DAV UNIVERSITY, JALANDHAR

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

1st to 4th SEMESTER
Examinations 2024–2025 Session Onwards
Syllabi Applicable For Admissions in 2024

Department of Mathematics

Vision

The department envisions to impart quality mathematics education and to inculcate the spirit of research through innovative teaching and research methodologies. The goal of the department is to provide excellent knowledge of mathematical softwares and tools to equip the students with conceptual understanding and computational skills so that they can become proficient in mathematics to solve real life problems.

Mission

M1: Enhance the capacity for critical thinking, problem-solving skills, and effective communication of mathematical concepts.

M2: Understand the concepts of mathematics for developing the advanced formulation in learning areas of other disciplines.

M3: Provide the knowledge of mathematical tools to equip the students with required skills for research and employability.

PROGRAMME EDUCATIONAL OBJECTIVES (PEO's)

PEO1: To apply the fundamental knowledge of Mathematics, Science and Technology to solve real world problems and find solutions using the applications of Mathematics.

PEO2: To prepare the students for competitive examinations for the job roles of teaching positions.

PEO3: To inculcate the leadership qualities along with ethical attitude and teamwork skills.

PROGRAMME OUTCOMES (POs)

After the successful completion of the course, student will be able to:

PO1: Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2: Effective Communication: Speak, read, write and listen clearly in person and through electronic media in English and in one Indian language, and make meaning of the world by connecting people, ideas, books, media and technology.

PO3: Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings.

PO4: Effective Citizenship: Demonstrate empathetic social concern and equity centered national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

PO5: Ethics: Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them.

PO6: Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

PO7: Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

PROGRAMME SPECIFIC OUTCOMES (PSO's)

PSO1: Demonstrate a deep and comprehensive understanding of advanced mathematical theories, concepts, and methodologies across various branches of mathematics.

PSO2: To simulate and analyze real time problems using Mathematical models and find solutions using the application of Mathematics in Sciences, Engineering and Technology.

PSO3: To utilize computational tools and software, such as MATLAB, to perform numerical computations, visualize data, and solve mathematical problems efficiently.

Code	Definitions
L	Lecture
T	Tutorial
P	Practical
HS Courses	Humanities & Social Science
BS	Basic Science Courses
ES	Engineering Science Courses
PC	Program Core Courses
PE	Program Elective Courses
OE	Open Elective Courses
EEC	Employment Enhancement Courses (Project/Summer Internship/Seminar)
AEC-C	Ability Enhancement Course-Common
VAC-C	Value Added Course-Common

Mapping of PEO with PO

POs \ PEOs	PEO1	PEO2	PEO3
PO1	Y		Y
PO2	Y	Y	Y
PO3	Y		Y
PO4	Y		Y
PO5	Y	Y	Y
PO6	Y	Y	Y
PO7	Y	Y	Y

Mapping of PEO with PSO

PEOs \ PSOs	PSO1	PSO2	PSO3
PEO1	Y	Y	Y
PEO2	Y	Y	Y
PEO3	Y	Y	Y

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
6	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	Theory of 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*			4	0	0	4/2
	MTH600A*		Project*	0	0	0	
5	Interdisciplinary Course-II						4
	Total						23/21

Departmental Elective-I (Choose any one course)

S. No.	Course Code	Course Type	Course Title	L	T	P	Cr
6	MTH 660	Elective	Integral Equations-I	4	0	0	4
7	MTH 664	Elective	Operations Research-I	4	0	0	4
8	MTH 665	Elective	Fluid Mechanics-I	4	0	0	4
9	MTH 678	Elective	Advanced Complex Analysis	4	0	0	4
10	MTH 679	Elective	Module Theory and Galois Theory	4	0	0	4

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

***Top 20% students in the class can opt for the project, provided the student obtains a minimum CGPA of 8. Other students will study a department elective course of 4 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	CEC		Community Engagement Course	1	0	2	2
6	Departmental Elective-II**						4/6
	MTH600B		Research project**				
	Total						26/28

Departmental Elective (Choose any one course)

S. No.	Course Code	Course Type	Course Title	L	T	P	Cr
6	MTH 666A	Elective	Discrete Mathematics	4	0	0	4
7	MTH 671	Elective	Operations Research-II	4	0	0	4
8	MTH 672	Elective	Fluid Mechanics-II	4	0	0	4
9	MTH 673	Elective	Algebraic Topology	4	0	0	4
10	MTH 674	Elective	Category Theory	4	0	0	4
11	MTH 676	Elective	Integral Equations-II	4	0	0	4

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

**** The students with projects will do Project work (MTH600B) of 6 credits and the others will study Departmental Elective-II of 4 credits in the 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand Functional and its properties, Brachistochrone problem, Geodesics.
CO2: Understand Variational problems for functionals involving several dependent variables, Approximate solutions of Boundary Value Problem- Rayleigh-Ritz method.
CO3: Understand Laplace Transforms and its properties and how to use it to solve differential equations
CO4: Fourier series and Fourier transforms and its application.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: The concept of convergence of sequences, completion of metric space, countable and uncountable sets, compact sets.
CO2: The concept of continuous functions in metric space, uniform convergence of sequence of functions, uniform convergence and differentiation, uniform convergence and integration and uniform convergence and continuity.
CO3: Reimann-Stieltjes integral as a generalization of Reimann integral, and rectifiable curves.
CO4: Calculus of severable variables, differentiation of vector-valued functions of several variables, and the implicit function theorem.

UNIT-I **15 HOURS**

Basic Topology: Review of finite, countable and uncountable sets, metric spaces, compact sets. Perfect sets. Connected sets.
Sequences and series: Review of convergent sequences, sub sequences, cauchy sequences (in metric spaces), completion of a metric space. Upper and lower limits of a sequence of real numbers. Riemann's Theorem on Rearrangements of series of real and complex numbers.

UNIT-II **15 HOURS**

Continuity: Limits of functions (in metric spaces), continuous functions, continuity and connectedness.
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, The Stone Weierstrass Theorem.

UNIT-III **16 HOURS**

The Riemann-Stieltjes integral: Definition and existence of the Riemann-Stieltjes integral, properties of the integral, integration of vector-valued functions. Rectifiable curves.

UNIT-IV **14 HOURS**

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 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 Edition1974.
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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand differential geometry of plane curves and space curves.
CO2: Understand the orientability of surfaces.
CO3: Understand geometrical interpretation of first fundamental form, second fundamental form and principal Curvature.
CO4: Understand geodesic curves and related notions.

UNIT-I **16 HOURS**

Vectors in the Euclidean space, Review of the basics of vector calculus, Level Curves vs Parametrized Curves, Arc length Reparameterization, 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. Sufaces 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,

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: understand the concepts of range space and null space, their dimension and applications.
CO2: associate a matrix with a linear transformation, about characteristic and minimal polynomials, and characteristic vectors.
CO3: convert matrices in to their canonical forms such as diagonal form, triangular form and also will learn about linear functional and dual spaces.
CO4: learn about inner product spaces, orthogonal/orthonormal vectors and adjoint operators.

UNIT-I **15 HOURS**

Review- Vector Spaces, Subspaces, Basis and Dimensions, Algebra of Linear Transformation. Row rank, Column rank and their equality (using range space and null space), Rank-Nullity Theorem and its applications.

UNIT-II **15 HOURS**

Eigen values and Eigenvectors, Characteristic and minimal polynomials, companion matrix, Cayley Hamilton Theorem with proof, 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Know the fundamental concepts of complex numbers.
CO2: Evaluate limits and checking the continuity of complex function & apply the concept of analyticity and the Cauchy-Riemann equations.
CO3: Evaluate complex integrals and apply Cauchy integral theorem and formula.
CO4: Solve the problems using complex analysis techniques applied to different situations in engineering and other mathematical contexts.

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, 9^{th} 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 Verlang, 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, 3^{rd} Edition*. Massachusetts: Jones and Bartlett Publishers, 2013.

Course Title: Theory of 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand σ-algebras, measurable sets, measures, outer measure, Lebesgue measure, measurable functions.
CO2: Understand Lebesgue integral, difference between Riemann and lebesgue integrals, Convergence in measure.
CO3: Understand differentiation of monotone functions, functions of bounded variation, Lebesgue differentiation theorem, convex functions.
CO4: Understand L^p Spaces, convergence, completeness and approximations in L^p Spaces.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1*:* Understand the concept of mathematical expectation, variance and moment generating function.
CO2**:** Acquire knowledge of discrete probability distribution and continuous probability distribution with their properties .
CO3: Understand types of sampling and various exact sampling distribution.
CO4: Understand MP and UMP test and likelihood ratio test.

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., JoesephMcKlean, 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Illustrate the dihedral groups, symmetric groups, cyclic groups and analyze the applications of Lagrange's theorem.
CO2: Understand the fundamental illustrate the dihedral groups, symmetric groups, cyclic groups and analyze the applications of Lagrange's theorem.
CO3: Concepts of Sylow p-subgroups, Sylow theorems and their application in non-simplicity of groups.
CO4: Connect the fundamental concepts of rings, subrings and ideals.

UNIT-I **15 HOURS**

Review of basic properties of Groups: Subgroups and cosets, cyclic groups, normal subgroups and quotient groups, Isomorphism theorems. Dihedral groups. Symmetric groups and their conjugacy classes. Group action, examples, orbit, stabilizer.

UNIT-II **15 HOURS**

Simple groups and their examples, simplicity of A_n $(n \geq 5)$. Normal and Subnormal Series, Derived Series, Composition Series, Solvable Groups and Nilpotent 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. Relation between one sided/two sided ideals of ring R and ring $M_n(R)$.

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. Shahi V., and V. Bist, *Algebra*, 4th Edition. Alpha Science International Ltd, Delhi: 2018.
3. Herstein, I. N. *Topics in Algebra, 2nd Edition*. Vikas Publishing House, New Delhi: 2006.
4. Singh, Surjeet, and Q. Zameeruddin, *Modern Algebra, 8th Edition*. New Delhi: Vikas Publishing House, 2006.
5. Dummit, David. S., and Richard M. Foote, *Abstract Algebra, 3rd Edition*. New Delhi: Wiley, 2011.

6. Malik D. S., J. N. Mordeson and M. K. Sen. *Fundamentals of Abstract Algebra*, McGraw-Hill, New York: 1997.
7. Luthar I. S. and I. B. S. Passi, *Algebra Vol. 2*, Narosa Publishing House, New Delhi: 1999.

L	T	P	Credits
4	0	0	4

Course Title: Numerical Analysis
Course Code: MTH 562A

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Find the solution of algebraic as well as transcendental equations using various methods.
CO2: Do Interpolation using various methods.
CO3: Find the solution of system of equations, eigen values & eigen vectors, Curve fitting.
CO4: Do Numerical integration and able to find solution of differential equations.

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. Shastry, S. S. *Introductory Methods of Numerical Analysis*. New Delhi: PHI Learning Private Limited, 2005.

L	T	P	Credits
0	0	4	2

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

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Write algorithms for numerical methods implementations.
CO2: Utilize a variety of numerical methods to find roots of an equation.
CO3: Able to program Interpolation, numerical differentiation and integration, solution of linear equations in MATLAB.
CO4: Able to solve initial-value problems of differential equation using different numerical methods in MATLAB.

List of Practicals:

1. Matrix Multiplication
2. Regula-Falsi Method
3. Newton-Raphson method and error analysis
4. Muller's method
5. Lagrange Interpolation
6. Numerical differentiation
7. Gauss-Elimination Method
8. Gauss-Jordan method
9. Power method for eigen value problem
10. Boole's Rule
11. Weddle's Rule
12. Double integration
13. Euler's method
14. Runge-Kutta method of order four
15. Predictor-Corrector methods
16. 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Basic concepts of integral equations and their classifications and their applications in solving ordinary differential equations and boundary value problems.
CO2: Introduction to Fredholm integral equations, The variational iteration method, The direct computation method, The successive approximations method, The method of successive substitutions, comparison between alternative methods and solution of Fredholm Integral Equations of second kind with separable kernel.
CO3: Introduction to Volterra's integral equations, The Adomian decomposition method, the modified decomposition method, the variational iteration method, the series solution method, and conversion of Volterra equation to initial value problem, Successive approximations method, The method of successive substitutions, and their comparison.
CO4: Understand Volterra integral equations of the first kind, the series solution method, Conversion of first kind to second kind, Resolvent kernel and Volterra Integral Equation, 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.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the definition of topology,subspace topology, product topology and concept of continuous functions.
CO2: Differentiate between connected spaces and path connected spaces
CO3: Understand compactness, Local compactness, basic notions of T2.
CO4: Understand normal spaces and regular spaces and related important theorems like Tietze Extension Theorem.

UNIT-I **15 HOURS**

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

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the concepts of Polynomial rings, UFD, PID, ED and relation between them.
CO2: Learn different criterions to check irreducibility of a polynomial, Concept of algebraic element, transcendental elements, Field extension, degree of extension and finite extensions.
CO3: Various field extensions, e.g. splitting fields, algebraically closed fields, normal extensions.
CO4: Concept of Galois groups and Galois extensions. Separable and inseparable extensions, Perfect Fields.

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.

L	T	P	Credits

Course Title: Ordinary Differential Equations
Course Code: MTH 663

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Explain the concept of differential equations and existence-uniqueness theorem of differential equations.
CO2: Solve systems of linear differential equations and determine fundamental solutions and independence using the Wronskian.
CO3: Understand the Strum Liouville problems and the ortho -normalization of functions.
CO4: Find solution of ordinary differential equations in more than three variables and understand the concept of singular points in 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 2^{nd} 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-Schmidth 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 Equation*s. 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the key concepts of Operational Research and Linear Programming and their role in various organizations.
CO2: Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
CO3: Employ the suitable methods for improving transportation cost of transportation problems.
CO4: Solve integer programming problem with different techniques.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Determine equation of continuity, incompressible fluid flow, acceleration of fluid, conditions at a rigid boundary.
CO2: Apply the Euler's equation of motion, Bernoulli's equation and understand Kelvin's theorem of circulation, equation of vorticity.
CO3: Understand sources, sinks and doublets, images in rigid planes, images in solid spheres, Stoke's stream function.
CO4: Understand complex velocity potential, Milne Thomson circle theorem and applications, theorem of Blasius, Vortex rows, Karman Vortex Street.

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. 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.

L	T	P	Credits

5	0	0	5

Course Title: Discrete Mathematics
Course Code: MTH 666A

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Learn Quantifiers, Logical statements and basic counting principle.
CO2: Learn Pigeon hole principle, Generating functions and solutions of recurrence relations.
CO3: Learn Different types of graph and coloring of graphs, solutions of problem related to graph and tree.
CO4: Learn boolean Algebra and its properties, Lattice and its Properties.

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 toComputer 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

L	T	P	Credits
5	0	0	5

Course Title: Functional Analysis
Course Code: MTH 667

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: The concept of normed linear space, Banach space, and compactness of normed linear spaces.
CO1: The concept of normed linear space, Banach space, and compactness of normed linear spaces. CO2: The concept of linear operators and their properties, linear functionals and their properties, and dual and reflexive spaces, and their properties.
CO3: The concept of inner product spaces, Hilbert space, and its properties, projection theorem, orthonormal sets, etc.
CO4: Fundamental theorems for normed and Banach space, partially ordered set, adjoint operators, strong and weak convergence, and contraction theorem.

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 Willey 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.
6. Bachman, G. and L. Narici, *Functional Analysis.* New Delhi: Dover Publications Inc.; 2003.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Learn Division Algorithm, Congruences and reduced residue system.
CO2: Learn Chinese Remainder theorem, Euler's theorem and Arithmetic functions
CO3: Learn Quadratic residues and twin primes and Fermat's numbers.
CO4:Learn Diophantine Linear Equations and Continued fractions.

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 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 **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. 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.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Describe theoretical aspects to solve linear and non-linear partial differential equations.
CO2: Enumerate methods for solving second order and higher order partial differential equations.
CO3: Describe model of physical phenomena using partial differential equations such as the heat equation, wave equation and Laplace equation.
CO4: Analyze the fundamental solutions and applications of heat equation, wave equation and Laplace equation.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the mathematical tools that are needed to solve inventory problems.
CO2: Conceptualise optimum event management through Network scheduling.
CO3: Analyze the queueing and its different models.
CO4: Understand methods like convex simplex method and penalty function methods for solving different types of nonlinear programming problems and Karush−Kuhn−Tucker conditions.

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:AddisionWesley, Reading Mass. 1967.
4. Rao, S. S.*Optimization theoryand Applications (4^{th} edition).*New Delhi: Wiley Eastern Ltd. 2009.

L	T	P	Credits
5	0	0	5

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

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Determine relations between stress and rate of strain, coefficient of viscosity and laminar flow.
CO2: Apply the Navier-Stokes equations of motion of a viscous fluid, steady motion of viscous fluid between parallel planes and uniform circular cross-section and cross section in the form of circle, ellipse and equilateral triangle
CO3: Understand Energy dissipation due to viscosity, steady flow past a fixed sphere, dimensional analysis, Reynolds numbers, Prandtl's boundary layer, Karman integral equation.
CO4: Understand 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.

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. 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: 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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the concepts of Homotopy classes and find the Fundamental Groups.
CO2: Learn the concepts of Deformation Retracts, Homotopy type and Homotopy invariance.
CO3: Find the structure of the fundamental group of a topological space in terms of the fundamental groups of open, path-connected subspaces and learn some properties of groups.
CO4: Classify various covering spaces and check equivalence of covering spaces .

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.

L	T	P	Credits

5	0	0	5

Course Title: Category Theory
Course Code: MTH 674

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the Lagrangian formulation and Lagrange's dynamical equations of motion
CO2: Understand the Hamiltonian formulation and Hamiltonian's dynamical equations of motion
CO3: Understand fundamental concepts of canonical transformation, invariance of Poisson bracket and Lagrange bracket.
CO4: Understand H-J equation, rigid body dynamical equations and Euler's angles.

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; Canonnical transformation, Properties of generator functions, Poisson bracket- Jacobi identity for Poisson bracket, Poission'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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand 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.
CO2: Understand Volterra integro-differential equations, 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.
CO3: Understand nonlinear Fredholm integral equations, 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 ecomposition Method.
CO4: Understand nonlinear Volterra integral equations, and their solutions by 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.

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.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Learn about Harmonic functions and their properties.
CO2: Learn about analytic continuation, open mapping theorem and Riemann mapping theorem.
CO3: Understand Weirestrass elliptic functions and their applications.
CO4: Understand Weirestrass Zeta functions and their applications.

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, Diritchlet 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.

Course Title: Module Theory and Galois Theory
Course Code: MTH679

L	T	P	Credits
5	0	0	5

Objective: This course provides the foundation required for more advanced studies in Algebra. Answers to some classical problems of ancient Greeks regarding the ruler and compass constructions shall be obtained as a consequence of the development of the subject.

Course Outcomes (COs): After successfully completing this course the students will be able to
CO1: Understand the difference between modules and vector spaces and learn various types of modules.
CO2: Find the Smith Normal form and rational canonical forms over PID.
CO3: Check the chain conditions on modules and find the nil & Jacobson radical.
CO4: Apply Galois theory to solvability of polynomials by radicals.

UNIT-A **15 HOURS**

Modules, Difference between Modules and Vector Spaces, Module Homomorphisms, Quotient Module, Completely reducible or Semi simple Modules, Free Modules, Representation and Rank of Linear Mappings.

UNIT-B **15 HOURS**

Smith normal Form over a PID, Finitely generated modules over a PID, Rational Canonical Form, Applications to finitely generated abelian groups.

UNIT-C **15 HOURS**

Modules with Chain Conditions: Noetherian and Artinian Rings and modules, Examples and Counter Examples, Nil Radical and Jacobson radical.

UNIT-D **15 HOURS**

Galois extensions, the fundamental theorem of Galois theory, Cyclotomic extensions, and Cyclic extensions, Applications of cyclotomic extensions and Galois theory to the constructability of regular polygons, Solvability of polynomials by radicals.

Reference Books:

1. Bhattacharya P.B.; S.K. Jain; and S.R. Nagpal, Basic Abstract Algebra, Cambridge University Press, New Delhi.
2. Musili C, Rings and Modules (Second Revised Edition), Narosa Publishing House, New Delhi, 1994
3. Singh Surjeet and Qazi Zameeruddin, Modern Algebra, Vikas Publishing House, New Delhi (8th Edition) 2006.
4. I. Stewart, Galois Theory, Chapman and Hall.
5. Gallian, Contemporary Abstract Algebra **Community Engagement** Narosa Publishing House.