P	Credits
4	0	0	4

Objective:

The objective of this course is to study measure in an abstract setting after having studied Lebesgue measure on real line. The general $\mathbf{L^P}$ spaces are also studied.

UNIT-I **13 Hours**

Lebesgue Measure: Introduction, Lebesgue outer measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesgue measurability, Non-measurable sets. Littlewood's three principles.

UNIT-II **13 Hours**

Lebesgue Integral: The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, the integral of a non-negative function, The general integral, Convergence and measures.

UNIT-III **14 Hours**

Differentiation and Integration: Differentiation of monotone functions, Functions of bounded variation, differentiation of an integral The Four derivatives, Lebesgue Differentiation Theorem. Absolute continuity. Convex Functions.

UNIT-IV **12 Hours**

The L^P-spaces, Minkowski and Holder inequalities, Convergence and Completeness of L^P spaces, Approximations in L^P spaces, Bounded linear functional on the L^P spaces.

Reference Books:

1. Rudin, W. *Principles of Mathematical Analysis, 3rd Edition*. New Delhi: McGraw-Hill Inc., 2013.
2. Royden, H. L., and P. M. Fitzpatrick. *Real Analysis, 4th Edition.* New Delhi: Pearson, 2010.
3. Barra, G. de. *Measure Theory and Integration*. New Delhi: Woodhead Publishing, 2011.

Course Title: Algebra-II
Paper Code: MTH 538

L	T	P	Credits
4	0	0	4

Objective:
This course is a basic course in Algebra for students who wish to pursue research work in Algebra. Contents have been designed in accordance with the UGC syllabi in mind.

UNIT-I **13 Hours**

Polynomial rings in many variables, factorization of polynomials in one variable over a field. Unique factorization domains, unique factorization in R[x], where R is a Unique Factorization Domain. Euclidean and Principal ideal domain.

UNIT-II **14 Hours**

Gauss Lemma, Eisenstein's Irreducibility Criterion, Fields, Algebraic and Transcendental elements. The degree of a field extension, finite extensions. Adjunction of roots. Splitting fields. Finite fields.

UNIT-III **12 Hours**

Algebraically closed fields, separable and purely inseparable extensions. Perfect fields. Normal extensions, Galois extensions. The fundamental theorem of Galois Theory.

UNIT-IV **12 Hours**

Modules and module homomorphism, sub module and quotient module, operation on sub modules, direct sum and product, finitely generated modules.

Reference Books:

1. Bhattacharya, P. B., S. K. Jain, and S. R. Nagpaul. *Basic Abstract Algebra, 2nd Edition.* U. K.: Cambridge University Press, 2004.
2. Herstein, I. N. *Topics in Algebra, 2nd Edition*. New Delhi: Wiley, 2006.
3. Singh, Surjeet, and Q. Zameeruddin. *Modern Algebra, 7th Edition*. New Delhi: Vikas Publishing House, 1993.
4. Dummit, David. S., and Richard M. Foote. *Abstract Algebra, 2nd Edition*. Wiley, 2008.

Course Title: Differential Geometry
Paper Code: MTH 539

L	T	P	Credits
4	0	0	4

Objective:
The objective of this course is to provide knowledge of differential geometry of curves and surfaces in space, with special emphasis on a geometric point of view, as a basis for further study or for applications.

UNIT–I **13 Hours**

Tangent, Principal normal, Curvature, Binomial, Torsion, Serret Frenet formulae, Locus of center of curvature, Spherical curvature, Locus of center of spherical curvature. Curve determined by its intrinsic equations, Helices, Involutes & Evolutes.

UNIT–II **14 Hours**

Surfaces, Tangent plane, Normal, Curvilinear co-ordinates First order magnitudes, Directions on a surface, The normal, second order magnitudes, Derivatives of n, Curvature of normal section. Meunier's theorem, Principal directions and curvatures, first and second curvatures, Euler's theorem. Surface of revolution.

UNIT--III **12 Hours**

Conjugate directions, asymptotic lines, Curvature and torsion of asymptotic lines, Gauss's formulae, Gauss characteristic equation, Mainardi – Codazzi relations, Derivalives of angle

UNIT–IV **13 Hours**

Introduction to Geodesics, Canonical Geodesic Equation, Normal property of Geodesic, Equations of geodesics, Surface of revolution, Torsion of Geodesic, Bonnet's theorem, vector curvature, Geodesic curvature.

Reference Books:

1. Weatherburn, C. E. *Differential Geometry of Three Dimensions*. Nabu Press, 2011.
2. Pressley, Andrew. *Elementary Differential Geometry*. Springer, 2004.
3. Willmore, T. J. *Introduction to Differential Geometry*. Oxford University Press India, 1997.
4. Do Carmo, M. P. *Riemannian Geometry*. Birkhauser, 2011.
5. Berger, M. *A Panoramic View of Riemannian geometry*. Springer, 2003.

Course Title: Probability and Statistics
Paper Code: MTH 540

L	T	P	Credits
4	0	0	4

Objective:
The course is designed to equip the students with various probability distributions and to develop greater skills and understanding of Sampling and Estimation.

UNIT-I **15 Hours**
Random Variables: Discrete and continuous random variables, Probability mass, probability density and cumulative distribution functions, Joint, marginal and conditional distributions, Mathematical expectation, variance and moments and Moment generating function.

UNIT-II **10 Hours**
Discrete distributions: Bernoulli, Binomial, Poisson, Geometric and Negative Binomial distributions and their properties.
Continuous distributions: Uniform, normal, beta, gamma and exponential distributions and their properties. Multivariate normal distribution.

UNIT-III **10 Hours**
Sampling Theory: Types of Sampling- Simple, Stratified, Systematic, Errors in sampling, Parameter and Statistics
Estimation: Unbiasedness, Consistency, Invariant Estimator, Efficient Estimator, Minimum Variance Unbiased Estimators, Characteristics of Estimators, the Method of Maximum Likelihood Estimation, Confidence intervals for parameters in one sample and two sample problems of normal populations, confidence intervals for proportions.

UNIT-IV **15 Hours**
Testing of Hypotheses: Null and alternative hypotheses, the critical and acceptance regions, two types of error, tests for one sample and two sample problems for normal populations, tests for proportions, Z test, t test, Chi-square test and its applications, F test as a comparison of two variances.

Reference Books:

1. Hogg Robert V., Joeseph McKlean, and Allen T Craig. *Introduction to Mathematical Statistics*. London: Pearson Education Limited, 2014.
2. Meyer, P. L. *Introductory Probability and Statistical Applications*. Philippines: Addison-Wesley Publishing Company, 1970.
3. Sheldon M. Ross, *Introduction to Probability Models*. 10th Edition.
4. Gupta, S. C., and V. K. Kapoor. *Fundamentals of Mathematical Statistics*. New Delhi: Sultan Chand & Sons, 2002.
5. J.S. Milton and J.C. Arnold, *Introduction to Probability and Statistics*, Fourth Edition, McGraw Hill 2003.

Course Title: Numerical Analysis
Paper Code: MTH 541

L	T	P	Credits
4	0	0	4

Objective:
The objective of this course is to teach methods which are extremely useful in scientific research. The contents of the curriculum have been designed keeping in view the UGC guidelines.

UNIT-A **13 Hours**
Errors, Error propagation, Order of approximation.
Solution of non-linear equations: Bisection, Regula-falsi, Secant, Newton-Raphson, Generalized Newton's method, Chebyshev method, Halley's methods, General iteration method, Muller's method. Rate of convergence. Newton's method for complex roots and multiple roots, Simultaneous non-linear equations by Newton-Raphson method.

UNIT –B **12 Hours**
Operators: Forward, Backward and Shift (Definitions and some relations among them).
Interpolation: Finite differences, divided differences, Newton's formulae for interpolation, Lagrange and Hermite interpolation, Cubic Spline interpolation. Numerical integration-Trapezoidal, Simpson's $1/3^{rd}$ rule, Simpson's $3/8^{th}$ rule, Boole's rule, Weddle's rule, Errors in Integration formulae.

UNIT –C **14 Hours**
Curve fitting: Linear and non-linear curve fitting, curve fitting by sum of exponentials, fitting of exponential and trigonometrical functions. Solution of Linear system of equations: Matrix inversion, Gauss-elimination and Gauss-Jordan method, LU decomposition method, Gauss Jacobi and Gauss Seidal method.

UNIT –D **12 Hours**
Solution of differential equations: Taylor series method, Euler's method, Modified Euler's method, Runge - Kutta methods of order two, three and four, Predictor –Corrector methods, Finite Difference Method for ODE and PDE (Boundary value problem).

Reference Books:

1. Shastry, S. S. *Introductory Methods of Numerical Analysis*. New Delhi: PHI Learning Private Limited, 2005.
2. Iyenger, S. R. K., R. K. Jain, and Mahinder Kumar. *Numerical Methods for Scientific and Engineering Computation.* Delhi: New Age International Publishers, 2012.
3. Gerald C. F., and P. O. Wheatley. *Applied Numerical Analysis.* India: Pearson Education, 2008.
4. Mathews, John H., and D. Fink Kurtis. *Numerical Methods using Matlab 4th Edition.* New Delhi: PHI Learning Private Limited, 2012.
5. Grewal B. S. *Numerical Methods in Engineering and Science.* New Delhi: Khanna Publishers, 2014.

Course Title: Topology
Paper Code: MTH 631

L	T	P	Credits
4	0	0	4

Objective:
The course is an introductory course on point-set topology so as to enable the reader to understand further deeper topics in topology like Differential/Algebraic Topologies etc.

UNIT-I **13 Hours**

Countable and uncountable sets, infinite sets and Axiom of choice, Cardinal numbers and their arithmetic. Schroeder-Bernstein Theorem, Cantor's theorem and the continuum hypothesis, Zorn's Lemma, Well-ordering theorem.

UNIT-II **14 Hours**

Topological Spaces: examples of topological spaces**,** the product topology, the metric topology, the quotient topology. Bases for a topology, the order topology, the box topology, the subspace topology. Open sets, closed sets and limit points, closures, interiors, continuous functions, homeomorphisms.

UNIT-III **12 Hours**

Connectedness and Compactness: Connected spaces, Connected subspaces of the real line, Components and local connectedness, Compact spaces, Compact space of the real line, Limit point compactness, Heine-Borel Theorem, Local -compactness.

UNIT-IV **12 Hours**

Separation Axioms: The Countability Axioms, The Separation Axioms, Normal Spaces, Urysohn Lemma, Tychonoff embedding and Urysohn Metrization Theorem, Tietze Extension Theorem, One-point Compactification.

Reference Books:

1. Munkers, James R. *Topology*. Delhi: Prentice Hall of India, 2002.
2. James, Dugundji. *Topology*. USA: William C Brown Pub, 1990.
3. Kelley, J. L. *General Topology.* Van Nostrand: Springer 1975.
4. Bourbaki, N. *General Topology*. New York: Springer, 1989.
5. Joshi, K. D. *Introduction to General Topology*. New Delhi: New Age International, 1983.

Course Title: Mathematical Methods
Paper Code: MTH 632

L	T	P	Credits
4	0	0	4

Objective:
To acquaint the students with the application of Laplace and Fourier Transform to solve Differential Equations.

UNIT-I **13 Hours**

Laplace Transform: Definition, existence and basic properties of the Laplace transform, Inverse Laplace transform, Convolution theorem, Laplace Transform solution of linear differential equation and simultaneous linear differential equation with constant coefficients, Complex inversion formula.

UNIT-II **14 Hours**

Fourier Transform: Definition, existence and basic properties, Inversion formula of Fourier transform Convolution theorem, Parseval's relation. Fourier transform of derivatives and integrals, Fourier sine and cosine transform, Inverse Fourier transform, Solution of linear ordinary differential equations and partial differential equations.

UNIT-III **14 Hours**

Integral Equation, Linear and nonlinear integral equations, Fredholm Integral Equation and its kinds, Volterra integral Equation and its kinds, Singular Integral Equation, Special kinds of kernels(Symmetric, Separable or degenerate kernel, Leibnit'z rule of differentiation under integral sign, An important formula for converting a multiple integral into a single ordinary integral
Conversion of ordinary differential equations into integral equation.
Volterra Equations: Integral equations and algebraic system of linear equations. Volterra equations of first and second kind. Volterra integral equation and linear differential equation.

UNIT-IV **12 Hours**

Fredholm Equations: Homogenous Fredholm integral equations of the second kind with Seprable (or Degenerate) Kernels, Fredholm integral equations of the second kind with separable (or degenerate) kernels. Solution by the method of successive approximations. Classical Fredholm theory

1. Raisinghania, M.D. *Integral equations and boundary value problems*. New Delhi: S. Chand, 2013
2. Kanwal, R. P. *Linear Integral Equations*. Boston: Birkhauser Boslon, 1996.
3. Pinckus, A., and S. Zafrany. *Fourier series and Integral Transform*. New York: Cambridge University Press, 1997.
4. Mikhlin, S. G. *Integral equations and their applications to certain problems in Mechanics. Mathematical Physics and Technology*. Oxford: Pergamon Press, 1964

Course Title: Operational Research
Paper Code: MTH 633

L	T	P	Credits
4	0	0	4

Objective:
The objective of this course is to acquaint the students with the concept of convex sets, their properties and various separation theorems so as to tackle with problems of optimization of functions of several variables over polyhedron and their duals. The results, methods and techniques contained in this paper are very well suited to the realistic problems in almost every area.

UNIT-I **14 Hours**

Operations Research and its Scope. Necessity of Operations Research in industry Mathematical formulation of linear programming problem Linear Programming and examples, Convex Sets, Hyper plane, Open and Closed half-spaces, Feasible, Basic Feasible and Optimal Solutions, Extreme Point & graphical methods. Simple method, Charnes-M method, two phase method, Determination of Optimal solutions, unrestricted variables.

UNIT-II **13 Hours**

Duality theory, Dual linear Programming Problems, fundamental properties of dual Problems, Complementary slackness, unbounded solution in Primal. Dual Simplex Algorithm, Sensitivity analysis.

UNIT-III **14 Hours**

The General transportation problem, transportation table, duality in transportation problem, loops in transportation tables, linear programming formulation, solution of transportation problem, test for optimality, degeneracy, transportation algorithm (MODI method), time minimization transportation problem. Assignment Problems: Mathematical formulation of assignment problem, the assignment method, typical assignment problem, the traveling salesman problem.

UNIT-IV **12 Hours**

Game Theory: Two-person zero sum games, maxmin-minmax principle, games without saddle points (Mixed strategies), graphical solution of $2 \times n$ and $m \times 2$ games, dominance property, arithmetic method of $n \times n$ games, general solution of $m \times n$ rectangular games.

Reference Books:

1. Taha, H. A. *Operations Research - An Introduction*. New York: Macmillan Publishing Company Inc., 2006.
2. Swarup, K., P. K. Gupta and M. Mohan. *Operations Research.* New Delhi: Sultan Chand & Sons, 2001.
3. Bazaraa, M. S., and S. M. Shetty. *Nonlinear Programming*, *Theory & Algorithms*. New York: Wiley, 2004.
4. Sinha, S. M. *Mathematical Programming*, *Theory and Methods*. Delhi: Elsevier, 2006.

Course Title: Fluid Mechanics-I
Paper Code: MTH 636

L	T	P	Credits
4	0	0	4

Objective:

The objective of this course is to introduce the fundamentals of modern treatment of incompressible and compressible fluid flows.

UNIT-I **14 Hours**

Real fluids and ideal fluids, velocity of fluid at a point, streamlines, path lines, streak lines, velocity potential, vorticity vector, local and particle rates of change, equation of continuity, incompressible fluid flow, acceleration of fluid, conditions at a rigid boundary.

UNIT-II **13 Hours**

Euler's equation of motion, Bernoulli's equation, their applications, some potential theorems, flows involving axial symmetry- stationary sphere in a uniform stream, impulsive motion, Kelvin's theorem of circulation, equation of vorticity.

UNIT-III **12 Hours**

Some three dimensional flows: sources, sinks and doublets, images in rigid planes, images in solid spheres, Stoke's stream function.

UNIT-IV **13 Hours**

Two dimensional flows: complex velocity potential, Milne Thomson circle theorem and applications, theorem of Blasius, Vortex rows, Karman Vortex Street.

Reference Books:

1. Charlton, F. *Text Book of Fluid Dynamics*. Delhi: GK Publishers, Reprint 2009.
2. Landau, L. D., and E. M. Lifhshitz. *Fluid Mechanics, 2nd Edition*. New-York: Pergamon Press Ltd., 1987.
3. Batchelor, G. K. *An Introduction to Fluid Mechanics*. Cambridge: Cambridge University Press, 1967.
4. Kundu P. K., and I. M. Cohen. *Fluid Mechanics*. Delhi: Harcourt (India) Pvt. Ltd., Reprint 2003.

Course Title: Discrete Mathematics
Paper Code: MTH 637

L	T	P	Credits
4	0	0	4

Objectives:
The objective of this course is to acquaint the students with the concepts in Discrete Mathematics. It includes the topics like Logics, Graph Theory, Trees and Boolean algebra.

UNIT-I **13 Hours**

Basic logical operations, conditional and bi-conditional statements, tautologies, contradiction, Quantifiers, prepositional calculus, Recursively Defined Sequences, The Characteristic Polynomial. Solution of Recurrence Relations, Generating Function, Basics of Counting and the Pigeon-hole Principle.

UNIT-II **13 Hours**

Language and Grammars: Computability and Formal Languages, Ordered sets, languages, Phrase structure grammars, Types of grammars and languages, Finite state machines-equivalent machines, Finite state machines as language recognizers, Analysis of algorithm-Time complexity.

UNIT-III **14 Hours**

Graphs and Planar Graphs: Basic Terminology, Special types of Graphs. The Handshaking Theorem, Paths and Circuits Shortest paths. Connectivity of Graphs. Isomorphism of Graphs. Homeomorphic Graphs. Eulerian and Hamiltonian Graphs. Planar and Non Planar Graphs. Euler's formula. Graph Coloring. Adjacency and Incidence Matrices. Travelling Salesman Problem.

UNIT-IV **14 Hours**

Trees: Basic Terminology. Binary Trees. Tree Traversing: Pre-order, Post-order and In-order Traversals. Minimum Spanning Trees, Prim's and Kruskal's Algorithm. Boolean algebra, Boolean Function, Logic Gates, Lattices and Algebraic Structures.

Reference Books:

1. Rosen, K. H. *Discrete Mathematics and its Applications*. Delhi: McGraw Hill, 2007.
2. Joshi, K. D. *Foundation of Discrete Mathematics*. Delhi: J. Wiley & Sons, 1989
3. Malik, D. S., and M. K. Sen. *Discrete Mathematical Structures Theory and Applications*. New Delhi: Thomson Cengage Learning, 2004.
4. Trembley, J. P. and R. P. Manohar. *Discrete Mathematical Structures with Applications to Computer Science*. New Delhi: McGraw Hall, 1975.
5. Liu, C. L. *Elements of Discrete Mathematics***.** Delhi: McGraw Hill, 1986.

Course Title: Finite Element Analysis
Paper Code: MTH 638

L	T	P	Credits
4	0	0	4

Objective:
The aim of this course is to make the students learn fundamental concepts of finite elements so as to enable the students to understand further topics related to solution of differential equations. Finite element analysis is a helpful tool to solve a variety of problems of science and engineering related to fluid flows, structures etc.

UNIT I **13 Hours**

General theory of finite element methods, Difference between finite element and finite difference, Review of some integral formulae, Concept of discretization, Convergence requirements, Different coordinates, One dimensional finite elements, shape functions, stiffness matrix, connectivity, boundary conditions, equilibrium equation, FEM procedure.

UNIT II **14 Hours**

Generalization of the finite element concepts-weighted residual and variational approaches (Ritz method, Galerkin method, collocation method etc.) Numerical integration, Interpolation formulas and shape functions, Axis symmetric formulations, solving one-dimensional problems.

UNIT III **13 Hours**

Two dimensional finite element methods, Element types: triangular, rectangular, quadrilateral, sector, curved, isoperimetric elements and numerical integration, two dimensional boundary value problems, connectivity and nodal coordinates, theory of elasticity, variational functions, triangular elements and area coordinates, transformations, cylindrical coordinates.

UNIT IV **14 Hours**

Three dimensional finite elements, higher order finite elements, element continuity, plate finite elements, Application of finite element methods to elasticity problems and heat transfer problems, Computer procedures for Finite element analysis.

Reference Books:

1. Braess, D., and L. Schumaker. *Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics.* New York: Cambridge University Press, 2001.
2. Desai C. S. *Introductory Finite Element Method*. Boca Raton: CRC Press, 2001.
3. Smith, G. D. *Numerical solution of Partial Differential Equations*. Oxford: Clarendon Press, 1986.
4. Bradie, B. *A friendly introduction to Numerical Analysis.* Delhi: Pearson, 2005.
5. Reddy, J. N. *An introduction to Finite Element Methods.* Delhi: McGraw-Hill Higher Education, 2005.

Course Title: Fuzzy Sets and Fuzzy Logic
Paper Code: MTH 639

L	T	P	Credits
4	0	0	4

Objective:
The objective of this course is to acquaint the students with the concept of fuzzy logics.

UNIT-I **14 Hours**

Fuzz Sets-Basic definitions. α-level sets. Convex fuzzy sets. Basic operations on fuzzy sets. Types of fuzzy sets. Cartesian products. Algebraic products. Bounded sum and difference. T-norms and t-conorms. The Extensions Principle- the Zadeh's extension principle. Image and inverse image of fuzzy sets. Fuzzy Numbers. Elements of fuzzy arithmetic.

UNIT-II **13 Hours**

Fuzzy Relations and Fuzzy Graphs-Fuzzy, relations on fuzzy sets. Composition of fuzzy relations. Min-Max composition and its properties. Fuzzy Equivalence relations. Fuzzy compatibility relations. Fuzzy relation equations. Fuzzy graph. Similarity relations.

UNIT-III **12 Hours**

Possibility Theory-Fuzzy measures. Evidence theory. Necessity measures. Possibility measures. Possibility distribution. Possibility theory and fuzzy sets.

UNIT-IV **13 Hours**

Fuzzy logic- An overview of classical logic, multivalued logics. Fuzzy propositions. Fuzzy Quantifiers. Linguistic variables and hedges. Inference from conditional fuzzy propositions, the compositional rule of inference.

Reference Books:

1. Zimmermann, H.J. *Fuzzy set theory and its Applications.* New Delhi: Allied Publishers Ltd., 1991.
2. Klir, G.J., and B. Yuan. *Fuzzy sets and fuzzy logic*. New Delhi: Prentice-Hall of India, 1995.

Course Title: Advanced Complex Analysis
Paper Code: MTH 640

L	T	P	Credits
4	0	0	4

Objectives:
This course is designed to enable the readers to understand further deeper topics of Complex Analysis and will provide basic topics needed for students to pursue research in pure Mathematics.

Unit –I **14 Hours**
Harmonic function: Definition, Relation between a harmonic function and an analytic function, Examples, Harmonic Conjugate of a harmonic function, Poisson's Integral formula, Mean Value Property, The maximum & minimum principles for harmonic functions, Diritchlet Problem for a disc and uniqueness of its solution, Characterization of harmonic functions by Mean Value Property.

Unit –II **13 Hours**
Analytic continuation: Direct Analytic continuation, Analytic continuations along arcs, Homotopic curves, The Monodromy theorem, Analytic continuation via reflection. Harneck's principle. Open mapping theorem, normal families, The Riemann Mapping Theorem, Picard's theorem.

Unit –III **15 Hours**
Weierstrass Elliptic functions: Periodic functions, Simply periodic functions, fundamental period, Jacobi's first and second question, Doubly periodic functions, Elliptic functions, Pair of Primitive Periods, Congruent points, First and Second Liouville's Theorem, Relation between zeros and poles of an elliptic function, Definition of Weierstrass elliptic function P(z) and their properties, The differential equation satisfied by P(z) [i.e., the relation between P'(z) and P(z)], Integral formula for P(z), Addition theorem and Duplication formula for P(z).

Unit –IV **13 Hours**
Weierstrass Zeta function: Weierstrass Zeta function and their properties, Quasi periodicity of (z), Weierstrass sigma function σ(z) and their properties, Quasiperiodicity of ς(z), associated sigma functions.

Reference Books:

1. Conway, J. B. *Functions of one Complex variable*. USA: Springer-Verlag, International, 1978.
2. Ahlfors, L.V. *Complex Analysis: An Introduction to the Theory of Analytic Functions of One Complex Variable*. Delhi: McGraw-Hill Higher Education, 1979.
3. Lang, S. *Complex Analysis.* New York: Springer, 2003.
4. Walter, R. *Real and Complex Analysis*. New Delhi: McGraw- Hill Book Co., 1986.
5. Ponnusamy, S. *Foundations of Complex Analysis*, New Delhi: Narosa Publication House, 1995.

Course Title: Advance Theory of Partial Differential Equations and Sobolev Spaces
Paper Code: MTH 641

L	T	P	Credits
4	0	0	4

Objectives:
The objective of this course is to equip the students with knowledge of some basic as well as advanced concepts related to partial differential equations and to understand some basic approach to mathematical oriented PDEs.

UNIT-I **14 Hours**
Distribution-Test Functions and Distributions, Examples, Operations on Distributions, Supports and Singular Supports, Convolution, Fundamental Solutions, Fourier Transform, Schwartz space, Tempered Distributions.
Sobolev spaces-Basic properties, Approximation by smooth functions, Extension theorems, Compactness theorems, Dual spaces, Functional order spaces, Trace spaces, Trace theory, Inclusion theorem.

UNIT-II **13 Hours**
Weak solutions of Elliptic Boundary Value Problems-Variational problems, Weak formulation of Elliptic PDE, Regularity, Galerkin Method, Maximum principles, Eigenvalue problems, Introduction to finite element methods.
Evolution Equations- Unbounded linear operators, C_0 – Semigroups, Hille-Yosida theorem, Contraction Semigroup on Hilbert Spaces, Heat equation, Wave equation, Schrodinger equation, Inhomogeneous equations.

UNIT-III **13 Hours**
Calculus of Variations-Euler-Lagrange Equation, Second variation, Existence of Minimizers(Coactivity, Lower Semi-continuity, Convexity), Regularity, Constraints(Nonlinear Eigenvalue problems, Variational Inequalities, Harmonic maps, Incompressibility), Critical points(Mountain Pass theorem and Applications to Elliptic PDE).

UNIT-IV **12 Hours**
Nonvariational Methods-Monotonicity Methods, Fixed Point Theorems, Sub and Super solutions, Geometric properties of solutions(Radial Symmetry) Nonexistence of solutions, Gradient Flows. Hamilton-Jacobi Equations-Viscosity solutions, Uniqueness, Control theory, Dynamic programming. System of Conservation Laws-Integral Solutions, Travelling waves, hyperbolic systems, Riemann's problem, System of two conservation laws, Entropy criteria.

Reference Books:

1. Kesavan, S. *Topics in Functional Analysis and Application.* New Delhi: Wiley-Eastern, New International, 1999.
2. Evans, L. C. *Partial Differential Equations. Graduate Studies in Mathematics*. Providence: AMS, 1998

Course Title: Functional Analysis
Paper Code: MTH 642

L	T	P	Credits
4	0	0	4

Objective:

The objective of this course is to introduce basic concepts, principles, methods of functional analysis and its applications. It is a first level course in functional analysis.

UNIT-I **12 Hours**

Metric Spaces: Metric spaces with examples, Holder inequality and Minkowski inequality, Open set, Closed set, Neighbourhood, Various concepts in a metric space, Separable metric space with examples, Convergence, Cauchy sequence, Completeness, Examples of Complete and Incomplete metric spaces, Completion of Metric spaces.

UNIT-II **13 Hours**

Normed / Banach Spaces: Vector spaces with examples, Normed Spaces with examples, Banach Spaces and Schauder Basis, Finite Dimensional Normed Spaces and Subspaces, Compactness of Metric/Normed spaces, Linear Operators- definition and examples, Bounded linear operators in a Normed Space, Bounded linear functionals in a Normed space, Concept of Algebraic Dual and Reflexive space, Dual spaces with examples.

UNIT-III **13 Hours**

Inner-Product Space & Hilbert Space: Inner Product and Hilbert space, Further properties of Inner product spaces, Projection Theorem, Orthonormal Sets and Sequences, Total Orthonormal Sets and Sequences, Representation of functionals on a Hilbert Spaces (Riesz's Lemma and Representation), Hilbert Adjoint Operator, Self Adjoint, Unitary and Normal Operators.

UNIT-IV **12 Hours**

Fundamental Theorems for Normed & Banach Spaces: Partially Ordered Set and Zorn's Lemma, Hahn Banach Theorem for Real Vector Spaces, Hahn Banach Theorem for Complex Vector Spaces and Normed Spaces, Baire's Category and Uniform Boundedness Theorems, Open Mapping Theorem, Closed Graph Theorem, Banach Fixed Point Theorem.

Reference Books:

1. Kreyzig, E. *Introductory Functional Analysis with Applications*. New Delhi: John Willey and Sons, Reprint 2013.
2. Limaye, B. V. *Functional Analysis.* New Delhi: New Age International (P) Ltd, 1996.
3. Siddiqui, A. H. *Functional Analysis with Applications*. New Delhi: Tata-McGraw Hill, 1986.
4. Rudin, W. *Functional Analysis, 2nd edition.* New Delhi: Tata-McGraw Hill Pub. Co., Reprint 2007.

Course Title: Number Theory
Paper Code: MTH 643

L	T	P	Credits
4	0	0	4

Objective:
The objectives of this course is to teach the fundamentals of different branches of Number Theory, namely, Geometry of Numbers and Analytic Number Theory.

UNIT-I **13 Hours**

Divisibility of Integers, Greatest common divisor, Euclidean algorithm. The Fundamental theorem of Arithmetic, Congruences, Residue classes and reduced residue classes.

UNIT-II **14 Hours**

Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Euler's theorem.
Arithmetic functions σ(n), d(n), τ(n), μ(n), Order of an integer modulo *n*, primitive roots for primes, composite numbers having primitive roots, theory of indices.

UNIT-III **14 Hours**

Quadratic residues, Legendre symbol, Euler's criterion, Gauss's lemma, Quadratic reciprocity law, Jacobi symbol. Perfect numbers, Characterization of even perfect numbers, Elementary results on the distribution of primes, Twin primes, Mersenne primes and Fermat numbers.

UNIT-IV **14 Hours**

Representation of an integer as a sum of two and four squares. Diophantine equations $ax+by=c$, $x^2+y^2=z^2$, $x^4+y^4=z^4$. Farey sequences, continued Fractions.

Reference Books:

1. Burton, D.M. *Elementary* Number Theory, 7^{th} Edition. New Delhi: Tata McGraw-Hill 2012.
2. Niven, I., S. Zuckeman, and H. L. Montgomery. *Introduction to Number Theory*. Wiley Eastern 1991.
3. Apostal, T.N. *Introduction to Analytic Number Theory*. Springer Verlag 1976.
4. Hardy, G.H. and E.M. Wright. *An Introduction to the Theory of Number*. U.K: Oxford Univ. Press 2008.

Course Title: Differential Geometry of Manifolds
Paper Code: MTH 645

L	T	P	Credits
4	0	0	4

Objective:
This course is a basic course in manifolds. The course starts with a review of multi-variable calculus. This is followed by an introduction to basic concepts related to manifolds and their tangent and cotangent spaces, and forms. This course builds foundation for geometry and theoretical physics courses.

UNIT-I **12 Hours**
Multi-variable Analysis: Differential calculus in several variables, Chain rule, mean value theorem, direction derivatives, Taylor's theorem, vector fields on open subsets of Euclidean spaces, implicit and inverse function theorems, Differentiable manifolds: Definition, differentiable functions between manifolds.

UNIT-II **12 Hours**
The tangent space at a point, local expression for the differential, bases for the tangent space at a point, curves in manifolds, computing the differential using the curves, rank, critical and regular points.

UNIT-III **13 Hours**
Regular sub manifolds, The regular level set theorem, Immersion, submersion, local immersions, embeddings, constant rank smooth maps, The topology of the tangent bundle, the manifold structure on the tangent bundle, vector bundles, smooth sections, vector fields, flows and exponential map.

UNIT-IV **13 Hours**
Lie groups: definitions and examples, Lie subgroups, The differential of determinant map at the identity, Lie algebras: Tangent space at the identity of a Lie group, Left invariant vector fields on a Lie group, Lie Algebra of a Lie group, The Lie bracket on $gl(n,\mathbb{R})$, push forward of vector fields,The Levi-Civita connection.

Reference Books:

1. Loring W. Tu. *An Introduction to Manifolds*. Delhi: Prentice Hall of India, 2008.
2. Lee, J. M. *Introduction to Smooth Manifolds, Graduate Texts in Mathematics.* New York: Springer Verlag (2003).
3. Gudmundsson, S. *An Introduction to Riemannian Geometry*, Lecture Notes.
4. Boothby, W. *An Introduction to Differentiable Manifolds and Riemannian geometry*, 2nd Edition. Orlando, FL: Pure and Applied Mathematics, Academic Press, 1986.
5. Kumaresan, S. *A Course in Differential Geometry and Lie Groups.* New Delhi: Hindustan Book Agency (India), 2002.

Course Title: Advanced Numerical Analysis
Paper Code: MTH 646

L	T	P	Credits
4	0	0	4

Objective:
The aim of this course is to teach the applications of various numerical techniques for a variety of problems occurring in daily life. At the end of the course, the students will be able to do programming in MATLAB and understand the basic concepts in Numerical Analysis of differential equations.

UNIT-I **14 Hours**
Finite difference approximation to partial derivatives, parabolic equations: An explicit method, Crank Nicolson Implicit method, solution of implicit equations by Gauss Elimination, derivative Boundary conditions, local truncation error, Convergence and stability, Multi-dimensional search without using derivatives, the Method of Rosen brock, Cyclic coordinate method, Method of Hooke and Jeeves and their convergence.

UNIT-II **13 Hours**
Hyperbolic equations: Implicit difference methods for wave equation solution of advection equation by finite difference method and Maccormack method, stability analysis, Lax, Wendroff explicit method on rectangular mesh for 1st order equations, Iterative methods for elliptic equations.

UNIT-III **13 Hours**
Numerical Differentiation, Trapezoidal and Simpson's one third, Simpson's three eight rule for Numerical integration, adaptive Integration, Boole, Weddle rule, Double integration.
Multidimensional search using derivatives, Steepest Descent algorithm and its convergence analysis, Newton's method and modified Newton's method. Methods using conjugate directions: the method of Davidon-Fletcher- Powell (DFP) method, the Broyden-Fletcher-Goldfarb-Shanno (BFGS) method

UNIT-IV **14 Hours**
Constrained optimization: Indirect methods, the concept of penalty functions, exterior penalty function method (EPF), exact absolute value and augmented Lagrangian Penalty methods and their convergence analysis. Direct methods, successive linear programming approximation (SLP), successive quadratic programming approximation (SQP), gradient project method of Rosen, generalized reduced gradient method (GRG), convex simplex algorithm of Zangwill

Reference Books:

1. Smith, G. D. *Numerical solution of Partial Differential Equations: Finite Difference Methods, third edition.* New York: Oxford University Press, 1985.
2. Bradie, B. *A friendly introduction to Numerical Analysis.* Delhi: Pearson Education, 2007.
3. Reddy, J.N. *An Introduction to Finite Element Methods.* Delhi: McGraw-Hill, 2000.
4. Bazaraa, M.S., H.D. Sherali and C.M. Shetty. *Nonlinear Programming Theory and Algorithms.* Delhi: John Wiley and Sons, 2004.

Course Title: Wavelets Analysis
Paper Code: MTH 647

L	T	P	Credits
4	0	0	4

Objectives:
The course is an introductory course on Wavelets so as to enable the students to understand further topics related to solution of differential equations. Wavelets are a helpful tool to solve a variety of problems of science and engineering such as image processing, cloud computing etc.

UNIT I **14 Hours**

Preliminaries, Different ways of constructing wavelets-Orthonormal bases generated by a single function, the Balian-Low theorem. Smooth projection on $L^2(R)$. Local sine and cosine bases and the construction of some wavelets. The unitary folding operators and the smooth projections. Multiresolution analysis and construction of wavelets. Construction of compactly supported wavelets and estimates for its smoothness. Band limited wavelets.

UNIT II **13 Hours**

Orthonormality. Completeness. Characterization of Lemare-Meyer wavelets and some other Characterizations. Franklin wavelets and spline wavelets on the real line. Orthonormal bases of piecewise linear continuous functions for $L^2(T)$. Orthonormal bases of periodic splines. Periodization of wavelets defined on the real line.

UNIT III **13 Hours**

Characterization in the theory of wavelets- The basic equations and some of its applications. Characterizations of MRA Wavelets, low pass filters and scaling functions. Non-existence of smooth wavelets in $H^2(R)$. Frames-The reconstruction formula and the Balian-Low theorem for frames. Frames from translation and dilation. Smooth frames for $H^2(R)$.

UNIT IV **12 Hours**

Discrete transforms and algorithms-The discrete and fast Fourier transforms. The discrete and fast cosine transforms. The discrete version of the local sine and cosine bases. Decomposition and reconstruction algorithms for wavelets.

Reference Books:

1. Goswami, J. C., and A.K. Chan. *Fundamentals of wavelets: Theory, Algorithms and Applications.* New York: Wiley, 1999.
2. Chui, C. K. *An Introduction to wavelets.* San Diego: Academic Press, 1992.
3. Hackbusch, W. *Multigrid Methods and Applications*. Berlin: Springer-Verlag, 1985.

Course Title: Fluid Mechanics-II
Paper Code: MTH 648

L	T	P	Credits
4	0	0	4

Objective:
This course is designed to make the students learn to develop mathematical models of fluid dynamical systems and use mathematical techniques to find solutions to these models.

UNIT-I **13 Hours**

Stress components in a real fluid, relation between Cartesian components of stress, rate of strain quadric and principal stresses, relations between stress and rate of strain, coefficient of viscosity and laminar flow.

UNIT-II **13 Hours**

The Navier-Stokes equations of motion of a viscous fluid, steady motion of viscous fluid between parallel planes, steady flow through tube of uniform circular cross-section, flow through tubes of uniform cross section in the form of circle, ellipse and equilateral triangle.

UNIT-III **11 Hours**

Diffusion of vorticity. Energy dissipation due to viscosity, steady flow past a fixed sphere, dimensional analysis, Reynolds numbers, Prandtl's boundary layer, Karman integral equation.

UNIT-IV **14 Hours**

Elements of wave motion, waves in fluids, Surface gravity waves, standing waves, group velocity, energy of propagations, path of particles, waves at interface of two liquids.

Reference Books:

1. Charlton, F. *Text Book of Fluid Dynamics*. Delhi: GK Publishers, Reprint 2009.
2. Landau, L. D., and E. M. Lifhshitz. *Fluid Mechanics, 2nd Edition*. New-York: Pergamon Press Ltd., 1987.
3. Batchelor, G. K. *An Introduction to Fluid Mechanics*. Cambridge: Cambridge University Press, 1967.
4. Kundu P. K., and I. M. Cohen. *Fluid Mechanics*. Delhi: Harcourt (India) Pvt. Ltd., Reprint 2003.

Course Title: Special functions
Paper Code: MTH 649

L	T	P	Credits
4	0	0	4

Objective:
The objective of this course is to introduce the special function as a solution of specific differential equations.

UNIT-I **13 Hours**

Legendre polynomial, Generating function, Rodrigue's formula, recurrence relations and differential equations, it's orthogonality, expansion of a function in a series of Legendre Polynomials.

UNIT-II **12 Hours**

Adjoint equation of n-the order: Lagrange's identity, solution of equation from the solution of its adjoint equation, self-adjoint equation, Green's function.

UNIT-III **14 Hours**

Hypergeometric and Generalized Hypergeometric functions: Function ${}_2F_1(a,b;c;z)$.
A simple integral form evaluation of ${}_2F_1(a,b;c;z)$ Contiguous function relations, Hyper geometrical differential equation and its solutions, ${}_2F_1(a,b;c;z)$ as function of its parameters, Elementary series manipulations, Simple transformation, Relations between functions of z and 1 –z

UNIT-IV **13 Hours**

Series Solution : Ordinary point and singularity of a second order linear differential equation in the complex plane; Fuch's theorem, solution about an ordinary point, solution of Hermite equation as an example; Regular singularity, Frobenius' method – solution about a regular singularity, solutions of hypergeometric, Legendre, Laguerre and Bessel's equation as examples.

Reference Books:

1. Rainville, E. D. *Special Functions.* New York: The Macmillan co., 1971.
2. Lebdev, N. N. *Special Functions and Their Applications*. New Jersey: Prentice Hall, Englewood Cliffs, 1995.
3. Saran, N., S. D. Sharma, and T. N. Trivedi. *Special Functions with Application*. Meerut: Pragati Prakashan, 7th Edition, 2000.
4. Srivastava, H.M., K.C. Gupta, and S.P. Goyal. *The H-functions of one and two variables with applications*. New Delhi: South Asian Publication, 1982.

Course Title: Algebraic Topology
Paper Code: MTH 650

L	T	P	Credits
4	0	0	4

Objective: The aim of the unit is to give an introduction to algebraic topology. Algebraic Topology concerns constructing and understanding topological spaces through algebraic, combinatorial and geometric techniques. In particular, groups are associated to spaces to reveal their essential structural features and to distinguish them.

UNIT-I **12 Hours**

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.

UNIT-II **13 Hours**

Retractions and fixed points, The Fundamental theorem of Algebra, The Borsuk - Ulam theorem, The Bisection theorem, Deformation Retracts and Homotopy type, Homotopy invariance.

UNIT-III **12 Hours**

Direct sums of Abelian Groups, Free products of groups, uniqueness of free products, least normal subgroup, free groups, generators and relations, Van Kampen theorem, also classical version, The Fundamental group of a wedge of circles.

UNIT-IV **13 Hours**

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

Reference Books:

1. Rotman, J. J. *An Introduction to Algebraic Topology.* New York: Springer, 1988.
2. Hatcher, A. E. *Algebraic Topology.* Cambridge: Cambridge University Press, 2002.
3. Munkres, James R. *Topology*. New Jersey: Prentice Hall, Upper Saddle River, 2000.
4. Dieck, T. T. *Algebraic Topology*. London: European Mathematical Society, 2008.

Course Title: Commutative Algebra
Paper Code: MTH 651

L	T	P	Credits
4	0	0	4

Objective: This course will give the student a solid grounding in commutative algebra which is used in both algebraic geometry and number theory.

UNIT-I **12 Hours**

Rings and ideals - Rings and ring homomorphism, Ideals, quotient rings, zero-divisors, nilpotent elements, units, The prime spectrum of a ring, the nil radical and Jacobson radical, operation on ideals, extension and contraction.

UNIT-II **13 Hours**

Modules - Modules and modules homomorphism, sub-modules and quotient modules, direct sums, free modules, finitely generated modules, Nakayama Lemma, simple modules, exact sequences of modules, Tensor product of modules.

UNIT-II **12 Hours**

Rings and Modules of fractions, Local properties, extended and contracted ideals in ring of fractions, primary decomposition, 1st uniqueness theorem, 2nd uniqueness theorem.

UNIT-IV **13 Hours**

Modules with chain conditions - Artinian and Noetherian modules, modules of finite length, Artnian rings, Noetherian rings, Hilbert basis theorem.

Reference Books:

1. Atiyah, M. F. and I.G. Macdonald. *Introduction to Commutative Algebra*. London: Addison-Wesley, 1969.
2. Musili, C. *Introduction to Rings and Modules.* New Delhi: Narosa Publishing House, 1994.
3. Reid, Miles. *Under-graduate Commutative Algebra*, Cambridge, UK: Cambridge University Press, 1996.
4. Gopalakrishnan, N. S. *Commutative Algebra*. New Delhi: Oxonian Press, 1984.
5. Dummit, David S., and M. Foote Richard. *Abstract Algebra*. Hoboken, NJ: John Wiley & Sons, Inc., 2004.
6. Matsumura, H. *Commutative Ring Theory*. Cambridge, UK: Cambridge University Press, 1989.

Course Title: Continuum Mechanics
Paper Code: MTH 652

L	T	P	Credits
4	0	0	4

Objectives:
The objective of this paper is to introduce the concept of strains tensors, stress tensors and basic concepts of elastic body deformation and to make students familiar about the constitutive relations and field equations. Dynamics of elastic bodies and basic problems related to elastic wave propagation are also introduced.

UNIT-I **12 Hours**

Tensors: Summation convention, coordinate transformation, tensors of several orders, algebra of tensors, symmetric and skew-symmetric tensors, Kronecker's delta, Gradient, Divergence, Curl tensor notations, contra-variant and covariant tensors.

UNIT-II **11 Hours**

Stress and Strain: Deformation in elastic bodies, affine transformation, strain-displacement relation, principal direction, stress and strain tensors, components of stress and strain, generalised Hooke's Law- relation between stress and strain, elastic constants and their physical significance.

UNIT-III **11 Hours**

Dilatation and Distortion waves: Two dimensional propagation of elastic waves in isotropic solid, waves of dilatation and waves of distortion, equation of motion in classical theory of elasticity, Helmholtz decomposition theorem.

UNIT-IV **12 Hours**

Surface Waves: Introduction to surface waves, Rayleigh and Love waves, Frequency equations of Rayleigh waves and Love waves.

Reference Books:

1. Narayan, S. *A text book of Cartesian Tensors (with an introduction to general tensors), 3rd Edition*. New Delhi: S. Chand publications, 1968.
2. Young, E.C. *Vectors and tensor analysis, 2nd Edition*. USA: CRC Press, 1993.
3. Sokolnikoff, I.S. *Mathematical theory of elasticity, 2nd Edition*. New York: McGraw-Hill, 1982.
4. Kolsky, H. *Stress waves in Solids, 2nd Edition*. USA: Dover Publications, Reprint 2002.
5. Ghosh, P.K. *Mathematics of waves and vibrations*. New Delhi: The Macmillan Company of India Ltd., 1975.
6. Ewing, W.M., W.S. Jardetzky, and F. Press. *Elastic waves in layered media*, New-York: McGraw-Hill Book Co., 1957.

Course Title: Advanced Operational Research
Paper Code: MTH 653

L	T	P	Credits
4	0	0	4

Objective:
To acquaint the students with the concepts of convex and non-convex functions, their properties, various optimality results, techniques to solve nonlinear optimization problems and their duals over convex and non-convex domains.

UNIT-I **14 Hours**

Queuing Theory: Introduction, Queuing System, elements of queuing system, distributions of arrivals, inter arrivals, departure service times and waiting times. Classification of queuing models, Queuing Models**:** (M/M/1): (∞/FIFO), (M/M/1): (N/FIFO), Generalized Model: Birth-Death Process, (M/M/C): (∞/FIFO), (M/M/C) (N/FIFO).

UNIT-II **14 Hours**

Inventory Control: The inventory decisions, costs associated with inventories, factors affecting Inventory control, Significance of Inventory control, economic order quantity (EOQ), and Deterministic inventory problems without shortage and with shortages, EOQ problems with Price breaks, Multi item deterministic problems.

UNIT-III **13 Hours**

Network Analysis-Shortest Path Problem, Minimum Spanning Tree Problem, Maximum Flow Problem, Minimum Cost Flow Problem. Project scheduling by PERT/CPM: Introduction, Basic differences between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM network Components and Precedence Relationships, Critical Path analysis, Probability in PERT analysis.

UNIT-IV **14 Hours**

Non Linear Programming –One and Multi Variable Unconstrained Optimization, Kuhn-Tucker Conditions for Constrained Optimization, Quadratic Programming, Separable Programming Convex programming. Non Convex Programming.

Reference Books:

1. Taha, H. A. *Operations Research - An Introduction (8th edition).* New York: Macmillan Publishing Co. 2006.
2. Swarup, K., P. K. Gupta and M. Mohan. *Operations Research.* New Delhi: Sultan Chand & Sons, 2001.
3. Hadly, G. *Non-Linear and Dynamic Programming.* New Delhi: Addision Wesley, Reading Mass. 1967.
4. Rao, S.S. *Optimization theory and Applications (4th edition).* New Delhi: Wiley Eastern Ltd. 2009.