

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 2021–2022 Session Onwards
Syllabi Applicable for Admissions in 2021**

Mission of the course

The mission of the M.Sc. (Hons.) Mathematics is to provide graduate students with a strong foundation that leads to success in subsequent careers and educational programs. This is achieved by developing the habit among our students to apply mathematics to real life situations. This very course in Mathematics aims:

- At developing mathematical ability among students with acute and abstract reasoning.
- To provide a broad and comprehensive knowledge of core areas of pure and applied mathematics.
- To enable students to cultivate a mathematician's habit of thought and reasoning.
- To enlighten students with mathematical ideas relevant to the course.
- To prepare students to work as professional mathematicians either in academia or elsewhere.
- To create, analyze, and interpret mathematical models and to communicate sound arguments based on mathematical reasoning and careful data analysis.

Programme Learning Outcomes

At the completion of this course, the students will be able to

- Understand the areas of pure and applied mathematics including geometry, algebra, mathematical analysis and discrete mathematics, numerical methods and differential equations.
- Solve problems in the advanced areas of mathematics
- Explain why mathematical thinking is valuable in daily life.
- Read, analyse, and write logical arguments to prove mathematical concepts.
- Communicate mathematical ideas with clarity and coherence, both written and verbally.
- Perform research in conjunction with others as well as individually.
- To use technological tools such as MATLAB for visualizations and calculations of various mathematical concepts.
- To write programs from the underlying algorithms, and demonstrate the ability to employ good commenting and coding techniques.

M.Sc. (HONS) MATHEMATICS

Semester 1

S. No	Course Code	Course Type	Course Title	L	T	P	Cr
1	MTH 549	Core	Mathematical Methods	5	0	0	5
2	MTH 550	Core	Real Analysis	5	0	0	5
3	MTH 558	Core	Differential Geometry	5	0	0	5
4	MTH 553	Core	Linear Algebra	5	0	0	5
5	Interdisciplinary Course-I						4
Total							24

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

M.Sc. (HONS)MATHEMATICS

Semester 2

S. No	Course Code	Course Type	Course Title	L	T	P	Cr
1	MTH 555	Core	Complex Analysis	5	0	0	5
2	MTH 556A	Core	Lebesgue Measure and Integration	5	0	0	5
3	MTH 557A	Core	Mathematical Statistics	5	0	0	5
4	MTH 552	Core	Algebra-I	5	0	0	5
5	MTH 562A	Core	Numerical Analysis	4	0	0	4
6	MTH 563A	Core	Numerical Analysis Lab	0	0	4	2
Total							26

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

M.Sc. (HONS) MATHEMATICS

Semester 3

S.No.	Course Code	Course Type	Course Title	L	T	P	Cr
1	MTH 661	Core	Topology	5	0	0	5
2	MTH 662	Core	Algebra-II	5	0	0	5
3	MTH 663	Core	Ordinary Differential Equations	5	0	0	5
4	Department Elective-I						5
5	Interdisciplinary Course-II						4
	Total						24
Departmental Elective-I(Choose any one course)							
6	MTH 660	Elective	Integral Equations-I	5	0	0	5
7	MTH 664	Elective	Operations Research-I	5	0	0	5
8	MTH 665	Elective	Fluid Mechanics-I	5	0	0	5
9	MTH 666	Elective	Discrete Mathematics	5	0	0	5

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

M.Sc. (HONS) MATHEMATICS

Semester 4

S.No.	Course Code	Course Type	Course Title	L	T	P	Cr
1	MTH 667	Core	Functional Analysis	5	0	0	5
2	MTH 668	Core	Number Theory	5	0	0	5
3	MTH 675	Core	Classical Mechanics	5	0	0	5
4	MTH 677	Core	Partial Differential Equations	5	0	0	5
5	Departmental Elective-II**						5
	Total						25
Departmental Elective (Choose any one course)							
6	MTH 671	Elective	Operations Research-II	5	0	0	5
7	MTH 672	Elective	Fluid Mechanics-II	5	0	0	5
8	MTH 673	Elective	Algebraic Topology	5	0	0	5
9	MTH 674	Elective	Category Theory	5	0	0	5
10	MTH 676	Elective	Integral Equations-II	5	0	0	5
11	MTH 678	Elective	Advanced Complex Analysis	5	0	0	5

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

** Students of fourth semester can choose the elective course from the list of elective courses provided below third and fourth semester.

Course Title: Mathematical Methods
Course Code: MTH 549

L	T	P	Credits
5	0	0	5

Objective: The objective of this paper is to introduce the concept of variation of functional and variational techniques. Two units are also devoted to acquaint the students with the applications of Laplace and Fourier Transform.

UNIT-I **15 HOURS**

Functional and its properties, Variation of functional, proximity of curves, Motivational problems of calculus of variation, Fundamental lemma of calculus of variation, derivation of Euler's equation for one dependent variable and its alternative forms, invariance of Euler's equation under co-ordinate transformation; Shortest distance in a plane, Minimum surface of revolution, Brachistochrone problem, Geodesics.

UNIT-II **15 HOURS**

Variational problems for functionals involving several dependent variables and higher order derivatives, functional involving functions of several independent variables, variational problems in parametric form, isoperimetric problems, Variational problems with moving boundaries- One end point is fixed and the other is movable, both the end points movable, Variational problem with a moving boundary for a functional dependent on two functions; Approximate solutions of Boundary Value Problem- Rayleigh-Ritz method.

UNIT-III **15 HOURS**

Laplace Transform- Definition and sufficient conditions for its existence, basic properties of the Laplace transform, shifting theorems, Laplace transform of derivatives and integrals, Unit step function, Dirac's delta function; Inverse Laplace transform- Definition and its uniqueness, shifting theorems, inverse Laplace transform of derivatives and integrals, the convolution theorem; Applications of Laplace Transform- Solution of ordinary differential equations and simultaneous ordinary differential equations, solution of boundary value problems.

UNIT-IV **15 HOURS**

Fourier series, Even and odd functions- Half range expansions, Fourier integral theorem, Fourier cosine and sine transforms, Fourier Transform-Introduction, Dirichlet's conditions, Inversion formula for inverse Fourier sine and cosine transform, relationship between Fourier and Laplace transform, the convolution for Fourier transform, Parseval's identity, Fourier transforms of derivatives and integrals, applications of infinite Fourier transforms to boundary value problems.

Reference Books:

1. Elsgolts, L. *Differential Equations and the Calculus of Variations*. University Press of the Pacific, 2003
2. Galfand, I. M. and Fomin, S. V. *Calculus of Variation*. Dover Publications, 2000.
3. Edwards, C. Henry and Penney, David E. and Calvis, David, *Differential Equations and Boundary Value Problems: Computing and Modeling*, Pearson, 2014.
4. Hildebrand, F. B. *Methods of Applied Mathematics*, Dover Publications, 1965.
5. Debnath, L. and Bhatta, D. *Integral Transforms and their Applications*. CRC Press, 2015.

Course Title: Real Analysis
Course Code: MTH 550

L	T	P	Credits
5	0	0	5

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

UNIT-I

15 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.

UNIT-II

15 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.

UNIT-III

16 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

Functions of several variables: Linear Transformations, Differentiation, The contraction principle, The Inverse function theorem. The implicit function theorem.

Reference Books:

1. Rudin, W. *Principles of Mathematical Analysis, 3rd Edition*. New Delhi: McGraw-Hill Inc., 2017.
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, 2nd Edition 1974.
4. Bartle R. G. and Sherbert D. R., *Introduction to Real Analysis, 3rd Ed.*, John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
5. Malik S. C. and Arora S. *Mathematical Analysis*, New Age International (P) Ltd, New Delhi, 3rd Edition, 2008.

Course Title: Differential Geometry
Course Code: MTH 558

L	T	P	Credits
5	0	0	5

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

16 HOURS

Vectors in the Euclidean space, Review of the basics of vector calculus, Level Curves vs Parametrized Curves, Arc length Reparametrisation, Plane Curves: curvature, osculating circles, Rigid motions, Fundamental theorem of plane curves, Space Curves: curvature, torsion and the Frenet frame, Fundamental theorem of space curves.

UNIT-II

14 HOURS

Simple Closed Curves, Rotation index, The Isoperimetric Inequality, Surfaces in three dimensions: Surface, Smooth Surfaces. Tangents, Normals and Orientability. Quadric Surfaces. Triply Orthogonal Systems, Application of Inverse Function Theorem.

UNIT-III

16 HOURS

The First Fundamental Form: Lengths of Curves on Surfaces, Isometries of Surfaces. Conformal mappings of Surfaces, Surface Area. Equiareal maps and a Theorem of Archimedes. The Second Fundamental Form. The curvature of Curves on a Surface. The Normal and Principal Curvature. Geometrical interpretation of Principal Curvature.

UNIT-IV

14 HOURS

The Gaussian and Mean Curvatures. The Pseudosphere. Flat Surfaces. Surfaces of constant Mean Curvature. Gaussian Curvature of compact Surfaces. The Gauss Map. Geodesic Equations.

Reference Books:

1. Willmore, T. J. *Introduction to Differential Geometry*. Oxford University Press India, 1997.
2. Pressley, Andrew. *Elementary Differential Geometry*. Springer, 2004.
3. Weatherburn, C. E. *Differential Geometry of Three Dimensions*. Nabu Press, 2011.
4. Berger, M. *A Panoramic View of Riemannian geometry*. Springer, 2003.
5. Prakash, N. *Differential Geometry: An Integrated Approach*. US: McGraw-Hill Inc, 1982.

Course Title: Linear Algebra
Course Code: MTH 553

L	T	P	Credits
5	0	0	5

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 **15 HOURS**

Review-Matrices. 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 **15 HOURS**

Eigen values and Eigenvectors, Characteristic and minimal polynomials, companion matrix, Cayley Hamilton Theorem, Matrix representation of Linear Transformation, Change of Basis.

UNIT-III **15 HOURS**

Canonical forms, Diagonal forms, triangular forms, Rational and Canonical Jordan Forms. Eigen spaces and similarity, Linear functional, Dual Spaces and dual basis, the double dual,

UNIT-IV **15 HOURS**

Inner Product Spaces, Norms and Distances, Orthonormal basis, The Gram-Schmidt Orthogonalization, Orthogonal complements. The Adjoint of a Linear operator on an inner product space, Normal and self-Adjoint Operators, Unitary and Normal Operators.

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.
5. Singh, S. *Linear Algebra*. New Delhi: Vikas Publishing, 2009.

Course Title: Complex Analysis
Course Code: MTH 555

L	T	P	Credits
5	0	0	5

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

15 HOURS

Complex plane, Stereographic projection, Riemann sphere, Function of complex variables, Continuity and Differentiability, Analytic functions, Conjugate function, Harmonic function, Cauchy Riemann equations (Cartesian and Polar form). Construction of analytic functions. Elementary Functions, Branch cut and Branch point.

UNIT-II

15 HOURS

Complex line integral, Cauchy's theorem, Cauchy's integral formula and its generalized form. Cauchy's inequality. Morera's theorem. Liouville's theorem, Fundamental theorem of Algebra, Maximum modulus Principle. Power series, Taylor's theorem, Laurent's theorem.

UNIT-III

15 HOURS

Singularities, Residues, Cauchy's Residue theorem, Residue at infinity, Classification of Isolated singularity, Residues at Poles. Zeros of Analytic functions, Zeros and Poles. Argument principle and Rouche's theorem.

UNIT-IV

15 HOURS

Applications of Residues: Evaluation of Improper Integrals. Jordan's Lemma. An indentation around a Branch point, Definite integrals involving Sine and Cosine. Elementary transformations, conformal transformation, bilinear transformation, critical points, fixed points, Cross ratio problems.

Reference Books:

1. Churchill, R. V. and J. W. Brown. *Complex Variables and Applications*. New Delhi: Tata McGraw Hill International, 9th Edition, 2013.
2. Copson, E. T. *Theory of functions of complex variables*. U.K.: Oxford University Press, 1970.
3. Ahlfors, L. V. *Complex Analysis 2nd Edition*. New Delhi: McGraw Hill, 1966.
4. Conway, J. B. *Functions of one complex variable*. New York: Springer Verlag, 1978.
5. Ponnusamy, S. *Foundation of Complex Analysis, 2nd Edition*. New Delhi: Narosa Publishing House Pvt. Ltd, 2011.
6. Zill, D. G. and P. D. Shanahan. *A First Course in Complex Analysis with Applications, 3rd Edition*. Massachusetts: Jones and Bartlett Publishers, 2013.

Course Title: Lebesgue Measure and Integration
Course Code: MTH 556A

L	T	P	Credits
5	0	0	5

Objective: The objective of this course is to study Lebesgue measure as generalization of lengths, Lebesgue integration and differentiation. General L^p spaces are also studied.

UNIT-I

15 HOURS

Lebesgue Measure: Introduction, classes of subsets of a set- algebra, σ -algebra, set function. Lebesgue outer measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesgue measurability, Non-measurable sets. Littlewood's three principles.

UNIT-II

15 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

15 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

15 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. Jain, P. K., V. P. Gupta and P. Jain. *Lebesgue Measure and Integration*. New Delhi: New Age International Publications, 2019.
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, 1st Edition 2013.

Course Title: Mathematical Statistics

Course Code: MTH 557A

L	T	P	Credits
5	0	0	5

Objective: The course is designed to equip the students with various probability distributions and to develop greater skills and understanding of sampling distribution and hypothesis Testing.

UNIT-I

15 HOURS

Random Variables and Distribution Functions: 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

15 HOURS

Discrete probability distributions: Bernoulli, Binomial, Poisson, Geometric and Negative Binomial distributions and their properties.

Continuous probability distributions: Uniform, normal, beta distribution of first and second kind, gamma, exponential distributions and their properties.

UNIT-III

15 HOURS

Sampling Theory: Types of Sampling- Simple, Stratified, Systematic, Errors in sampling, Parameter and Statistics.

Exact Sampling Distributions: Chi-square distribution, Student's-t distribution, Snedecor's F-distribution, Fisher's – Z distribution.

UNIT-IV

15 HOURS

Hypothesis Testing: Tests of significance for small samples, Null and Alternative hypothesis, Critical region and level of significance, Tests of hypotheses: most powerful and uniformly most powerful tests, likelihood ratio tests. Tests of significance based on t, Z and F distributions, Chi square test of goodness of fit. Large Sample tests, Sampling of attributes, Tests of significance for single proportion and for difference of proportions, Sampling of variables, tests of significance for single mean and for difference of means and for difference of standard deviations.

Reference Books:

1. Hogg Robert V., JoeseephMcKlean, and Allen T Craig. *Introduction to Mathematical Statistics*. London: Pearson Education Limited, 8th Edition 2019.
2. Gupta, S. C., and V. K. Kapoor. *Fundamentals of Mathematical Statistics*. Sultan Chand & Sons: New Delhi, 2020.
3. J.S. Milton and J.C. Arnold, *Introduction to Probability and Statistics*, Fourth Edition, McGraw Hill 2006.
4. Lehmann, E. L., & Casella, G. *Theory of point estimation* (Vol. 31). Springer Science & Business Media, 1998.
5. Mood, A.M., Graybill, F.A. and Boes, D.C. *Introduction to the Theory of Statistics*, 3rd Edition, McGraw-Hill series, New York, 1974.

Course Title: Algebra-I
Course Code: MTH 552

L	T	P	Credits
5	0	0	5

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 662.

UNIT-I **15 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 conjugacy classes.

UNIT-II **15 HOURS**

Simple groups and their examples, simplicity of A_n ($n \geq 5$). Normal and Subnormal Series, Derived Series, Composition Series and Solvable Groups.

UNIT-III **16 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 **14 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*. Vikas Publishing House, New Delhi: 2006.
3. Singh, Surjeet, and Q. Zameeruddin, *Modern Algebra, 8th Edition*. New Delhi: Vikas Publishing House, 2006.
4. Dummit, David. S., and Richard M. Foote, *Abstract Algebra, 3rd Edition*. New Delhi: Wiley, 2011.
5. Malik D. S., J. N. Mordeson and M. K. Sen. *Fundamentals of Abstract Algebra*, McGraw-Hill, New York: 1997.
6. Luthar I. S. and I. B. S. Passi, *Algebra Vol. 2*, Narosa Publishing House, New Delhi: 1999.

Course Title: Numerical Analysis
Course Code: MTH 562A

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-I **15 HOURS**

Solution of non-linear equations: Review of Bisection, Regula-falsi and Secant methods, Functional Iteration method, Newton-Raphson method and its family, Muller's method. Rate of convergence of these methods. Simultaneous non-linear equations by Newton-Raphson method. Newton's method for complex roots and multiple roots.

UNIT-II **15 HOURS**

Interpolation: Finite difference operators, divided differences, Newton's formulae for interpolation, Lagrange interpolation, Inverse interpolation, Hermite interpolation, cubic spline interpolation. Numerical differentiation.

Central Difference Interpolation Formulae: Gauss's central difference formulae, Stirling's formula.

UNIT-III **15 HOURS**

Solution of Linear system of equations: Gauss-elimination method, Gauss-Jordan method, Factorization method. Concept of partial and complete pivoting.

Eigen Values and Eigen Vectors: Power method, Jacobi's method, Given's method, House-Holder's method.

Curve fitting (Method of Least squares): Linear and non-linear curve fitting, fitting of exponential curve.

UNIT-IV **15 HOURS**

Numerical integration: Boole's rule, Weddle's rule. Romberg Integration. Numerical Double Integration.

Solution of Ordinary Differential Equations: Picard method of Successive approximations, Euler's method, Runge-Kutta method of order four, Predictor – Corrector methods: Milne's method, Adam's method, Finite Difference Method for boundary value problems (BVP), Shooting method for BVP.

Reference Books:

1. Conte S. D. and C. Deboor. *Elementary Numerical Analysis: An Algorithmic Approach. 3rd Edition*, McGraw Hill Education, 2005.
2. Jain, M.K., Iyenger, S. R. K. and R. K. Jain. *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. Shastri, S. S. *Introductory Methods of Numerical Analysis*. New Delhi: PHI Learning Private Limited, 2005.

Course Title: Numerical Analysis Lab
Course Code: MTH 563A

L	T	P	Credits
0	0	4	2

Objective: Writing Programs in C/C++ /MATLAB for the problems based on the methods studied in theory paper and to run the Program on PC.

List of Practicals:

1. Matrix Multiplication
2. Newton-Raphson method and error analysis
3. Muller's method
4. Lagrange Interpolation
5. Numerical differentiation
6. Gauss-Jordan method
7. Factorization method
8. Power method for eigen value problem
9. Boole's Rule
10. Weddle's Rule
11. Double integration
12. Euler's method
13. Runge-Kutta method of order four
14. Predictor-Corrector methods
15. Shooting method

Reference Books:

1. Pratap, R. *Getting Started with MATLAB, 7th Edition*, Oxford University Press, New Delhi, 2019.
2. Chapman, S.J., *MATLAB Programming for Engineers, 4th Edition*, Cengage Learning, Boston, USA. 2015.
3. Jain, M.K., Iyenger, S. R. K. and R. K. Jain. *Numerical Methods for Scientific and Engineering Computation*. Delhi: New Age International Publishers, 2012.

Course Title: Integral Equations-I
Course Code: MTH 660

L	T	P	Credits
5	0	0	5

Objective: The objective of the course module is to study Integral Equations and to know that what is the relationship between the integral equations and ordinary differential equations and how to solve the linear and non-linear integral equations by different methods with some problems which give rise to Integral Equations.

UNIT-I

15 HOURS

Basic Concepts: Abel's Problem, Initial value problem, Boundary value problem, Integrals equations, Classification of integral equations, Iterated kernel, resolvent kernel, Eigenvalues and eigenfunctions, Solution of an integral equation, Applications to ordinary differential equations: Method of conversion of initial value problem to a Volterra integral equation, Boundary value problem and its conversion to Fredholm integral equation.

UNIT-II

15 HOURS

Fredholm Integral Equations: Introduction, The Adomian decomposition method, The Modified decomposition method, The variational iteration method, The direct computation method, The successive approximations method, The method of successive substitutions, Comparison between alternative methods, Solution of Fredholm Integral Equations of second kind with separable kernel.

UNIT-III

15 HOURS

Volterra Integral Equations: The Adomian decomposition method, the modified decomposition method, the variational iteration method, the series solution method, Converting Volterra equation to IVP, Successive approximations method, The method of successive substitutions, Comparison between alternative Methods.

UNIT-IV

15 HOURS

Volterra Integral Equations of the First Kind: The series solution method, Conversion of first kind to second kind, Resolvent kernel and Volterra Integral Equation, Fredholm's first theorem, working rule for evaluating the resolvent kernel and solution of Fredholm Integral Equation of second kind using Fredholm's first theorem, Fredholm's second fundamental theorem.

Reference Books:

1. Wazwaz, A. M. *A First Course in Integral Equations*. London: World Scientific, 2015.
2. Moiseiwitsch, B. L. *Integral Equations*. New York: Pitman press, Bath Ltd. 1977.
3. Jerry, A. *Introduction to Integral Equations with Applications*. Wiley Publication, 1999.
4. Kanwal, R. P. *Linear Integral Equations*. Birkhauser, 1997.
5. Hildebrand, F. B. *Methods of Applied Mathematics*, Dover Publications, 1965.

Course Title: Topology
Course Code: MTH 661

L	T	P	Credits
5	0	0	5

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

15 HOURS

Cardinals: Equipotent sets, Countable and Uncountable sets, Cardinal Numbers and their Arithmetic, Bernstein's Theorem and the Continuum Hypothesis.

Topological Spaces: Definition and examples, basis for a topology, the order topology, the product topology on $X \times Y$, the Subspace topology, open sets, closed sets and limit points, continuous functions, Pasting Lemma.

UNIT-II

15 HOURS

The metric topology, the quotient topology. Connectedness: Connectedness and its characterizations, Continuous image of connected sets, Connectedness of Product Spaces, Applications to Euclidean spaces. Components, Local Connectedness and Components, Product of Locally Connected Spaces. Path Connectedness.

UNIT-III

14 HOURS

Compactness: Compactness, Compactness in metric spaces, Local Compactness, One-point Compactification, T_0 , T_1 , and T_2 spaces.

UNIT-IV

16 HOURS

Higher Separation Axioms: Normal spaces, regular spaces, completely regular spaces, the Urysohn Lemma, Countability axioms, Stone-Čech compactification, the Tietze Extension Theorem.

Reference Books:

1. Munkers, James R. *Topology*. Delhi: Prentice Hall of India, 2nd Edition, 2015.
2. Dugundji, J. *Topology*. USA: William C Brown Pub, 1990.
3. Simmons, G.G. *Introduction to Topology and Modern Analysis*. USA: Krieger Publishing Company, 2003.
4. Kelley, J. L. *General Topology*. Dover Publications, 2017.
5. Joshi, K. D. *Introduction to General Topology*. New Delhi: New Age International, 2017.

Course Title: Algebra-II
Course Code: MTH 662

L	T	P	Credits
5	0	0	5

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 **15 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 **15 HOURS**

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

UNIT-III **15 HOURS**

Adjunction of roots. Splitting fields. Normal extensions. Finite fields. Algebraically closed fields.

UNIT-IV **15 HOURS**

Galois extensions. The fundamental theorem of Galois Theory, Separable and purely inseparable extensions. Perfect fields.

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: Ordinary Differential Equations
Course Code: MTH 663

L	T	P	Credits
5	0	0	5

Objective: The objective of this course is to equip the students with fundamental knowledge and problem solving skills in Power series methods of solution of ODE, Existence and Uniqueness theory of Initial Value Problems and Solution of system of differential equations.

UNIT-I

14 HOURS

Review of fundamentals of Ordinary differential equations. The method of successive approximation. Initial value problem, Ascoli's Lemma, Gronwall's inequality, Cauchy Peano Existence Theorem, Picard's existence and uniqueness theorem, Lipschitz condition.

UNIT-II

16 HOURS

Linear system of equations (homogeneous & non-homogeneous). Superposition principle, Fundamental set of solutions, Fundamental Matrix, Wronskian, Abel Liouville formula, Reduction of order, Adjoint systems and Self Adjoint systems of second order. Linear 2nd order equations, preliminaries, Sturm's separation theorem, Sturm's fundamental comparison theorem.

UNIT-III

15 HOURS

Orthogonal set of functions, Orthonormal set of functions, Gram-Schmidt process of orthonormalization, Sturm Liouville's boundary value problems, Orthogonality of Eigenfunctions and reality of Eigenvalues. Adjoint forms, Lagrange identity, Green function to solve boundary value problems.

UNIT-IV

15 HOURS

Power series solution of differential equation about an ordinary point, Solution about regular singular points: The method of Frobenius, Applications, Legendre's, Hermite's and Bessel's equation. Ordinary differential equations in more than two variables: Simultaneous Differential equations of the first order and the first degree in three variables, Methods of their solution and applications.

Reference Books:

1. Coddington, E. *An Introduction to Ordinary Differential Equations*. Prentice-Hall of India Private Ltd., New Delhi, 2001.
2. Ross, S. L. *Differential Equations*. New Delhi: John Wiley and Sons, 2004.
3. Boyce and Diprima, R. C. *Elementary Differential Equations*, Wiley, 2008.
4. Piaggio, H. T. H. *Differential Equations*. New Delhi: CBS Publisher, 2004.
5. George, F Simmons. *Differential equations with applications and historical notes*. New Delhi: Tata McGraw Hill, 1974.
6. Sneddon, I. N. *Elements of Partial Differential Equations*. New Delhi: Tata McGraw Hill 1957.

Course Title: Operations Research-I
Course Code: MTH 664

L	T	P	Credits
5	0	0	5

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

15 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

15 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

15 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

15 HOURS

Integer Programming: Pure and mixed Integer Programming Problems, Cutting plane techniques, Branch and Bound Technique.

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., 20019.
2. Swarup, K., P.K.Gupta and M. Mohan. *Operations Research*. New Delhi: Sultan Chand & Sons, 2019.
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
Course Code: MTH 665

L	T	P	Credits
5	0	0	5

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

UNIT-I **15 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 **15 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 **16 HOURS**

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

UNIT-IV **14 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. Lifshitz. *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
Course Code: MTH 666A

L	T	P	Credits
5	0	0	5

Objective: 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

14 HOURS

Fundamentals of Logic: Basic connectives and truth tables. Logical equivalence, the laws of logic, rules of inference. The use of quantifiers, quantifiers, definitions and proof of theorems. Set theory: Basic operations, ordinal numbers, continuum hypothesis. Basic counting techniques.

UNIT-II

15 HOURS

Further Topics in Enumeration: The inclusion–exclusion principle, generalizations of the principle. The pigeonhole principle and generalized pigeon hole principle. Solution of recurrence relations, generating function.

UNIT-III

15 HOURS

Introduction to Graph Theory: The Handshaking Theorem. Connectivity of Graphs. Isomorphism of Graphs. Homomorphism Graphs. Eulerian and Hamiltonian Graphs. Planar and Non-Planar Graphs. Euler's formula. Graph Colouring. Trees: Basic Terminology. Binary Trees. Tree Traversing: Pre-order, Post-order and In-order Traversals. Minimum Spanning Trees, Prim's and Kruskal's Algorithm.

UNIT-IV

16 HOURS

Boolean algebra, Boolean Function, Switching circuit and Logic Gates, K-map. Lattice Theory: Lattices and Algebraic Structures, Lattice as algebraic structures, complete lattices, Sub-lattices, Homomorphism on lattices, Modular lattices.

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.
Grimaldi, R. P. *Discrete and Combinatorial Mathematics 5th Edition*. New York: Pearson, 1999.

Course Title: Functional Analysis
Course Code: MTH 667

L	T	P	Credits
5	0	0	5

Objective: The objective of this course is to introduce basic concepts, methods of Functional Analysis and its Applications. It is a first level course in Functional Analysis.

UNIT-I

14 HOURS

Review of Metric spaces, Holder inequality and Minkowski inequality, Vector spaces with examples, Normed Spaces with examples $l^p, l^\infty, C[a, b]$ etc, Banach Spaces & Schauder Basis, Incomplete normed spaces, Finite Dimensional Normed Spaces and Subspaces, Equivalent norms, Compactness of Metric/ Normed spaces, Riesz's Lemma for two subspaces of a Normed space.

UNIT-II

16 HOURS

Linear Operators- definition and examples, Range and Null space, Inverse Operator, Bounded and Continuous linear operators in a Normed Space, Bounded Linear Functionals in a Normed space with examples, Concept of Algebraic Dual and Reflexive space, Dual basis and Algebraic Reflexive space, Dual spaces with examples.

UNIT-III

17 HOURS

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

UNIT-IV

13 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 (Banach-Steinhaus Theorem), Open Mapping Theorem, Closed Graph Theorem, Strong and weak convergence, Contraction Theorem.

Reference Books:

1. Kreyzig, E., *Introductory Functional Analysis with Applications*. New York: John Wiley and Sons, 1989.
2. Limaye, B. V., *Functional Analysis*. New Delhi: New Age International (P) Ltd, 1996.
3. Rudin, W., *Functional Analysis*, Tata-McGraw Hill Pub. Co.
4. Nair, M. T., *Functional Analysis-A First Course*. New Delhi: Prentice- Hall of India Private Limited, 2008.
5. Simmons, G. F., *Introduction to topology and modern analysis*. New Delhi: Tata McGraw-Hill Education Private Limited, 2012.

Course Title: Number Theory
Course Code: MTH 668

L	T	P	Credits
5	0	0	5

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 **15 HOURS**

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

UNIT-II **15 HOURS**

Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Euler's theorem. Arithmetic functions $\sigma(n)$, $d(n)$, $\tau(n)$, $\mu(n)$, Order of an integer modulo n , primitive roots for primes, composite numbers having primitive roots, theory of indices.

UNIT-III **15 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 **15 HOURS**

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

Reference Books:

1. Burton, D.M. *Elementary Number Theory*, 7th Edition. New Delhi: Tata McGraw-Hill 2012.
2. Niven, I., S. Zuckerman, and H. L. Montgomery. *Introduction to Number Theory*. Wiley Eastern 1991.
3. Apostol, 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.

Course Title: Partial Differential Equations
Course Code: MTH 677

L	T	P	Credits
5	0	0	5

Objective: The objective of this course is to introduce the concepts of partial differential equations. To develop analytical techniques to solve partial differential equations. To understand the properties of solution of partial differential equations

UNIT-I

15 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, Charpit's Method and Jacobi's Method, Cauchy problem for first order PDE's.

UNIT-II

15 HOURS

Partial Differential Equations of Second and Higher Order: Origin of second order partial differential equations. Higher order partial differential equations with constant coefficients. Equations with variable coefficients. Classification of second order partial differential equations. Canonical forms. Solution of non-linear second order partial differential equations by Monge's method.

UNIT-III

15 HOURS

Method of Solution: Separation of variables in a PDE; Laplace, wave and diffusion equations, Elementary solutions of Laplace equations.

UNIT-IV

15 HOURS

Applications of PDE: Wave equation, the occurrence of wave equations, elementary solutions of one dimensional wave equation; vibrating membranes, three dimensional problems. Diffusion equation, resolution of boundary value problems for diffusion equation, elementary solutions of diffusion equation.

Reference Books:

1. Sneddon, I. N. *Elements of Partial Differential Equations*. New Delhi: Tata McGraw Hill 1957.
2. Rao, Sankara. K. *Introduction to Partial Differential Equations*, PHI Pvt. Ltd., 2010.
3. Strauss, W. A. *Partial Differential Equations: An Introduction 2nd Edition*, Wiley, 2007.
4. Evans, L. C. *Partial Differential Equations (Graduate Studies in Mathematics)*, American Mathematical Society; 2nd Edition, 2010.

Course Title: Operations Research-II
Course Code: MTH 671

L	T	P	Credits
5	0	0	5

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

15 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

15 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

15 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

15 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: Addison Wesley, Reading Mass. 1967.
4. Rao, S. S. *Optimization theory and Applications (4th edition)*. New Delhi: Wiley Eastern Ltd. 2009.

Course Title: Fluid Mechanics-II
Course Code: MTH 672

L	T	P	Credits
5	0	0	5

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

16 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

14 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

14 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

16 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.

References:

1. Charlton, F. *Text Book of Fluid Dynamics*. Delhi: GK Publishers, Reprint 2009.
2. Landau, L. D., and E. M. Lifshitz. *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: Algebraic Topology

Course Code: MTH 673

L	T	P	Credits
5	0	0	5

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

15 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

15 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

15 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

15 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: Category Theory
Course Code: MTH 674

L	T	P	Credits
5	0	0	5

Objective: The objective of this course is to introduce the basic concepts of modern Category Theory.

UNIT-I

15 HOURS

Categories: Introduction with Functions of Sets, Definition and examples of Categories: Sets, Pos, Rel, Mon, Groups, Top, Dis (X), Finite Category, Abstract Mappings, Additive Categories, The category of modules, The concept of functor and the category Cat, Functors of several variables. Isomorphism. Constructions: Product of two categories, The Dual Category, The Arrow Category, The Slice and Co- Slice Category.

Free Categories: Free Monoids and their Universal Mapping Property, The category Graphs, the category C (G) generated by a graph, Homomorphism of Graphs and the Universal Mapping Property of C (g).

UNIT-II

15 HOURS

Abstract Structures: Epis and mono, Initial and Terminal objects, Generalized elements, Sections and Retractions, Product diagrams and their Universal Mapping Property, Uniqueness up to isomorphism, Examples of products: Product of Sets, Product in Cat, Poset, Product in Top. Categories with Products, Hom-Sets, Covariant representable functors, Functors preserving binary product.

UNIT-III

15 HOURS

Duality: The duality principle, Formal duality, Conceptual duality, Coproducts, Examples in Sets, Mon, Top, Coproduct of monoids, of Abelian Groups and Coproduct in the category of Abelian Groups. Equalizers, Equalizers as a monic, Coequalizers, Coequalizers as an epic. Coequalizer diagram for a monoid.

Groups and Categories: Groups in categories, topological group as a group in Top. The category of groups, Groups as categories, Congruence on a category, quotient category and its univalent mapping property, finitely presented categories.

UNIT-IV

15 HOURS

Limits and Co-limits: Subobjects, Pullbacks, Properties of Pullbacks, Pullback as a functor, Limits, Cone to a diagram, limit for a diagram, Co-cones and Colimits. Preservation of limits, contra variant functors. Direct limit of groups. Functors Creating limits and co-limits.

Reference Books:

1. Steven Awodey: Category Theory, (Oxford Logic Guides, 49, Oxford University Press.)

Course Title: Classical Mechanics
Course Code: MTH 675

L	T	P	Credits
5	0	0	5

Objective: The objective of this paper is to introduce classical mechanics with an emphasis on the understanding of the fundamentals. Lagrangian and Hamiltonian equations for dynamical systems are introduced at large. A small section is also devoted to rigid body dynamics.

UNIT-A

15 HOURS

Newton's laws of motion, its extensions to a system of particles and limitations; review of Work, power and energy; Constraints and their classification- Scleronomic and rheonomic, Holonomic and non-holonomic dynamical systems, conservative and dissipative, Examples of constraints; Virtual work- Virtual displacement, Principle of virtual work; D'Alembert's principle and its applications; Lagrangian formulation- Degrees of freedom, generalised coordinates, generalized force, generalized velocity, Expression of kinetic energy using generalized velocity, Lagrange's equation of motion, simple applications of the Lagrangian formulation.

UNIT-B

15 HOURS

Cyclic coordinates, Generalized momenta, conjugate momenta; Conservation theorems- conservation of linear momentum, conservation of angular momentum, conservation of energy; Hamilton's principle and Principle of least action, Difference between these principles, solving problems using these principles, Lagrange's equation from Hamilton's principle and vice-versa. Hamiltonian formulation- Legendre's dual transformations and its extension to include passive variables.

UNIT-C

15 HOURS

Hamilton's function and Hamilton's equations of motion, properties of Hamiltonian, simple applications of the Hamiltonian equations of motion, Routhian function and its use; Canonical transformation, Properties of generator functions, Poisson bracket- Jacobi identity for Poisson bracket, Poisson's theorem, Hamilton's equation in Poisson bracket. Invariance of Lagrange and Poisson brackets under canonical transformation.

UNIT-D

15 HOURS

Action-angle variables, Hamilton-Jacobi equation, Solution of H-J equation by method of separation of variables, Examples. Angular momentum of a rigid body, Kinetic energy of rotating body, Euler's dynamical equations, Symmetric top, Stability of vertical top. Eulerian angles.

Reference Books:

1. Goldstein H., C. Poole and J. Safko. *Classical Mechanics*, 3rd edition. Pearson Publications, New Delhi, 2011.
2. Rana N.C. and Joag P.S., *Classical Mechanics*. McGraw Hill Education, Chennai, 2016.
3. Chorlton F. *Text book of Dynamics*. CBS Publishers, Reprint, 2002.
4. Grantmacher F., *Lecture in analytical Mechanics*. Mir Publication, 1975.
5. Biswas S. N., *Classical Mechanics*, Books and Allied (P) Ltd. Calcutta, 1999.

Course Title: Integral Equations-II
Course Code: MTH 676

L	T	P	Credits
5	0	0	5

Objective: The objective of the course module is to study Integral Equations and to know that what is the relationship between the integral equations and ordinary differential equations and how to solve the linear and non-linear integral equations by different methods with some problems which give rise to Integral Equations.

UNIT-I

15 HOURS

Fredholm Integro-Differential Equations: Introduction, Fredholm Integro-Differential Equations, The Direct Computation Method, The Adomian Decomposition Method, The Modified Decomposition Method, The Noise Terms Phenomenon, The Variational Iteration Method, Converting to Fredholm Integral Equations.

UNIT-II

15 HOURS

Volterra Integro-Differential Equations: Introduction, Volterra Integro-Differential Equations, The Series Solution Method, The Adomian Decomposition Method, The Variational Iteration Method, converting to Volterra Integral Equation, Converting to Initial Value Problems, Volterra in taro-Differential Equations of the First Kind.

UNIT-III

15 HOURS

Nonlinear Fredholm Integral Equations: Introduction, Nonlinear Fredholm Integral Equations of the Second Kind, The Direct Computation Method, The Adomian Decomposition Method, The Variational Iteration Method, Nonlinear Fredholm Integral Equations of the First Kind, The Method of Regularization, Nonlinear Weakly-Singular Fredholm Integral Equations, The Modified Decomposition Method.

UNIT-IV

15 HOURS

Nonlinear Volterra Integral Equations: Introduction, Nonlinear Volterra Integral Equations of the Second Kind, The Series Solution Method, The Adomian Decomposition Method, The Variational Iteration Method, Nonlinear Volterra Integral Equations of the First Kind, The Series Solution Method, Conversion to a Volterra Equation of the Second Kind, Nonlinear Weakly-Singular Volterra Integral Equations, The Modified Decomposition Method.

Reference Books:

1. Wazwaz, A. M. *A First Course in Integral Equations*. London: World Scientific, 2015.
2. Moiseiwitsch, B. L. *Integral Equations*. New York: Pitman press, Bath Ltd. 1977.
3. Sharma, D. C. and Goyal, M. C. *Integral Equations*. PHI learning, 2017.
4. Zemyan, S. M. *The Classical Theory of Integral Equations: A Concise Treatment*. New York: Birkhäuser, 2012.

Course Title: Advanced Complex Analysis
Course Code: MTH 678

L	T	P	Credits
5	0	0	5

Objective: 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

15 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, Dirichlet Problem for a disc and uniqueness of its solution, Characterization of harmonic functions by Mean Value Property.

UNIT –II

15 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 $\wp(z)$ and their properties, The differential equation satisfied by $\wp(z)$ [i.e., the relation between $\wp(z)$ and $\zeta(z)$], Integral formula for $\wp(z)$, Addition theorem and Duplication formula for $\wp(z)$.

UNIT –IV

15 HOURS

Weierstrass Zeta function: Weierstrass Zeta function and their properties, Quasi periodicity of $\zeta(z)$, Weierstrass sigma function $\sigma(z)$ and their properties, Quasi periodicity of $\zeta(z)$, 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.