SEMESTER I

Course Title: Calculus I

Course Code: MTH-104

Credit Hours: 4(4-0)

COURSE LEARNING OBJECTIVES:

Calculus serves as the foundation of advanced subjects in all areas of mathematics. Starting from the notion of functions, the basic concepts of mathematical analysis, the limit, the derivative and the integral shall be developed. Upon completion of the course, students will be able to:

Understand the basic limit and continuity of a function and apply it upon various polynomial, root, and trigonometric, logarithmic and exponential functions, grasp the concept of derivative of a function and applying different techniques to differentiate and optimize various functions. Handle indefinite integral of a given function and to be able to apply it for finding the areas between the curves and finding the volumes.

THEORY:

Preliminaries: Real numbers and the real line, Complex numbers system, Polar form of complex numbers, De Moivre's theorem, Polynomials, Division of polynomials, synthetic division

Functions and graphs: Functions and their graphs,

Shifting and scaling graphs, Absolute value function, Intervals and their types, Domain and range of functions

Equations and inequalities: Equation of a straight line, slope, intercepts, Solution of equations involving absolute values, Inequalities

Limit and Continuity: Limit of a function, left hand and right-hand limits, Theorems of limits, Continuity, Continuous functions

Derivatives and its Applications: Differentiable functions, Differentiation of polynomial, rational and transcendental functions, Mean value theorems and applications, Higher derivatives, Leibniz's theorem, L'Hopitals Rule, Intermediate value theorem, Rolle's theorem, Taylor's and McLaurin's theorem with their remainders

Integration and Definite Integrals: Techniques of evaluating indefinite integrals, Integration by substitutions, Integration by parts, Change of variable in indefinite integrals, Definite integrals, Fundamental theorem of calculus, Reduction formulas for algebraic and trigonometric integrands, Improper integrals, and Gamma functions.

RECOMMENDED BOOKS:

1. Intermediate Algebra (3rd Edition), A. Kaseberg, Thomson Brooks/Cole, 2004.
2. Schaum's Outline of Calculus (Latest Edition), F. A. Jr., E. Mendelson, McGraw Hill Inc.
3. Thomas's Calculus (Latest Edition), G. B. Thomas, Jr., M. D. Weir, J. R. Hass, and F. R. Giordano, Pearson Education.
4. Calculus (Latest Edition), H. Anton, I. Bivens, and S. Davis, John Wiley & Sons, Inc.
5. A Concise Introduction to Pure Mathematics (3rd Edition), M. Liebeck, CRC Press, 2011.
6. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability) (2nd Edition), T. M. Apostol, John Wiley & Sons, 2014.
7. Thomas' Calculus, 15th edition. J. R. Hass, C. E. Heil, M. D. Weir, P. Bogacki, 2023.

SEMESTER II

Course Title: Calculus II

Course Code: MTH-105

Credit Hours: 4(4-0)

COURSE LEARNING OBJECTIVES:
In continuation of Calculus I, it focuses on techniques of integration and applications of integrals for functions of Multiple variables. The course also aims at introducing the students to infinite series, parametric curves and polar coordinates. Upon completion of the course, students will be able to prepare the students to understand comparatively the advanced concepts than the concepts they learnt in Calculus-I course, to make the participants learn the techniques of handling multivariable functions i.e., calculating the limits and continuity of multivariable functions, partial differentiation, multiple integrals, etc., to enhance the vision of participants in developing mathematical models of real-life physical problems.

THEORY:
Review of Conic Section: Conic section, parameterized curves and polar coordinates. Curves defined by parametric equations. Calculus with parametric curves: **tangents, areas,** arc length. Polar coordinates. Polar curves, tangents to polar curves. Areas and arc length in polar coordinates.
Functions of Several Variables: Functions of two variables, Graphs of functions of two variables, Contour diagrams, Linear functions, Functions of three variables, Limit and continuity of a function of two variables, The partial derivative, Computing partial derivatives algebraically, The second-order partial derivative, Tangent planes and normal lines, Optimization, Maxima and minima of a function of two variables.
Multiple Integrals: Double integral in rectangular and polar form, Triple integral in rectangular, Cylindrical and spherical coordinates, Substitutions in multiple integrals, Moments and center of mass.

RECOMMENDED BOOKS:

1. Intermediate Algebra (3rd Edition), A. Kaseberg, Thomson Brooks/Cole, 2004.
2. Schaum's Outline of Calculus (Latest Edition), F. A. Jr., E. Mendelson, McGraw Hill Inc.
3. Thomas's Calculus (Latest Edition), G. B. Thomas, Jr., M. D. Weir, J. R. Hass, and F. R. Giordano, Pearson Education.
4. Calculus (Latest Edition), H. Anton, I. Bivens, and S. Davis, John Wiley & Sons, Inc.
5. Thomas' Calculus, 15th edition. J. R. Hass, C. E. Heil, M. D. Weir, P. Bogacki, 2023.
6. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability) (2nd Edition), T. M. Apostol, John Wiley & Sons, 2014.

SEMESTER III

Course Title: Calculus III

Course Code: MTH-206

Credit Hours: 4(4-0)

COURSE LEARNING OBJECTIVES:
In continuation of Calculus I & Calculus II. The students would be introduced to the vector calculus, the calculus of multivariable functions and double and triple integrals along with their applications.
Upon completion of the course, students will be able to: Understand the concepts of vector valued functions and curvilinear coordinates. To construct series and shall be familiar with the concept of convergence and divergence of a series. Understand applications of derivative and integration in single and multivariable functions.

THEORY:
Vectors and analytic geometry in space: Vector-valued functions: Vector-valued functions and space curves. Derivatives and integrals of vector valued functions. Arc length. Curvature, normal and bi-normal vectors.
Sequence and Series: Sequences, Infinite series, Convergence of sequence and series, The integral test, Comparison tests, Ratio test, Root test, Alternative series, Absolute and conditional convergence, Power series, Interval and radius of convergence. Differentiation and integration of power series. Taylor and McLaurin series. Approximations by Taylor polynomials.
Applications of Multivariable functions: Directional derivatives and the gradient vector, Implicit function theorem for several variables. Maximum and minimum values. Optimization problems. Lagrange Multipliers, Lagrange multipliers, Various methods for finding area and volume surface of revolution. Applications to Economics, Physics, Engineering and Biology.

RECOMMENDED BOOKS:

1. Intermediate Algebra (3rd Edition), A. Kaseberg, Thomson Brooks/Cole, 2004.
2. Schaum’s Outline of Calculus (Latest Edition), F. A. Jr., E. Mendelson, McGraw Hill Inc.
3. Thomas’s Calculus (Latest Edition), G. B. Thomas, Jr., M. D. Weir, J. R. Hass, and F. R. Giordano, Pearson Education.
4. Calculus (Latest Edition), H. Anton, I. Bivens, and S. Davis, John Wiley & Sons, Inc.
5. Thomas' Calculus, 15th edition. J. R. Hass, C. E. Heil, M. D. Weir, P. Bogacki, 2023.
6. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability) (2nd Edition), T. M. Apostol, John Wiley & Sons, 2014.

Course Title: Elements of Set Theory and Mathematical Logic

Course Code: MTH-211

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
Everything mathematician do can be reduced to statements about sets, equality and membership which are basics of set theory. This course introduces these basic concepts. The course aims at familiarizing the students with cardinals, relations and fundamentals of propositional and predicate logics.

THEORY:

Set theory: Sets, subsets, operations with sets: union, intersection, difference, symmetric difference, Cartesian product and disjoint union.
Functions: graph of a function. Composition, injections, surjections, bijections, inverse function.
Computing cardinals: Cardinality of Cartesian product, union, Cardinality of all functions from a set to another set, Cardinality of all injective, surjective and bijective functions from a set to another set, Infinite sets, finite sets, Countable sets, properties, examples (Z, Q), R is not countable. R, RxR, RxRxR have the same cardinal, Operations with cardinal numbers, Cantor Bernstein theorem.

Relations: Equivalence relations, partitions, quotient set, examples, parallelism, similarity of triangles, Order relations, min, max, inf, sup; linear order, Examples: N, Z, R, P(A), Well-ordered sets and induction, inductively ordered sets and Zorn's lemma.
Mathematical logic: Propositional Calculus. Truth tables. Predicate Calculus.

RECOMMENDED BOOKS:

1. A Transition to Advanced Mathematics (7th Edition), D. Smith, M. Eggen, and R. S. Andre, Brooks/Cole, 2001.
2. A Concise Introduction to Pure Mathematics (3rd Edition), M. Liebeck, CRC Press, 2011.
3. Discrete Mathematics (2nd Edition), N. L. Biggs, Oxford University Press, 2002.
4. Structure and Randomness in Computability and set Theory, Douglas Cenzer, Christopher Porter, Jindrich Zapletal, 2020.
5. Discrete Mathematics (3rd Edition), R. Garnier and J. Taylor, CRC Press, 2010.

Course Title: Ordinary Differential Equations

Course Code: MTH-241

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

To introduce students the existence and uniqueness of solutions, enable them to evaluate first order differential equations including separable, homogeneous, and exact and linear equations, solve second order and higher order linear differential equations. Create and analyze mathematical models using higher order differential equations to solve application problems such as harmonic oscillators and circuits. Solve differential equations using variation of parameters. Solve linear system of ordinary differential equations. After the completion of this course, students will be able to: Solve first order differential equations utilizing the standard techniques for separable, exact, linear, and homogeneous or Bernoulli cases. Find the complete solution of non-homogeneous differential equation as a linear combination of the complimentary function and a particular solution. Students will be introduced to the complete solution of a non-homogeneous differential equation with constant coefficients by the method of undetermined coefficients. Students will be able to find the complete solution of differential equation with constant coefficients by variation of parameters. Students will have a working knowledge of basic application problems described by second order linear differential equations with constant coefficients.

THEORY:

Differential equations of first order: Differential equation and their classifications, formation of differential equations, solution of differential equations, initial and boundary conditions,

Methods of solution of differential equation of first order and first-degree: Separable equations, homogeneous equations, equations reducible to homogeneous, exact differential equations, integrating factor, linear equations, reducible to linear differential equations, Bernoulli equations, orthogonal trajectories in Cartesian and polar coordinates, applications of first order differential equations.

Non-linear first order differential equations: Equations solvable for p, for y and for x, Clairauts equations.

Higher order linear differential equations: Homogeneous linear equations of order n with constant coefficients, auxiliary\characteristic equations. Solution of higher order differential equation according to the roots of auxiliary equation. (Real and distinct, Real and repeated, and Complex). Non-homogeneous linear equations; Working rules for finding particular integral. Cauchy Euler equation. Applications of higher order linear differential equations.

RECOMMENDED BOOKS:

1. Differential Equations with Boundary Value Problems (7^{th} Edition), D. G. Zill and M. R. Cullin, Brooks/Cole, 2009.
2. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability) (2^{nd} Edition), T. M. Apostol, John Wiley & Sons, 2014.
3. Elementary Differential Equations and Boundary Value Problems (7^{th} Edition), W. E. Boyce and R. C. Diprima, John Wiley & Sons. Inc., 2001.
4. Ordinary Differential Equations: Methods and Applications, W. T. Angand Y. S. Park, Universal Publishers, Boca Raton, 2008.
5. A First Course in Ordinary Differential Equations, Suman Kumar Tumuluri, 2021.

SEMESTER IV

Course Title: Discrete Mathematics

Course Code: MTH-212

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

Discrete Mathematics is study of distinct, un-related topics of mathematics; it embraces topics from early stages of mathematical development and recent additions to the discipline as well. The present course restricts only to counting methods, relations and graphs. The objective of the course is to inculcate in the students the skills that are necessary for decision making in non-continuous situations.

THEORY:

Counting methods: Basic methods: Product, inclusion-exclusion formulae, Permutations and combinations, Recurrence relations and their solutions, Generating functions, Double counting, Applications, Pigeonhole principle, Applications.

Relations: Recurrence relation, Binary relations, n-ary relations, Representing Relations, Closures of relations, Compositions of relations Inverse relations.

Graphs: Graph terminology, Representation of Graphs, Graphs isomorphism,

Algebraic methods: the incidence matrix, connectivity, Eulerian and Hamiltonian paths, shortest path problem, Trees and spanning trees Complete graphs.

RECOMMENDED BOOKS:

1. Applied Combinatorics, A. Tucker, John Wiley & sons. Inc. New York, 2002.
2. Discrete Mathematical Structures (5^{th} Edition), B. Kolman, R. C. Busby, and S. C. Ross, Prentice-Hall of India, New Delhi, 2008.
3. Discrete Mathematics and Its Applications (6^{th} Edition), K. H. Rosen, Mc Graw-Hill, 2007.
4. Discrete Mathematics, K.A. Ross and C. R. B. Wright, Prentice Hall, New Jersey, 2003.
5. Discrete Mathematics (2^{nd} Edition), N. L. Biggs, Oxford University Press, N. L. Biggs. 2002.
6. Practical Dicscrete Mathematics by Ryan T. White and Archana Tikayat Ray, 2021.
7. Michaels, J., & Rosen, K. Applications of Discrete Mathematics. Journal of Algorithms, vol. 5, pp. 531-546, 2007.

Course Title: Linear Algebra

Course Code: MTH-231

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

Linear algebra is the study of vector spaces and linear transformations. The main objective of this course is to help students learn in rigorous manner, the tools and methods essential for studying the solution spaces of problems in mathematics, engineering, the natural sciences and social sciences and develop mathematical skills needed to apply these to the problems arising within their field of study; and to various real-world problems.

THEORY:

Introduction to Matrices: Basic concepts of matrices, Types of matrices, Algebraic properties of matrices, Row and column operation on matrices, Echelon and reduced echelon form of matrices, Rank of a matrices, Inverse of matrices, singular and non-singular matrices, minors and cofactors of matrices. System of Linear Equations, Gauss Jordan Method, Gauss Elimination Method.

Determinants: Permutations of order two and three and definitions of determinants of same order, Computing of determinants, Definition of higher order determinants, Properties, Expansion of determinants, Definition of higher order determinants.

Vector spaces: Definition and examples, subspaces, Linear combinations and spanning set, linearly independent set, finitely generated vector spaces, Bases and dimensions of a vector spaces, Operations on subspaces, Intersections, sum and direct sum of subspaces, Quotient spaces.

Linear Mappings: Definitions and examples, kernel and image of linear mapping, Rank and nullity Reflections, Eigen values and Eigen Vectors.

Inner Product spaces; Definitions and examples, Properties, Projection, Cauchy Inequality, Orthogonal and Orthonormal basis, Gram- Schmidt process, Diagonalization.

RECOMMENDED BOOKS:

1. Abstract Algebra (3^{rd} Edition), D. Dummit, R. M. Foote, Wiley, 2003.
2. Elementary Linear Algebra: Applications Version (10^{th} Edition), H. Anton and C. Rorres. John Wiley & Sons, 2010.

3. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability) (2nd Edition), T. M. Apostol, John Wiley & Sons, 2014.
4. Linear Algebra (3rd Edition), S. Lang, Springer-Verlag, 2004.
5. Linear Algebra (4th Edition), S. Friedberg and A. Insel, Pearson Education, Canada, 2003.
6. Linear algebra, 1st Edition, Lina Oliveira, 2022.

Course Title: Topology

Course Code: MTH-251

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to introduce metric spaces and topological spaces. After completion of this course, they would be familiar with separation axioms, compactness and completeness. They would be able to determine whether a function defined on a metric or topological space is continuous or not and what homomorphisms are.

THEORY:

Preliminaries: Metric spaces.

Topological Spaces: Topological spaces, Topological subspaces, Open and closed subsets, Neighborhood, Limit points/ Accumulation points, Interior, Closure, Derived sets, Perfect sets, Dense subsets, Interior, exterior and boundary of a set.

Continuity and Countability: Continuity of a topological space, Open Bases and sub-bases, Countability in topological spaces, Product of a topological space.

Separation axioms:T_0 spaces, T_1 spaces,T_2 spaces, Regular spaces, Completely regular spaces, Normal spaces.

Compact spaces: Properties, power of compactness, Image of compact set through a continuous map. Completeness.

Connected space: Connected and disconnected spaces, totally disconnected spaces.

RECOMMENDED BOOKS:

1. Introduction to Topology and Modern Analysis (9th Edition), G. F. Simmons, McGraw-Hill, 2004.
2. General Topology (1st Edition), J. Kelly, Springer, 2005.
3. Topology (5th Edition), J. G. Hocking and G. S. Young, Dover Publications, 2012.
4. Topology-A First Course (2nd Edition), J. R. Munkres, Prentice-Hall, 2000.
5. General Topology (1st Edition), S. Lipschutz, McGraw-Hill, 2004.
6. Introduction to topology: pure and applied (No. Sirsi) i9780131848696), Adams, C. C., & Franzosa, R. D., 2008.
7. Elementary Topology and Applications, Carlos R Borges, 2021.

Differential Geometry

Course Code: MTH-352

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

After having completed this course, the students would be expected to understand classical concepts in the local theory of curves and surfaces including normal, principal, mean, curvature, and geodesics. They will also learn about tensors of different ranks.

Theory:

Theory of Space Curves: Introduction, index notation and summation convention. Space curves, arc length, tangent, normal and binormal. Osculating, normal and rectifying planes. Curvature and torsion. The Frenet-Serret theorem. Natural equation of a curve. Involutes and evolutes, helices. Fundamental existence theorem of space curves.

Theory of Surfaces: Coordinate transformation. Tangent plane and surface normal. The first fundamental form and the metric tensor. The second fundamental form. Principal, Gaussian, mean.

The Equations of Gauss and of Codazzi: Gauss's formulae for r_{11}, r_{12}, r_{22}, Gauss characteristic equation, Mainardi-Codazzi relations. Gauss and Weingarten equations. Gauss and Codazzi equations.

Geodesic: Geodesic property, Equations of geodesies, Surface of revolution, Torsion of a geodesic, Geodesic and normal curvature.

Tensor Analysis: Einstein summation convention. Tensors of different ranks. Contravariant, covariant and mixed tensors. Addition, subtraction, inner and outer products of tensors. Contraction theorem, quotient law. The line element and metric tensor. Christoffel symbols.

RECOMMENDED BOOKS:

1. Elementary Differential Geometry (2nd Edition), A. N. Pressley, Springer, 2010.
2. Matrices and Tensors in Physics (Latest Edition), A. W. Joshi, Wiley Eastern Limited.
3. Differential Geometry, D. Somasundaram, Narosa Publishing House, New Delhi, 2005.
4. Differential Geometry (1st Edition), E. Kreyszig, Dover, 2002.
5. Schaum's Outline of Differential Geometry, M. M. Lipschutz, McGraw Hill, Latest edition.

SEMESTER V

Course Title: Real Analysis I

Course Code: MTH-321

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

This is the first course in analysis. It develops the fundamental ideas of analysis and is aimed at developing the students' ability in reading and writing mathematical proofs. Another objective is to provide sound understanding of the axiomatic foundations of the real number system, in particular the notions of completeness and compactness.

THEORY:

Real Numbers: Algebraic and ordered properties of Real Numbers, Absolute values, Inequalities (Cauchy's, Minkoski's, Bernoulli's) Properties and concepts of supremum and infimum, ordered sets, Fields, Field of Real, The extended real number system, Euclidean spaces.
Sequence: Sequences, Subsequences, Cauchy sequence, Series of Numbers and their convergence. The Comparison, Root, Ratio and Integral tests. Absolute and Conditional convergence of infinite series.
Continuity and Differentiation: Limit and continuity, Properties of continuous functions. Types of discontinuities. Differentiable functions. Mean-value theorems, Continuity of derivatives. Partial Derivatives and Differentiability. Derivative and differentials of Composite functions. The Directional Derivative, the Laplacian in polar cylindrical and Spherical coordinates. Monotonic functions, Asymptotes.

RECOMMENDED BOOKS:

1. Introduction to Real Analysis (5^{th} Edition), R .G. Bartle and D. R. Sherbert, John Wiley New York, 2000.
2. Mathematical Analysis (Latest Edition), T. M. Apostol, Addison-Wesley Publishing Company.
3. Advance Calculus (5^{th} Edition), W. Kaplan, Published by Pearson Education, 2002.
4. Principles of Mathematics Analysis (3^{rd} Edition), W. Rudin, McGraw-Hill. New York, 2013.
5. Concepts of Real Analysis, R.D. Sarma, Ankit gupta, Rajesh singh, 2022.

Course Title: Complex Analysis I

Course Code: MTH-323

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
This is an introductory course in complex analysis, giving the basics of the theory along with applications, with an emphasis on applications of complex analysis and especially conformal mappings. Students should have a background in real analysis (as in the course Real Analysis- I), including the ability to write a simple proof in an analysis context.
THEORY:
The Concept of Analytic Functions: Complex numbers, complex planes, complex functions, Analytic functions, entire functions, Harmonic functions. Elementary functions: complex exponential, logarithmic and hyperbolic functions.
Infinite Series: Power series, derived series, radius of convergence, Taylor series and Laurent series.
Conformal Representation: Transformation, conformal transformation, linear transformation, Möbius transformations.
Complex Integration: Complex integrals, Cauchy-Goursat theorem, Cauchy's integral formula and their consequences, Liouville's theorem, Morera's theorem, Derivative of an analytic function.
RECOMMENDED BOOKS:

1. Complex Analysis, D. G. Zill and P. D. Shanahan, Jones and Bartlett Publishers, 2003.
2. Complex Variables: Theory and Applications, H. S. Kasana, Prentice Hall, 2005.

3. Complex Variables and Applications (7th Edition), J. W. Brown and R. V. Churchill, McGraw Hill Company, 2004.

Complex Analysis, Andrei Bourchtein and Ludmila Bourchtein, 2021.

Course Title: Algebra I

Course Code: MTH-332

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
This course introduces basic concept of groups and their homomorphisms. The main objective of this course is to prepare students for courses which require a good background in group theory like Rings and Modules, Linear Algebra, Group Representation, Galois Theory etc.

THEORY:

Motivation of groups: Introductory concepts

Groups: Properties of Groups, Order of an element of a finite group, Finite groups, Subgroups, Cyclic groups, Lagrange's theorem and its applications

Groups of Permutations: Permutations, Cyclic Permutations, Order of a Permutation, Transpositions, Even and Odd Permutations

Homomorphism: Homomorphism and its properties, Isomorphisms,
Cayley's theorem

Complexes in groups: Center, Centralizer and normalizer of a group, Conjugacy class, double cosets

Normal Subgroups: Cosets, Normal subgroups and its properties, Construction of quotient or factor group, Conjugacy classes, Automorphism group, Commutator Subgroup

Sylow Theorems: Cauchy's theorems for Abelian and non-abelian groups, Sylow's theorems.

RECOMMENDED BOOKS:

1. Abstract Algebra (3rd Edition), D. S. Dummit and R. M. Foote, Addison-Wesley Publishing Company, 2004.
2. A Course on Group Theory (Revised edition), J. S. Rose, Dover Publications, 2012.
3. A First Course in Abstract Algebra (7th Edition), J. B. Fraleigh, Addison-Wesley Publishing company, 2002.
4. Algebra (2nd Edition), P. M. Cohn, John Wiley and Sons. London, 2000.

Contemporary Abstract Algebra, Joseph A Gallian 10th edition, 2020.

Course Title: Vector and Tensor Analysis

Course Code: MTH-381

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The objective of this course is to introduce the vectors and tensor analysis which is useful for advance courses.

THEORY:

Algebra of Vectors: Scalars and Vectors, Dot Product, Cross Product, Vector-triple products, Scalar-triple product, Collinear vectors, Coplanar vectors, Reciprocal vectors.

Vector differentiation and integration: Scalar and vector function of one variable, Limit and continuity of a vector function, Space curve, Surface in space, Vector integration.

Gradient, Divergence and Curl: Scalar and vector field, Level surfaces, The Operator Del, Gradient of a scalar point function. Divergence of a vector point function, Curl of a vector point function.

Line integrals: Path independence, Surface integrals, Volume integrals, Gradient, Divergence and curl with physical significance and applications, Vector identities, Green's theorem in a plane, Divergence theorem, Stokes' theorem.

Cartesian Tensors: Coordinate systems and their bases, the spherical-polar- and the cylindrical-coordinate meshes, Kronecker delta, Summation convention, vectors as quantities transforming under rotations with €ijk notation, scalar- and, tensors of first second and higher orders, Algebra of tensors, Contraction of tensor, Quotient theorem, Symmetric and skew-symmetric tensors, invariance property, Study of physical tensors (moment of inertia, index of refraction, etc.)

RECOMMENDED BOOKS:

1. Vector Analysis and Cartesian Tensors (Latest Edition), D. E. Bourne and P. C. Kendall, Thomas Nelson.
2. Vector Analysis (Latest Edition), G. D. Smith, Oxford University Press, 2000.
3. Vector and Tensor Analysis (Latest Edition), N. A. Shah, A-One Publishers, Lahore, 2005.
4. Advanced Engineering Mathematics (4^{th} Edition), K. A. Stroud, Palgrave Macmillan, 2003.
5. Vector and tensor Analysis, Meinhard T. Schobeiri, 2021.

SEMESTER VI

Course Title: Real Analysis II

Course Code: MTH-322

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVE:

A continuation of Real Analysis I, this course will continue to cover the fundamentals of real analysis, concentrating on the Riemann-Stieltjes integrals, Functions of Bounded Variation, Improper Integrals, and convergence of series.

THEORY:

Riemann Integrals: The Riemann - Stieltjes (R-S) Integrals. Properties of R-S integrals.

Sequences of Functions: Functions of bounded variations. Point wise and uniform convergence of sequences and series of functions, Weierstrass M-Test, Uniform convergence and continuity. Uniform Convergence and differentiation, Uniform Convergence and integration. Convergence of improper integrals.

Functions: Beta and Gamma functions and their properties. Implicit functions, Jacobians, Functional dependence. Taylor's theorem for a function of two variables. Maxima and minima of functions of two and three variables. Method of Lagrange Mulitipliers.

RECOMMENDED BOOK:

1. Introduction to Real Analysis (5^{th} Edition), R .G. Bartle and D. R. Sherbert, John Wiley New York, 2000.
2. Mathematical Analysis (Latest Edition), T. M. Apostol, Addison-Wesley Publishing Company.
3. Advance Calculus (5^{th} Edition), W. Kaplan, Published by Pearson Education, 2002.
4. Principles of Mathematics Analysis (3^{rd} Edition), W. Rudin, McGraw-Hill. New York, 2013.
5. Concepts of Real Analysis, R.D. Sarma, Ankit Gupta, Rajesh Singh, 2022.

Course Title: Complex Analysis II

Course Code: MTH-324

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

The course unit aims to introduce the ideas of complex analysis with particular emphasis on Cauchy's theorem and the calculus of residues. Students should have a background in complex analysis (as in the course Complex Analysis- I), including the ability to write a simple proof in an analysis context.

THEORY:

Singularity and Poles: Review of Laurent series, zeros, singularities, Poles and residues, Contour Integration: Cauchy's residue theorem, applications of Cauchy's residue theorem.

Expansion of Functions and Analytic Continuation: Mittag-Leffler theorem, Weierstrass's factorization theorem, analytic continuation.

Elliptic Functions: Periodic functions, Elliptic functions and its properties, Weierstrass function φ(z), differential equation satisfied by φ(z), integral formula for φ(z), addition theorem for φ(z), duplication formula for φ(z), Elliptic functions in terms of Weierstrass function with the same periods.

Quasi periodic functions: The zeta and sigma functions of Weierstrass, Jacobian elliptic functions and its properties.

RECOMMENDED BOOKS:

1. Complex Variables: Theory and Applications, H. S. Kasana, Prentice Hall, 2005.
2. Complex Variables, M. R. Spiegel, McGraw Hill Book Company, 1974.
3. Elements of Complex Variables, Louis L. Pennisi, Holt, Linehart and Winston, 1976.
4. Introduction to Analytic Functions, W. Kaplan, Addison-Wesley, 1966.

A pathway to complex Analysis, S. Kumaresan, 2022.

Course Title: Algebra II

Course Code: MTH-333

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

This is a course in advanced abstract algebra, which builds on the concepts learn in Algebra -I. The objectives of the course are to introduce the basic ideas and methods of modern algebra. And, to enable to understand the idea of ring and an integral domain, significance of unique factorization in rings and integral domains.

THEORY:

Rings: Rings, Quadratic integer's rings, non-commutative rings, Polynomial Rings, Matrix Rings, Unit, zero divisor, Nilpotent, Idempotent, Subrings.

Ideals: Ideals, Maximal and Prime Ideals, Left, right and two-sided ideals, operations with ideals, The ideals generated by sets, Quotient rings, Ring homomorphism, The isomorphism theorems and applications, finitely generated ideals, Rings of fractions.

Integral Domain: Divisibility in integral domains, Greatest common divisor, least common multiple, Euclidean domains, The Euclidean algorithm, Principle ideal domains, Prime and irreducible elements in an integral domain, Gauss lemma, Irreducibility criteria for polynomials, Unique factorization domains, Finite fields, Polynomial in several variables.

RECOMMENDED BOOKS:

1. Abstract Algebra (3rd Edition), D.S. Dummitand R.M. Foote, Addison-Wesley Publishing Company, 2004.
2. A First Course in Abstract Algebra (Latest Edition), J. B. Fraleigh, Addison Wesley Publishing Company, 2002.
3. Algebra (2nd Edition), P. M. Cohn, John Wiley and Sons. London, 2000.
4. Basic Abstract Algebra (2nd Edition), P. B. Bhattacharya, S. K. Jain, and S.R. Nagpaul, Cambridge University Press, 1994.
5. Contemporary Abstract Algebra, Gaiam, J.A., Chapman and Hall/CRC, 2021.
6. Contemporary Abstract Algebra, Joseph A Gallian 10th edition, 2020.

Course Title: Classical Mechanics

Course Code: MTH-382

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

To give students a firm grasp of classical mechanics and to enable them to employ this understanding while attending courses in electromagnetism, quantum mechanics, statistical mechanics, fluid dynamics, space-flight dynamics, astrodynamics, and continuum mechanics.

THEORY:

Non-Inertial Reference Systems: Accelerated coordinate systems and inertial forces. Rotating coordinate systems. Velocity and acceleration in moving system: Radial and transverse velocity, radial and transverse acceleration. Dynamics of a particle in a rotating coordinate system. Planar Motion of Rigid Bodies

Kinetics: Work, power, kinetic energy, conservative force fields. Conservation of energy, impulse, torque, Conservation of linear and angular momentum. Non-conservative forces.

Simple Harmonic Motion: The simple harmonic oscillator, equation of motion for SHM, period, frequency. Resonance and energy. Damping, the damped harmonic oscillator, over damped, critically damped and under damped Motion, forces and vibrations.
Central Forces and Planetary Motion: Central force fields, equations of motion, potential energy, Kepler's law of planetary motion. Derivation of Newton's law from Kepler's laws, Apsides and apsidal angles for nearly circular orbits and related proofs. Motion in an inverse square field.
Planer Motion of Rigid Bodies: Introduction to rigid and elastic bodies, degree of freedom, translations, rotations, instantaneous axis and center of rotation. Euler's theorem and Chasles' theorem. Rotation of a rigid body about a fixed axis. Parallel and perpendicular axis theorem.
Motion of Rigid Bodies in Three Dimensions: General motion of rigid bodies in space. Angular momentum vector and rotational kinetic energy. Principal axes and principal moments of inertia.
Euler Equations of Motion of a Rigid Body: Force free motion. Free rotation of a rigid body with an axis of symmetry. The Eulerian angles, angular velocity and kinetic energy in terms of Euler angles. Motion of a spinning top and gyroscopes-steady precession, sleeping top.

RECOMMENDED BOOKS:

1. Text Book of Dynamics (2nd Edition), C. F. Chorlton, CBS Publishers, 2004.
2. Classical Mechanics: Theory and Mathematical Modeling (Latest Edition), E. DiBenedetto, Birkhauser Boston, 2011.
3. Analytical Mechanics (5th Edition), G. R. Fowles and G. L. Cassiday, Thomson Brooks/Cole, USA, 2005.
4. Classical Mechanics (Latest Edition), John R. Taylor, University of Colorado, 2005.
5. Theoretical Mechanics (3rd Edition), M. R. Spiegel, Addison-Wesley Publishing Company, 2004.
1. Foundations of Classical Mechanics, Deshmukh, P. C., India: Cambridge University Press. 2023.y

Course Title: Partial Differential Equations

Course Code: MTH-342

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

Introduce students to partial differential equations. Introduce students to how to solve linear Partial Differential with different methods. To derive heat and wave equations in 2D and 3D. Find the solutions of PDEs are determined by conditions at the boundary of the spatial domain and initial conditions at time zero. Technique of separation of variables to solve PDEs and analyze the behavior of solutions in terms of eigen function expansions. After the completion of the course, Students will be able to classify partial differential equations and transform into canonical form, solve linear partial differential equations of both first and second order, apply partial derivative equation techniques to predict the behavior of certain phenomena, apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialization, extract information from partial derivative models in order to interpret reality, identify real phenomena as models of partial derivative equations. Solution of Laplace equation in Cartesian, cylindrical and spherical coordinates, Cauchy's problem for quasilinear first order PDEs, PDEs of second order in two independent variables with variable coefficients. Linear transformation from one equation to another equation, Normal form, Cauchy's problem for second order PDEs in two independent variables.

THEORY:

Partial Differential Equations: Introduction, Formation of PDE.

Types of PDE: Elliptic PDE: Laplace equation, Parabolic PDE: Heat equation, Hyperbolic PDE: Wave equation.

Methods to solve PDE: Method of Separation of variables and related examples, various possible solutions of one-dimensional wave equation and heat equation and Laplace equation by the method of separation variables and examples.

Laplace Transforms: Definition, Laplace transforms of elementary functions, Properties of Laplace transform, linearity, 1st shifting, 2nd shifting, change of scale, Periodic functions, Unit step function and their Laplace transforms.

Inverse Laplace transform: Inverse Laplace transform and its properties, Inverse Laplace transform by partial fraction methods, by Convolution theorem, Solution of PDE's by Laplace Transform method, Applications of partial differential equations.

RECOMMENDED BOOKS:

1. Elements of Partial Differential Equations, I. N. Sneddon, Dover Publishing, Inc., 2006.
2. Introduction to Partial Differential Equations and Boundary Value Problems, R. Dennemyer, McGraw Hill Book Company, 1968.
3. Boundary Value Problem and Partial Differential Equations, M. Humi and W. B. Miller, PWS-Kent Publishing Company, Boston, 1991.
4. Techniques in Partial Differential Equations, C. R. Chester, McGraw Hill Book Company, 1971.
5. Partial differential equations (Vol. 19). Evans, L. C, American Mathematical Society, 2022.

Partial Differential Equations of Applied Mathematics, E. Zauderer, Wiley-Interscience, Englewood Cliff, New York, 2006.

SEMESTER VII

Course Title: Number Theory

Course Code: MTH-453

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

The focus of the course is on study of the fundamental properties of integers and develops ability to prove basic theorems. The specific objectives include study of division algorithm, prime numbers and their distributions, Diophantine equations, and the theory of congruence's.

THEORY:

Preliminaries: Well-ordering principle, Principle of finite induction.

Divisibility theory: The division algorithms, The greatest common divisor, The Euclidean algorithm, Latest common multiple.
Linear Diophantine equations: Prime and composite numbers, Canonical decomposition, The Fundamental theorem of arithmetic, The sieve of Eratosthenes.
Congruences: Linear congruences, System of linear congruences, The Chinese remainder theorem, Divisibility tests, Solving polynomial congruences, Fermat's little theorems, Pseudo primes, Wilson's theorem.

Number Theoretic Functions: The sum and number of divisors, The Mobius function. The Mö bius Inversion Formula, Euler's phi-function. Euler's theorem.
Primitive Roots and indices: The order of integer mod n, Primitive roots for primes, Composite numbers having primitive roots, The theory of indices.
Quadratic residues: Euler's criterion, Legendre symbols and its properties, The quadratic reciprocity law. Perfect numbers. Fermat and Mersenne primes.

RECOMMENDED BOOKS:

1. The Theory of Numbers, A. Adler and J. E. Coury, Jones and Bartlett Publishers, 2002.
2. Elementary Number Theory, D. M. Burton, McGraw-Hill, 2007.
3. An Introduction to The Theory of Numbers, I. Niven, H. S. Zuckerman, H. L. Montgomery, John Wiley and Sons, 2014.
4. Elementary Number Theory and Its Applications (5th Edition), K. H. Rosen, Pearson/Addison Wesley, 2005.
5. Topics in Number Theory (7th Edition), W. J. Leveque, Addison-Wesley, 2015.
6. Undergraduate Course in Number Theory, Ashok Godase, 2021.

Course Title: Numerical Analysis I

Course Code: MTH-461

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

This course is designed to teach the students about numerical methods and their theoretical bases. The course aims at inculcating in the students the skill to apply various techniques in numerical analysis, understand and do calculations about errors that can occur in numerical methods and understand and be able to use the basics of matrix analysis.

THEORY:

Number Systems and Error Analysis. Round of errors & Computer Arithmetic, algorithms & convergence.
Interpolation: Interpolation by Polynomials: Existence and uniqueness of the interpolating polynomial. Error of the interpolating polynomial; interpolation with equally spaced data, Newton's forward and backward difference formulas, Bessel's interpolation formula, Lagrangian interpolation, The divided differences
Solution of non-linear Equations: Bisection method, Fixed point method, Regular falsi method, Newton-Raphson method, Secant method. Convergence criterion & Error Analysis of all above methods.

System of Linear Equations: Gauss elimination methods, triangular factorization, Crout method, Choleski method.

Iterative methods: Jacobi method, Gauss-Seidel method, SOR method.

Numerical Differentiation: Numerical differentiation formulae based on interpolation polynomials, error estimates Richardson extrapolation.

RECOMMENDED BOOKS:

1. Principles of Partial Differential Equations, A. Komech, Springer, New York, 2009.
2. Applied Numerical Analysis, C. F. Gerlad and P.O. Wheatley, Pearson Education. Singapore, 2005.
3. Numerical Methods for Mathematics (Latest Edition), J. H. Mathews, Prentice Hall International,
4. Nonlinear Partial Differential Equations for Scientists and Engineers,. L. Debnath, Birkhauser-Boston, 2005.
5. Numerical Analysis (Latest Edition), R. L. Burden and J. D. Faires, PWS Pub. Co.
6. Elementary Differential Equations and Boundary Value Problems, W. E. Boyce, and R. C. DiPrima., John Wiley & sons, Inc.27, 2001.
7. Numerical Analysis: A Graduate Course, David E. Stewart, 2022.

Course Title: Theory of Optimization
Course Code: MTH-465
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

The aim of this course is to obtain a rigorous mathematical background to optimization techniques used in other related fields.

THEORY:

Optimization- an Overview: Optimization, Origin and development of optimization methods, Mathematical models. Optimization Methods in Engineering-Modelling and Application, Characteristics of optimization models, method of optimization, application in engineering areas.

Formulation of Optimization Problems: Decision variables or design vector, objective function, design constraints, boundary conditions, formulation, distinction between linear programming and nonlinear programming problems.

Analytical One-dimensional (Single Variable) Unconstrained Optimization: The Concept, Necessary and sufficient conditions, Necessary and sufficient conditions for single variable optimization, Working rule for single variable optimization.

Analytical Multidimensional (Multivariable) Unconstrained Optimization: Classification of Multivariable Optimization problems, Optimization Techniques to Solve Unconstrained Multivariable Functions, Necessary conditions, sufficient conditions, working rule for unconstrained Multivariable Optimization.

Analytical Multidimensional Optimization with Equality Constraints: Multivariable optimization with equality constraints, solution methods for multidimension optimization with equality constraints, direct substitution method, constrained variation method.

Analytical Multidimensional Optimization with Inequality Constraints: Solution Method, Kuhn-Tucker Conditions for solving Multivariable inequality constrained problems.
Numerical Methods for One Dimensional Nonlinear Programming: The philosophy, General method of solution, Classification, Distinction between Analytical and Numerical Methods, Fibonacci Search, Golden section search method, cubic interpolation.
Simplex Method for Linear programming problems: Simple algorithm, use of surplus and artificial variables in simplex method, Big m Method, two phase method, Variation in simplex solutions.
Degeneracy and duality in simplex: Degeneracy in simplex method, Degeneracy due to Beale's Cycling, Degeneracy due to tie between basic variables for leaving the basis, Tie for incoming variable, Unrestricted variables in LPPs, Equality constraints in LPPs, duality in simplex, Working rules for conversion of Primal to Dual and dual to primal, Comparison between prime and dual, Advantages and applications of duality.

RECOMMENDED BOOKS:

1. Introduction to Optimization Theory (Latest Edition), B. S. Gotfried and J. Weisman, Prentice-Inc. New Jersy.
2. Introduction to Nonlinear Optimization (Latest Edition), D. A. Wismer and R Chattergy, North - Holland, New York.
3. Differential Equations and the Calculus of Variations (New Edition), L. Elsgolts, University Press of the Pacific.
4. Mathematical Optimization and Economic Theory (Latest Edition), M. D. Intriligator, Society Forindustrial and Applied Mathematics.

Course Title: Advanced Group Theory
Course Code: MTH-435
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to study advance topics of group theory.

THEORY:
Preliminaries: Group Theory.
Group Actions: Group Actions and its kernel, transitive group actions, group action by conjugation and class equation.
p-groups: p-groups, Some results on finite p-groups, The Sylow theorems.
Direct product: Direct product, semi direct product.
Abelian groups: Fundamental theorem of finitely generated Abelian groups, Table of groups of small order.
Some Special Types of Groups: Simple groups, short survey about free groups, Nilpotent and solvable groups.

RECOMMENDED BOOKS:

1. Visual Group Theory, N. Carter, American Association of America Inc., 2009.
2. Classic Algebra, P.M. Cohn, John Wiley & Sons Inc., 2000.

3. Abstract Algebra (3rd Edition), D.S. Dummitand R.M. Foote, John Wiley & Sons, 2004.
4. Contemporary Abstract Algebra (8th Edition), J. Gallian, Brooks/Cole Cengage Learning.30., 2013.

Course Title: Continuous Group
Course Code: MTH-436
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to give introduction on continuous groups which is useful to learn theoretical physics related subjects.
THEORY:
Preliminaries: Group Theory.
Continuous Groups: Continuous Groups, Gl(n,r), Gl(n,c), So(p,q), Sp(2n), generalities on Continuous Groups, Groups of isometrics.
Lie groups and Lie Algebra: Introduction to Lie groups with special emphasis on matrix Lie groups; Relationship of isometrics and Lie group, Theorem of Cartan, Correspondence of continuous groups with Lie algebras.
Dimension and Homogeneous Spaces: Classification of groups of low dimensions, Homogeneous spaces and orbit types, Curvature of invariant metrics on Lie groups and homogeneous spaces.

RECOMMENDED BOOKS:
1. Introduction to Compact Transformation Groups, G. E. Bredon, Academic Press, 2006.
2. Introduction to Topological Groups, H. Taqdir, W. B. Saunder's-Company, 2007.
3. Symmetry Groups and Their Application, Jr. M. Willard, Academic Press-New York and London, 2008.
4. Continuous Groups of Transformations, L. P. Eisenhart, Priceton U. P., 2003.

Course Title: Rings and Modules
Course Code: MTH-437
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to realize the importance of rings and modules as central objects in algebra and to study some applications.
THEORY:
Preliminaries: Group Theory and Vector Space.
Elementary properties of rings: Basic concepts of Ring Theory, Some Special Classis of Rings, Product, Matrix and Polynomial Rings.
Subrings; Homomorphisms: Subrings and its examples, Ring Homomorphism, Isomorphisms.
Kernels and Ideals: Ideal and Quotient Rings, Prime and maximal ideals.

Special Classes of Rings: Integral Domain, Zero Divisors, Units, Nilpotents, Idempotents, Field of Quotients.
Basic Concept of Module Theory: Module Theory, Submodules, Quotient Modules, Direct Sums.
Homomorphism and Free Modules: Homomorphism, finitely generated Modules, Free Modules.

RECOMMENDED BOOKS:

1. Introduction to Commutative Algebra, M. F. Atiyah and I. G. Macdonald, Addison-Wesley Publishing Company, Inc., 1969.
2. Commutative Algebra, O. Zariski and P. Samuel, Springer, 1975-6.
3. Abstract Algebra (3rd Edition), D. S. Dummit and R. M. Foote, John Wiley & Sons., 2004.
4. Multiplicative Ideal Theory, R. Gilmer, Marcel Dekker, New York, 1972.

Course Title: Advanced Topology
Course Code: MTH-454
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to introduce advance topics in topology.

THEORY:
Compactness: Compactness in metric spaces, Limit point, Compactness, Sequential compactness and theirvarious characterizations, Equivalence of different notions of compactness.
Connectedness: Connectedness,various characterizations of connectedness, Connectedness and T spaces, Localconnectedness, Path-connectedness, Components. Homotopic maps, Homotopic paths.
Function Spaces: Loopspaces, Fundamental groups, Covering spaces, the lifting theorem, Fundamental groups of thecircle etc.
Chain complex, Notion of homology.

RECOMMENDED BOOKS:

1. Topology, J. Hocking and G. Young, Dover Publications, 2001.
2. General Topology, J. Kelly, Springer, 2005.
3. Topology - A First Course, J. R. Munkres, Prentice-Hall, 2003.
4. General Topology, S. Lipschutz, McGraw-Hill.34, 2004.

Course Title: Algebraic Topology
Course Code: MTH-455
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

The aim of the unit is to give an introduction to algebraic topology with an emphasis on cell complexes, fundamental groups and homology.

THEORY:

Preliminaries: Topology.

Introduction: Introduction to Algebraic Topology, One-dimensional objects,

Homeomorphic Spaces: Homeomorphism and the group structure on a circle, Two-dimensional surfaces (the sphere), Two-dimensional objects (the torus and genus), non-orientable surfaces (the Mobius band),The Klein bottle and projective plane.

The Euler Characteristic and Identification Spaces: Polyhedra and Euler's formula, Applications of Euler's formula and graphs, More on graphs and Euler's formula.

Curvature: Rational curvature, winding and turning, Duality for polygons and the Fundamental theorem of Algebra, More applications of winding numbers, The Ham Sandwich theorem and the continuum, Rational curvature of a polytope, Rational curvature of polytopes and the Euler number, Classification of combinatorial, An algebraic ZIP proof of the classification, The geometry of surfaces, The two-holed torus and 3-crosscaps surface, Knots and surfaces.

The Fundamental Group and Covering Spaces: The fundamental group, covering spaces, covering spaces and 2-oriented graphs, Covering spaces and fundamental groups, Universal covering.

Introduction to abstract algebra: An informal introduction to abstract algebra, Introduction to group theory, More on commutative groups (isomorphisms, homomorphisms, cosets and quotient groups), Free abelian groups and non-commutative groups.

Homology and Application: An introduction to homology, Simplices and simplicial, Computing homology groups, Delta complexes, Betti numbers and torsion.

RECOMMENDED BOOKS:

1. Algebraic Topology Homology and Cohomology, A. H. Wallace, W.A. Benjamin Inc. New York, 2004.
2. Algebraic Topology, A. Hatcher, Cambridge University Press, 2002.
3. First Course in Algebraic Topology, C. A. Kosniowski, C.U.P, 2003.
4. Basic Concept of Algebraic Theory, F. H. Croom, Spinger-Verlag, New York, 2005.
5. Algebraic Topology, A First Course, M. J. Greenberg and J. R. Harper, The Bonjan Cunning Pub. Co.35, 2007.

Course Title: Operations Research
Course Code: MTH-463
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

This course deals with the optimization techniques that allocate the available resources in an optimal manner.

THEORY:

Linear Programming: Mathematical modeling. Formulation and graphical solution. Analytical solution. Simplex method. Two- phase and M-technique for Linear programs. Duality. Duality simplex method. Sensitivity Analysis.

Transportation Problems: Definition. Various methods including North –West Corner method. Least –cost method and Vogel's approximation. The Assignment model. Application to Networks. Shortest- Route Algorithm for acyclic and cyclic networks. Maximal- flow problems.
Integer Programming: Definition and formulation- Cutting-Plane Algorithm and Branch-and Bound method, Application. The mixed Algorithm, Zero-one polynomial programming.

RECOMMENDED BOOKS:

1. Operation Research, . C. M. Harvey, North Holland, New Delhi, 1979.
2. Operational Research, F. S Hiller and G. J. Liebraman, CBS Publisher and Distributors, New Delhi, 1974.
3. An Introduction to Operations Research, H. A. Taha, Macmillan Publishing Company Inc. New York, 1987.
4. Operations Research, S. Kalavathy, Vikas Publishing House Ltd.
5. Operations Research: An Introduction, S. A. Bhatti, Shaharyar Publishers, Lahore, 1996.

Course Title: Mathematical Statistics I

Course Code: MTH-471

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The principal aim of this course is to provide students with a solid grounding in probability theory and mathematical statistics.
THEORY:
Probability Distributions: The postulates of probability, Some elementary theorems, Addition and multiplication rules, Baye's rule and future Baye's theorem. Random variables and probability functions
Discrete Probability Distributions: Uniform, Bernoulli and Binomial distribution, Hypergeometric and geometric distribution, Negative binomial and Poisson distribution.
Continuous Probability Distributions: Uniform and exponential distribution, Gamma and beta distributions, Normal distribution.
Mathematical Expectations: Moments and moment generating functions, Moments of binomial, hypergeometric, Poisson, gamma, beta and normal distributions.

RECOMMENDED BOOKS:

1. Mathematical Statistics, J. E. Freund, Prentice Hall Inc., 1992
2. Introduction to Mathematical Statistics, Hogg and Craig, Collier Macmillan, 1958.
3. Introduction to the Theory of Statistics, Mood, Greyill and Boes, McGraw Hill.
4. Introduction to Statistics (3rd Edition), R. E. Walpole, Macmillan Publishing Company London, 1982.
5. Mathematical Statistics with Resampling and R by Laura, M. Chihara and Tim C. Hesterberg, 2022.
6. Wackerly, D., Mendenhall, W., & Scheaffer, R. L. Mathematical statistics with applications, (Cengage Learning, 2014).
7. 2. Devore, J. L. Probability and Statistics for Engineering and the Sciences. (Cengage Learning, 2015).

8. 3. Devore, J. L., Berk, K. N., & Carlton, M. A. Modern mathematical statistics with applications (Vol. 285), (New York: Springer, 2012).
9. 4. Kapadia, A. S., Chan, W., & Moyé, L. Mathematical statistics with applications, (CRC Press, 2017).

Course Title: Methods of Mathematical Physics
Course Code: MTH-481
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The main objective of this course is to provide the students with a range of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics and engineering. In addition this course is intended to prepare the students with mathematical tools and techniques that are required in advanced courses offered in the applied physics and engineering programs.

THEORY:
Fourier Methods: The Fourier transforms. Fourier analysis of the generalized functions. The Laplace transforms. Hankel transforms for the solution of PDEs and their application to boundary value problems.
Green's Functions and Transform Methods: Expansion for Green's functions. Transform methods. Closed form Green's functions.
Perturbation Techniques: Perturbation methods for algebraic equations. Perturbation methods for differential equations.
Variational Methods: Euler- Langrange equations. Integrand involving one, two, three and n variables. Special cases of Euler- Langrange's equations. Necessary conditions for existence of an extremum of a functional. Constrained maxima and minima.

RECOMMENDED BOOKS:
1. Partial Differential Equations. Sources and Solutions, A. D. Snider, Prentice Hall Inc., 2007.
2. Boundary Value Problems and Partial Differential Equations (5^{th} Edition), D. L. Powers, Academic Press, 2005.
3. Fourier Series and Boundary Value Problems, J. W. Brown and R. V. Churchil, McGraw-Hill, 2006.

Elementary Differential Equations (8^{th} Edition), W. E. Boyce, John Wiley and Sons. 31, 2005.

Course Title: Quantum Mechanics I
Course Code: MTH-482
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of the course is to provide mathematics students with a thorough introduction to nonrelativistic quantum mechanics, with emphasis on the mathematical structure of the theory.

THEORY:

Inadequacy of Classical Mechanics: Black body radiation, Photoelectric effect, Compton effect, Bohr's theory of atomic structure, Wave-particle duality, the de- Broglie postulate.

The Uncertainty Principle: Uncertainty of position and momentum, statement and proof of the uncertainty principle, Energy time uncertainty.

Operators and eigen functions: Eigenvalues and eigen functions, Linear Operators, Operator formalism in Quantum Mechanics, Orthonormal systems, Hermitian operators and their properties, Simultaneous eigen functions. Parity operators.

Postulates of quantum mechanics: the Schrödinger wave equation.

Motion in one Dimension: Step potential, potential barrier, Potential well, and Harmonic oscillator.

RECOMMENDED BOOKS:

1. Quantum Mechanics (5th Edition), E. Merzdacker, John Wiley and Sons Inc. New York, 2005.
2. The Physics of Elementary Particles, H. Muirhead, Pergamon Press, 2002.
3. Quantum Mechanics, J.G. Taylor, George Allen and Unwin, 2010.
4. Fundamental of Modern Mechanics, R. M. Eisberg, John Wiley and Sons Inc., 2005.
5. Quantum Mechanics, T. L.Powell and B. Crasemann, Addison-Wesley, 2002.
6.

Course Title: Fluid Mechanics I
Course Code: MTH-484
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics.

THEORY:

Fluids and their properties: Introduction, Fields and continuum concepts,Surface and body forces, Stress at a point, Viscosity and Newton's viscosity law, Viscous and inviscid flow, Laminar and turbulent flows, Compressible and incompressible flows.

Fluid Kinematics: Lagrangian and Eulerian specifications, Local, convective, and total rates of change, Conservation of mass, Equation of continuity, Boundary conditions.

Irrotational Fluid Motion: Velocity potential from an irrotational velocity field, Streamlines, Vortex lines and vortex sheets, Kelvin's minimum energy theorem, Conservation of linear momentum, Bernoulli's theorem and its applications, Circulations, rate of change of circulation (Kelvin's theorem, Axially symmetric motion, Stokes's stream function.

Two-dimensional Motion: Stream function, Complex potential and complex velocity, Uniform flows, Sources, sinks, and vortex flows, Flow in a sector, Flow around a sharp edge, Flow due to a doublet.

RECOMMENDED BOOKS:

1. Fundamental Mechanics and Fluids, G. Currie, CRC Press, 2012.
2. Boundary Layer Theory, H. Schlichting, Springer, 2000.
3. Fluid Mechanics (2nd Edition), J. H. Spurk and N. Aksel, Springer, 2008.
4. A Textbook of Fluid Mechanics, R. K. Bansal, Laxmi Publications (P) LTD, New Delhi, 2005.
5. Fluid Mechanics Fundamentals and Applications, 3rd Edition, McGraw Hill, 2023.

Course Title: Special Theory of Relativity
Course Code: MTH-486
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to introduce the concept of special relativity and its application to Physical Sciences.

THEORY:
Fundamental concepts: Historical background and fundamental concepts of Special Theory of Relativity, Derivation of Special Relativity, Einstein's formulation of special relativity, Galilean Transformation, The Lorentz transformation, Length contraction, time dilation and simultaneity, The velocity addition formulae, Three dimensional Lorentz transformations.
The Four-Vector Formulation of Special Relativity : The four-vector formalism, The Lorentz transformations in 4-vectors, The Lorentz and Poincare groups, The null cone structure, Proper time.
Applications of Special Relativity: Relativistic kinematics, The Doppler shift in relativity, The Compton effect, Particle scattering, Binding energy, particle production and particle decay.
Electromagnetism in Special Relativity: Review of electromagnetism, The electric and magnetic field intensities, The electric current, Maxwell's equations and electromagnetic waves, The four-vector formulation of Maxwell's equations.

RECOMMENDED BOOKS:
1. Relativity: An Introduction to the Special Theory, A. Qadir, World Scientific Press, 1989.
2. Classical Relativity, J. D. Jackson, Springer-Verlag, 1977.
3. Special Relativity, J. G. Taylor, Oxford University Press, 1965.
4. Introduction Einstein's Relativity, R. D' Inverno, Oxford University Press, 1992.
5. Special theory of relativity book: A Student's Guide to Special Relativity, Norman Gray, 2022.
6. Special theory of relativity book: A Mathematical Journey to Relativity, Wladimir-Georges Boskoff and Salvatore Capozziello, 2020.

SEMESTER VIII

Course Title: Functional Analysis

Course Code: MTH-425

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES

This course extends methods of linear algebra and analysis to spaces of functions, in which the interaction between algebra and analysis allows powerful methods to be developed. The course will be mathematically sophisticated and will use ideas both from linear algebra and analysis.

THEORY:

Review of Metric Spaces: Metric spaces, Separable metric spaces, Complete metric space, Isometric spaces, Completion of metric spaces,

Normed Spaces: Normed spaces, Banach spaces, Infinite series in normed spaces, Absolute convergence, Schauder basis, Semi norms, Quotient norm spaces, Finite dimensional normed spaces, Equivalent norms, compact sets in norm spaces, Compactness and finite dimension, Compactness and continuity, bounded linear operators, Continuity and boundedness, Bounded linear functional, Linear operators and functionals on finite dimensional normed spaces, Dual spaces,

Inner Product Spaces: Inner product spaces, Properties of inner product spaces, Hilbert spaces, Completion of inner product spaces, Direct sums, Orthogonal compliments, Orthonormal sets and sequences, Bessel inequality, Total orthonormal sets and sequences, Parseval identity, separable Hilbert spaces, Bounded linear functionals on Hilbert spaces, Hilbert adjoint spaces.

RECOMMENDED BOOKS:

1. Applied Functional Analysis (2nd Edition), A. V. Balakrishnan, Springer-Verlag, Berlin, 2000.
2. Introduction to Functional Analysis with Applications (Latest Edition), E. Kreyszig, John Wiley and Sons, 2004.
3. A Course in Functional Analysis (2nd Edition), J. B. Conway, Springer-Verlag, Berlin, 2000.
4. Functional Analysis (5th Edition), K. Yosida, Springer-Verlag. Berlin.
5. An Introduction to Functional Analysis, James C. Robinson, 2020.

Course Title: **Cryptography**
Course Code: **MTH-466**
Credit Hours: **3(3-0)**

COURSE LEARNING OBJECTIVES:

We can introduce this course in 7th semester. This course includes for security purposes. This course will explain the relationship of mathematics with security system that how we can secure our system by using mathematical term and methods.

THEORY:

Classic Ciphers and their analysis, Shanon's Information theory, Public Key Cryptography (PKC), Discrete Logarithm Problem (DLP), RSA Algorithm, Codes and cryptosystems

Detailed Contents:

• **Classical Ciphers and their analysis:** Suit-case problem, Introduction to Cryptography and its applications, Advanced Topics in Number Theory (Solution of system of congruencies, Modular Arithmetic), classical ciphers and their deciphering

• **Shanon's Information theory:** Shanon's theorem, Entropy, Redundancy and Unicity Distance, Mutual Information and Unconditionally Secure Systems

• **Public Key Cryptography(PKC):** The Theoretical Model, Motivation and Set-up, Confidentiality, Digital Signature, Confidentiality and Digital Signature

• **Discrete Logarithm Based Systems:** The Discrete Logarithm System, The Discrete Logarithm Problem(DLP), ElGamal's Public-Key Cryptosystems, ElGamal's Signature Scheme, How to Take Discrete Logarithms, Digital signature verification schemes

• **RSA:** The RSA System, Setting Up the System, RSA for Privacy, RSA for Signatures

• **Coding Theory Based Systems:** Introduction to coding theory, Repetition code and examples, decoding, Error-detection codes and Error-correcting codes, Setting Up the System, Encryption and Decryption.

Recommended Books:

1. Henk C.A. van Tilborg, *Fundamentals of Cryptology*, Springer; 2000.

2. J. Katz, Y. Lindell, *Introduction to Modern Cryptography*, Chapman and Hall/CRC, 3rd Edition.

3. A. J. Menezes, P. C. van Oorschot, S. A. Vanstone, *Handbook of Applied Cryptography*, CRC Press, August 2001.

4. Martin Tomlison , C. J. Thai, Error-Correction Coding and Decoding, 1st Edition 2017.

Course Title: Numerical Analysis II

Course Code: MTH-462

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

Numerical methods for the solution of some of the main problems of the scientific computing are introduced (nonlinear systems, data approximation, numerical differentiation and integration, numerical solution of ODE); their implementation and analysis are given by using interactive environments for the computing and the scientific visualization.

THEORY:

Numerical Integration: Composite Numerical Integration; trapezoidal rule, Simpson's formulas, Error estimation of integration formulas, Romberg integration, Gaussian quadrature.

Initial Value Problems for Ordinary Differential Equations: Elementary Theory of initial value problems, Euler's method, The Taylor series method, Runge-Kutta methods, Error Control and the Runge-Kutta-Fehlberg method, Multistep methods.

Finite Difference Methods: Explicit and implicit finite difference methods, stability, The method of characteristic.

Eigen value problems: Estimation of Eigen values and corresponding error bounds, Gerschgorian's theorem and its applications Schur's theorem, Power method, Shift of origin, Deflation method for the subdominant Eigen value.

RECOMMENDED BOOKS:

1. Principles of Partial Differential Equations, A. Komech, Springer-New York, 2009.
2. Applied Numerical Analysis, C. F. Gerladand P.O. Wheatley, Pearson Education, Singapore, 2005.
3. Numerical Methods for Mathematics (Latest Edition), .J. H. Mathews, Prentice Hall International,
4. Nonlinear Partial Differential Equations for Scientists and Engineers, L. Debnath, Birkhauser-Boston, 2005.
5. Numerical Analysis (Latest Edition), R. L. Burden and J. D. Faires, PWS Pub. Co.
6. Elementary Differential Equations and Boundary Value Problems, W. E. Boyce and R. C. DiPrima., John Wiley & sons, Inc., 2001.

Numerical Analysis: A Graduate Course, David E. Stewart, 2022.

Course Title: Advanced Set Theory

Course Code: MTH-413

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES

The aim of the course is to present advance topics of set theory.

THEORY:

Sets: Equivalent sets and examples, Countable sets, examples of countable sets, uncountable sets, examples of uncountable sets, partially ordered sets, Chasins,

Cardinal Numbers: Introduction, one-to-one correspondence, Equipotent sets, Denumerable and Countable sets, Real numbers **R** and power of the continuum, Cardinal numbers, Ordering of cardinal numbers, Cardinal arithmetic, Cardinal number as equivalence classes,

Ordinal Numbers: Ordinal numbers, Ordinal addition, Ordinal multiplication, Structure of ordinal numbers,

Axiom Of Choice, Zorn's Lemma, Well-Ordering Theorem: Introduction, Cartesian product and choice functions, Axiom of choice, Well-Ordering theorem, Zorn's lemma, Cantor's theorem, Cantor-Bernstein theorem, and applications.

RECOMMENDED BOOKS:

1. Basic Set Theory, S. Shen, N. K. Vereshchagin, and A. Shen, American Mathematical Soc.; 2002.
2. Set theory and metric spaces, I. Kaplansky, American Mathematical Soc., 2001.
3. Introductory Real Analysis, A. N. Kolmogorov and S. V. Fomin, Courier Corporation, 2012.
4. Naïve Set Theory, P. R. Halmos, New York, Van Nonstrand.
5. Introduction to Set Theory, Revised and Expanded, Hrbacek, Karel and Thomas JechCrc Press, 1999.

6. Structure and Randomness in Computability and set Theory, Douglas Cenzer, Christopher Porter, Jindrich Zapletal, 2020.
7. Structure and Randomness in Computability and set Theory, Douglas Cenzer, Christopher Porter, Jindrich Zapletal, 2020.

Course Title: Category Theory
Course Code: MTH-414
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course unit is to introduce the basic ideas of Category theory.
THEORY:
Preliminaries: functions, Group homomorphism and its types, kernel of homomorphism.
Basic concepts of category: Definition of category, examples, epimorphism, monomorphism, retractions, Initial, Terminal, and null objects, Category of graphs.
Limits in categories: Equalizers, Pull backs, Inverse images and intersections, Constructions with kernel pairs, Functions and adjoint Functions, Functions, Bifunctions, Natural transformations Diagrams, Limits, Colimits, Universal problems and adjoint functions. Subjects, Quotient objects and factorization, (EM) Categories, (Epi external mono) and (external epi mono) Categories, (Generating external mono) factorization.
Types of categories: Pointed categories, Normal and exact categories, Additive categories, Abelian categories, Definition of automation and examples.
Category of automata: Epimorphism, Monomorphism, initial, terminal and null objects in Aut. Congruences and factor automata, Automata with constant input and output.

RECOMMENDED BOOKS:
1. Basic Category Theory, J. V. Oosten, University of Otrecht, 2007.
2. Arrows, structure and functions, M. A. Arbib and E. G. Manes, Academic press New York, 1977.
3. Abelian Categories: An Introduction to the Theory of Funtors, P. Freyd, Harper and Row, 1964.
4. Basic Category Theory, T. Leinster, Cambridge University Press, 2014.

Course Title: Measure Theory
Course Code: MTH-426
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
To gain understanding of the abstract measure theory and definition and main properties of the integral. To construct Lebesgue's measure on the real line and in *n*-dimensional Euclidean space. To explain the basic advanced directions of the theory.

THEORY:

Sets and Functions: Definitions of set theory and properties of sets, Relations and functions, Relationship between equivalence relations on a set, Partitions of set, Different types of functions. Choice functions, Axiom of choice, Equivalent sets, Definition of countable set and its properties.
Topology: Metric space, Topological space, Open sets, Closed sets, Continuity in topological spaces.
Real Analysis: Set of extended real numbers, Intervals, Integration, Reimann integration.
Measurable Space: Algebra, $\sigma-$algebra of sets and relationship between them, Ring, $\sigma-$Ring of sets and their relationship, Existence of smallest $\sigma-$algebra containing a given collection of subsets of a set.
Outer Measure: General definitions of outer measure, Measure of a set and their properties.
Lebesgue Outer Measure: Lebesgue outer measure. Definition and its properties Lebesgue measurable set, Its Caratheodar's definition and properties, Approximation of measurable sets by open and closed sets.
Lebesgue Measure: Lebesgue measure, Definition and its properties, Lebesgue measure of Cantor set, Existence of Lebesgue non-measurable set.
Measurable Function: Definition of Measurable function, Algebra of measurable functions and various other properties of measurable functions, Measurability of step. Characteristic function, Dirichlet's function and simple functions etc.

RECOMMENDED BOOKS:

1. The Elements of Integration and Lebesgue Measure (International Edition), R. G. Bartle, WileyInterscience, 1965.
2. Measure and Integration Theory, H. Bauer, Berlin. de Gruyter, 2001.
3. A Primer of Lebesgue Integration (2nd Edition), H. S. Bear, San Diego. Academic Press, 2001.
4. Measure Theory, V. I. Bogachev, Berlin. Springer, 2007.

Course Title: Integral Equations
Course Code: MTH-427
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

Many physical problems that are usually solved by differential equation methods can be solved more effectively by integral equation methods. This course will help students gain insight into the application of advanced mathematics and guide them through derivation of appropriate integral equations governing the behavior of several standard physical problems.

THEORY:

Basic Concepts: Abel’s problem, Initial Value Problem and Boundary Value Problem, Integral Equation, Special Kinds of Kernels, Classification of Integral Equation, Iterated Kernels, Reciprocal Kernel or Resolvent Kernel, Eigenvalues and Eigenfunctions, Solution of an Integral Equation.

Applications to ordinary differential equations: Method of Conversion of an Initial Value Problem to a Volterra Integral Equation, Alternate Method of Transforming the Initial Value Problem into a Volterra Integral Equation, Boundary Value Problem and its Conversion to Fredholm Integral Equation.

Solutions of Homogenous Fredholm integral equations of second kind: Characteristic Value (or Eigenvalue) and Characteristic Function (or Eigenfunction), Solution of Homogeneous Fredholm Integral Equation of the Second Kind with Separable (or Degenerate) Kernel, Orthogonality of Two Functions, Orthogonality of Eigenfunctions, Real Eigenvalues.

Fredholm Integral Equation with Separable kernel: Solution of Fredholm Integral Equation of the Second Kind with Separable (or Degenerate) Kernel.

Integral Equations with symmetric kernel: Symmetric Kernel, Regularity Condition, Inner or Scalar Product of Two Functions , Orthogonal System of Functions , Fundamental Properties of Eigenvalues andEigenfunctions of Symmetric Kernels, Hilbert–Schmidt Theorem, Schmidt's Solution of Non-homogeneous Fredholm,Integral Equation of the Second Kind.

Solutions of integral equations of the 2nd kind by successive approximation:
Iterated Kernel or Function, Resolvent Kernel or Reciprocal Kernel, Solution of Fredholm Integral Equation of the SecondKind by Successive Substitution, Solution of Volterra Integral Equation of the SecondKind by Successive Substitutions,Solution of Fredholm Integral Equation of the SecondKind by Successive Approximations Iterative Method,(Iterative Scheme) Neumann Series, Resolvent Kernel of a Fredholm Integral Equation, Equation by Successive Approximations (Iterative Method),Reciprocal Functions, Equation of the Second Kind (Volterra Solution), Solution of Volterra Integral Equation of the SecondKind by Successive Approximations: Iterative Method (Neumann Series), Resolvent Kernel and Volterra Integral Equation.

RECOMMENDED BOOKS:

1. A First Course in Integral Equations, A. M. Wazwaz, World Scientific Pub.
2. Integral Equations, C. T. H. Baker, Clarendon Press.
3. Integral Equations, F. Smithies, Cambridge University Press.
4. Linear Integral Equations, W. V. Lovitt, Dover Publications, 2005.

Course Title: Theory of Modules
Course Code: MTH-438
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:

The main objective of this course is to introduce the basic theory of modules which is useful in advance level algebra courses.

THEORY:

Preliminaries: Vector Space and Ring Theory.

Basic Concept of Module Theory: Elementary notions and examples of Modules.

Special Classes of Modules: Submodules, Quotient modules, finitely generated and cyclic modules, Direct sums of modules, Radicals.

Free modules: Free modules, Matrices over Rings and their connections with the basis of free modules.
More Theory of Modules: Noetherian and Artinian rings and modules, Semi-simple rings and modules.
Exact sequences: Exact sequences and elementary notions of homological algebra.

RECOMMENDED BOOKS:

1. Module Theory, T. S. Blyth, Oxford University Press, 2004.
2. Abstract Algebra (3rd Edition), D. S. Dummit and R. M. Foote, John Wiley & Sons, 2004.
3. Rings, Modules and Linear Algebra, B. Hartley and T. O. Hawkes, Chapman and Hall, 2006.
4. A Course in Commutative Algebra, G. Kemper, Springer, 2010.

Course Title: Galois Theory
Course Code: MTH-439
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
To present an introduction to Galois theory in the context of arbitrary field extensions and apply it to a number of historically important mathematical problems.

THEORY:
The Concept of Extension Fields: Algebraic extensions, Finite fields.
The basic isomorphism of algebraic field theory, Automorphism and fields.
Introduction to: The Isomorphism Extension Theorem, Splitting fields, Separable extensions - Galois Theory, Illustrations of Galois Theory.

RECOMMENDED BOOKS:

1. Galois Theory (2nd Edition), D. A. Cox, John Wiley & Sons, Inc., 2012.
2. Abstract Algebra (3rd Edition), D. S. Dummit and R. M. Foote, John Wiley & Sons, 2004.
3. Fields and Rings (Latest Edition), I. Kaplansky, Chicago: University of Chicago Press.
4. Galois Theory (3rd Edition), I. Stewart, Chapman & Hall/CRC, 2004.

Course Title: Graph Theory
Course Code: MTH-443
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to introduce basic graph theory and applications.

THEORY:

Graphs: Graphs Models, Some special classes of graphs, Connected graphs, Multigraphs, Digraphs.
Degrees: The Degree of a vertex, Degree Sequence, Graphs and Matrices Regular and Irregular graphs.
Isomorphic Graphs: Graphs and Groups.
Trees: Bridges, Trees, The minimum spanning tree.
Connectivity: Cut-Vertices, Blocks, Menger Theorem, Eulerian Graphs, Hamiltonian graphs, Planar graphs.
Digraphs: Strong digraphs, Tournaments.

RECOMMENDED BOOKS:

1. Modern Graph theory, B. Bollobas, Springer Verlag, Newyork, 2002.
2. Graph theory, B. Bollobas, Springer Verlag, Newyork, 1979.
3. Graph theory and Its Applications, J. L. Gross and J. Yellen, Chapman and Hall, 2005.
4. Introduction to Graph Theory (Latest Edition), R. J. Wilson, Pearson Education Ltd.

Course Title: Mathematical Statistics II

Course Code: MTH-472

Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of the course is to present a solid calculus-based background in statistical theory together with its applications to solving practical real-world problems.

THEORY:
Functions of Random Variables: Distribution function technique, Transformation technique: One variable, Several variables (Two variable, Three or more variables), Moment-generating function technique**.**
Statistical Inference: Hypotheses Testing**:** Null and alternative hypotheses, Test-Statistics, Acceptance and Rejection Region, The Significance Level, Test of Significance, One-Tailed and Two-Tailed Tests
Sampling Distributions: The distribution of the mean and variance, The distribution of the mean: Finite populations, The Chi-Square distribution and statistical inference, The T-distribution and statistical inference, The F distribution and statistical inference.
Regression and Correlation: Linear regression**,** The simple linear regression (SLR) model, the methods of least squares, Normal regression analysis, Normal correlation analysis,
Multiple linear regression: Multiple linear regression (matrix notation).

RECOMMENDED BOOKS:

1. Mathematical Statistics, J. E. Freund, Prentice Hall Inc., 1992
2. Introduction to Mathematical Statistics, Hogg and Craig, Collier Macmillan, 1958.
3. Introduction to the Theory of Statistics, Mood, Greyill and Boes, McGraw Hill.
4. Mathematical Statistics with Resampling and R by Laura M. Chihara and Tim C. Hesterberg, 2022.

5. Statistics, M. R. Spiegel and L. J. Stephens, McGraw Hill Book Company, 1984.

Course Title: Probability Theory
Course Code: MTH-473
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
A prime objective of the course is to introduce the students to the fundamentals of probability theory and present techniques and basic results of the theory and illustrate these concepts with applications. This course will also present the basic principles of random variables and random processes needed in 24applications.

THEORY:
Finite probability spaces: Basic concept, probability and related frequency, combination of events, examples, Independence.
Random variables: Independence of random variables.
Mathematical Expectation: Expected value, Standard deviation and Chebyshev's inequality, Multiplicativity of the expected value, Additivity of the variance, Discrete probability distribution.
Probability as a continuous set function: Sigma-algebras, examples. Continuous random variables, Expectation and variance. Normal random variables and continuous probability distribution.
Applications: de Moivre Laplace limit theorem, weak and strong law of large numbers. The central limit theorem, Markov chains and continuous Markov process.

RECOMMENDED BOOKS:
1. Measure, Integral and Probability, M. Capinski and E. Kopp, Springer-Verlag, 1998.
2. Real Analysis and Probability, R. M. Dudley, Cambridge Univer-sity Press, 2004.
3. A Probability Path, S. I. Resnick, Birkhauser, 1999.
4. A first Course in Probability Theory (5^{th} Edition), S. Ross, Prentice Hall, 1998.
5. Basic Probability Theory, Robert B. Ash, Dover. B, 2048.

Course Title: Combinatorics
Course Code: MTH-474
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this class is to introduce the basic combinatorial tools of computer science, to train students in mathematical thinking and reasoning that is pertinent to computer science, and to present that reasoning in rigorous written text.

THEORY:
Preliminaries: Basic Math.
Basic Concept of Counting: Basic counting principles, Permutations, Combinations, The injective and bijective principles, Arrangements and selections with repetitions, Graphs in Combinatorics.

Binomial and Multinomial Theorem: The Binomial theorem, combinatorial identities. Properties of binomial coefficients, Multinomial coefficients, The multinomial theorem.
Existence of Combinatorial Configuration: The Pigeonhole principle, Examples, Ramsay numbers, The principle of inclusion and exclusion, Generalization, Integer solutions, Surjective mapping, Stirling numbers of the second kind, The Sieve of Eratostheries.
Functions: Euler φ-function, The Problem des Manages, Ordinary Generating Functions, Modeling problems. Partition of integers, Exponential generating functions.
Linear Algebra: Linear homogeneous recurrence relations, Algebraic solutions of linear recurrence relations and constant functions, The method of generating functions, A non-linear recurrence relation and Catalpa numbers.

RECOMMENDED BOOKS:

1. Applied Combinatorics (Latest Edition), A. Tucker, John Wiley & Sons. New York,
2. Principles and Techniques in Combinatorics, C. C. Chen and K. M. Koh, World Scientific Pub. Co. Pte. Ltd. Singapore, 1992.
3. Introduction to Combinatorial Mathematics, C. L. Liu, McGraw-Hill. New York, 1968.
4. A Course on Combinatorics (2^{nd} Edition), J. H.V. Ling, and R. M. Wilson, Cambridge University Press, Cambridge, 2001.
5. Theory and Problems of CombunatoricsSchaum's Outline Series, V. K. Balakrishnan, McGraw-Hill International Edition. Singapore, 1995.

Course Title: Quantum Mechanics II
Course Code: MTH-483
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of the course is to provide mathematics students with a thorough introduction to nonrelativistic quantum mechanics, with emphasis on the mathematical structure of the theory.

THEORY:
Motion in three dimensions: angular momentum, commutation relations between components of angular momentum, and their representation in spherical polar coordinates, simultaneous Eigen functions of L_z and L^2, Spherically symmetric potential and the hydrogen atom.
Scattering Theory: The scattering cross-section, scattering amplitude, scattering equation, Born approximation, partial wave analysis.
Perturbation Theory: Time independent perturbation of non-degenerate and degenerate cases. Time-dependent perturbations.
Identical Particle: Symmetric and anti-symmetric Eigen function, The Pauli exclusion principle.

RECOMMENDED BOOKS:

1. Quantum Mechanics (2^{nd} Edition), E. Merzdacker, John Wiley and Sons.
2. Quantum Mechanics (Latest Edition), J. G. Taylor, George Allen and Unwin.
3. Quantum Mechanics (Latest Edition), R. Dicke and J. P. Witke, Addison Wesley.
4. Fundamental of Modern Mechanics (Latest Edition), R. M. Eisberg, John Willey and Sons
5. The Physics of Elementary Particles, H. Muirhead, Pergamon Press.

6. .Quantum Mechanics (Latest Edition), T. L. Powell, and B.Crasemann, Addison Wesley.

Course Title: Fluid Mechanics II
Course Code: MTH-485
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics.

THEORY:
Irrotational Motion: Flow net, Source, sink, doublet, and vortex, Kelvin's minimum energy theorem, Uniqueness theorem.
Vortex motion: Line Vortex, Vortex row Image System, Fluid streaming past a circular cylinder, Irrational motion produced by a vortex filament, The Helmholtz vorticity equation, Karman's vortex-street.
Fundamental equations of viscous compressible flow: Analysis of stress, Analysis of fluid motion near a point, Components of strain rate tensor, Stress-strain rate relationship for a Newtonian fluid, Navier Stokes equations.
Viscous incompressible flow: Exact solution of Navier-Stokes equations, Steady laminar flow between two parallel plates, Simple Couette flow, Generalized Couette flow, plane Poiseuille flow steady laminar flow over an inclined plate , Steady laminar flow of the two immiscible fluids, Flow between two parallel porous plates with injection and suction, Hagen Poiseuille flow, Flow through an inclined pipe steady laminar flow between two coaxial cylinders, Flow between two moving coaxial circular cylinders, Flow between two concentric rotating cylinders.

RECOMMENDED BOOKS:
1. Boundary Layer Theory (8^{th} Edition), H. Schlichting, Springer, 2000.
2. Fundamental Mechanics and Fluids (4^{th} Edition), I. G. Currie, CRC Press, 2012.
3. Fluid Mechanics (2^{nd} Edition), J. H. Aksel and N. Spurk, Springer, 2008.
4. A Textbook of Fluid Mechanics (9^{th} Edition), R. K. Bansal, Laxmi Publications LTD, New Delhi, 2005.

Course Title: Theory of Elasticity
Course Code: MTH-487
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The objective of the course is to introduce the theory of elasticity and to analyze some real problems and to formulate the conditions of theory of elasticity applications.

THEORY:
Tensors: Cartesian tensors.

Analysis of stress and strain: Generalized Hooke's law.
Crystalline Structures: Point groups of crystals, Reduction in the number of elastic moduli due to crystal symmetry.
Equations of equilibrium: Boundary conditions, compatibility equations.
Plane stress and planestrain problems: Two dimensional problems in rectangular and polar co-ordinates, torsion of rods and beams.

RECOMMENDED BOOKS:

1. Elasticity Engineering Mechanics (2nd Edition), A. P. Boresi and K. P. Chong, John Wiley & Sons, 2000.
2. Advanced Strength and Applied Elasticity (Latest Edition), A. C. Ugural and S. K. Fenster, Elsevier Science Publishing Co., Inc.
3. Elasticity: Theory and Applications (Latest Edition), A. S. Saada, Krieger Publishing, Malabar, Florida.
4. Theory of Elasticity (Latest Edition), S. P. Timoshenko and J. N. Goodier, McGraw Hill Book Company.

Course Title: Electromagnetism
Course Code: MTH-488
Credit Hours: 3(3-0)

COURSE LEARNING OBJECTIVES:
The aim of this course is to provide the students with the fundamental principles of electrical energy (electro- magnetism).

THEORY:
Electrostatics: Introduction and the solution of electrostatics problems in vacuum and in media, Electrostatic energy, Electro currents.
The magnetic field of steady currents: Magnetic properties of matter. Magnetic energy.
Electromagnetism: Introduction, Maxwell's equations, Boundary Value Potential Problems in two dimensions, Electromagnetic Waves, Radiation, Motion of electric charges.

RECOMMENDED BOOKS:

1. Introduction to Electromagnetic Fields and Waves (Latest Edition), D. Corson and P. Lerrain, Freeman.
2. Foundation of Electromagnetic Theory (Latest Edition), J. R. Reitz and F. J. Milford, Addison-Wesley.
3. Classical Electricity and Magnetism (Latest Edition), K. H. Panofsky and M.Philips. Addison-Wesley.
4. Electromagnetic Theory (Latest Edition), V. C. A. Ferraro, The Athlone Press.