



Two-Year Post-Graduate Programme

Master of Science

Applied Mathematics

Faculty of Applied Sciences

Parul University

Vadodara, Gujarat, India

Faculty of Applied Sciences
Master of Science in Applied Mathematics

1. Vision of the Department

To offer quality applied education to the youngsters for excellence in their branch and catalysing their better career prospects and opportunities ahead by increasing their mathematical and physical science knowledge and grooming them for campus drive.

2. Mission of the Department

M1	Providing high-quality instruction to students at various levels, fostering mathematical understanding, problem-solving skills, and critical thinking.
M2	Conducting cutting-edge mathematical research to contribute to the advancement of knowledge within the field.
M3	Offering resources and support services to help students succeed in their mathematical studies, addressing individual needs and fostering a positive learning environment.

3. Program Educational Objectives

The statements below indicate the career and professional achievements that the B.Tech. Electrical Engineering curriculum enables graduates to attain.

PEO 1	To Prepare graduates with advanced knowledge and expertise in applied mathematics, enabling them to proficiently analyze and solve complex problems in diverse fields.
PEO 2	Foster the ability to collaboratively apply mathematical principles across disciplines, promoting effective communication and teamwork in interdisciplinary environments.
PEO 3	To Develop graduates as innovative and adaptable problem solvers, capable of leveraging mathematical modelling, computation, and critical thinking to address real-world challenges in academic, industrial, and research settings.

4. Program Learning Outcomes

Program learning outcomes for a degree in Applied Mathematics typically encompass a range of skills and knowledge that students are expected to acquire during their course of study. These outcomes reflect the goals of the program and the skills that are deemed essential for graduates in the field of Applied Mathematics. Here are some common program learning outcomes for an Applied Mathematics degree:

PLO 1	Mathematical Proficiency:	Demonstrate a strong foundation in core mathematical concepts, including calculus, algebra, differential equations, and numerical methods. Apply advanced mathematical techniques to solve real-world problems in various scientific, engineering, and business contexts.
PLO 2	Modelling and Problem-Solving:	Formulate mathematical models to represent and analyze real-world phenomena.

		Apply mathematical reasoning and problem-solving skills to address complex problems in diverse fields, such as physics, engineering, biology, finance, and computer science.
PLO 3	Computational Skills:	Utilize computational tools and software to perform mathematical analysis and simulations. Demonstrate proficiency in programming languages commonly used in applied mathematics, such as MATLAB, Python, or others.
PLO 4	Interdisciplinary Application:	Apply mathematical concepts to interdisciplinary areas, collaborating with professionals from other fields to address complex challenges. Translate mathematical solutions into meaningful insights for non-mathematical audiences
PLO 5	Critical Thinking and Analytical Skills:	Develop the ability to think critically and analyze problems from multiple perspectives. Evaluate the appropriateness of mathematical models and methods for specific problems.
PLO 6	Communication Skills:	Effectively communicate mathematical ideas and solutions through written reports, oral presentations, and visualizations. Collaborate with others, including non-mathematicians, in a team environment.
PLO 7	Ethical and Professional Conduct:	Demonstrate ethical behavior in mathematical research and applications. Understand and adhere to professional standards and norms in the field of applied mathematics.
PLO 8	Lifelong Learning:	Foster a commitment to lifelong learning and staying current with developments in mathematics and related disciplines. Engage in professional development activities to enhance skills and knowledge.
PLO 9	Research Skills:	Develop basic research skills, including the ability to conduct literature reviews, formulate research questions, and analyze data. Engage in independent or collaborative research projects applying mathematical methods.

5. Program Specific Learning Outcomes

PSO 1	Advanced Mathematical Modelling:	Formulate and solve complex real-world problems by creating advanced mathematical models, demonstrating proficiency in selecting appropriate mathematical techniques, and interpreting results in the context of the specific application.
--------------	---	--

PSO 2	Computational Implementation and Analysis:	Utilize computational tools and programming languages to implement mathematical models, conduct simulations, and analyze numerical solutions. Develop the ability to assess the accuracy and efficiency of computational methods, and make informed decisions about their application in solving applied mathematical problems.
--------------	---	---

6. Credit Framework

Semester wise Credit distribution of the programme		Category wise Credit distribution of the programme	
		Category	Credit
Semester-1	23	Major Core	94
Semester-2	23	Minor Stream	0
Semester-3	22	Multidisciplinary	0
Semester-4	26	Ability Enhancement Course	0
Total Credits:	94	Total Credits:	94

7. Program Curriculum

Semester 1						
Sr. No.	Subject Code	Subject Name	Credit	Lect	Lab	Tut
1	11206101	Measure Theory	4	4	-	-
2	11206102	Theory of Ordinary Differential Equations	4	4	-	-
3	11206103	Advanced Numerical Analysis	4	4	-	-
4	11206104	Topology	4	4	-	-
5	11206106	Matlab Programming	3	2	2	-
6	11206107	Transform Theory	4	4	0	0
Total			23	22	2	0
Semester 2						
Sr. No.	Subject Code	Subject Name	Credit	Lect	Lab	Tut
7	11206151	Complex Analysis	4	4	-	-

8	11206152	Applied Partial Differential Equations	4	4	-	-
9	11206153	Advanced Abstract Algebra	4	4	-	-
10	11206154	Advanced Linear Algebra	4	4	-	-
11	11206156	Python Programming	3	2	2	-
12	11206157	Mechanics	4	4	0	0
Total			23	22	2	0
Semester 3						
Sr. No.	Subject Code	Subject Name	Credit	Lect	Lab	Tut
13	11206201	Functional Analysis	4	4	0	0
14	11206202	Mathematical Modelling	4	4	0	0
15	11206203	Integral Equations and Calculus of Variation	4	4	0	0
16	11206205	Seminar	2	-	-	2
17	11206210	Inferential Statistics	4	4	0	0
18		Elective - 1 (Compulsory Subjects :1) -	4	4	-	-
Total			22	20	0	2
Semester 4						
Sr. No.	Subject Code	Subject Name	Credit	Lect	Lab	Tut
25	11206251	Operator Theory	4	4	-	-
26	11206252	Finite Element Method	4	4	-	-
27	11206257	Dissertation	6	0	0	6
28	11206258	Operations Research	4	4	0	0
29	11206259	Dynamical Systems and Control	4	4	0	0
		Elective - 2 (Complsoy Subjects :1) -	4	4	-	-
Total			26	20	0	6

8. Detailed Syllabus

Semester – 1

Course Name: Measure Theory

Course Code: 11206101

Prerequisite: Set Theory, Real Analysis, Topology.

Rationale: Measure theory provides a broader and more general framework for defining integration. It extends the concept of integration to a wider class of functions and allows for a more flexible approach in handling diverse mathematical structures.

Course Objectives:

This course will help the learner to

COBJ1	Understand sigma-algebras, measurable sets, and measures.
COBJ2	Master Lebesgue integration, comparing and contrasting it with the Riemann integral.
COBJ3	Learn methods for constructing measures and understand their properties.
COBJ4	Master the Monotone, Fatou's Lemma, and Dominated Convergence Theorems and apply them in integral analysis.
COBJ5	Extend integration to product spaces, applying Fubini-Tonelli theorems.
COBJ6	Apply measure theory to probability spaces, studying random variables and distributions.
COBJ7	Introduce basic functional analysis concepts like L_p spaces.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Get knowledge and understand basic concepts of measure and integration theory.
CLO2:	Study the theory on the basis of examples of application.
CLO3:	Use abstract methods to solve problems.
CLO4:	Ability to use a wide range of references and critical thinking.
CLO5:	Understand the fundamentals of measure theory.
CLO6:	Use mathematical concepts such as volume, area, and integration and they will develop a perspective on the broader impact of measure theory in ergodic theory.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	-	-	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit-1	Lebesgue Measure: Algebra and Sigma-algebra of sets, Borel sets, outer measure, measurable sets and Lebesgue measure, a non-measurable set, measurable function, Little wood's three principles.	25%	15
Unit-2	Lebesgue Integral: The Riemann integral, the Lebesgue integral of a bounded function over a set of finite measure, the integral of non-negative function, the general Lebesgue integral, convergence in measure.	25%	15
Unit-3	Differentiation and Integration Differentiation of monotone functions, functions of bounded variation, Differentiation of an integral, absolute continuity, convex functions.	27%	16
Unit-4	The Classical Banach spaces: The L^p spaces, convergence and completeness, approximations in L^p bounded linear functions on L^p bounded linear functions on L^p spaces.	23%	14
	Total	100	60

Text Book

Real Analysis (TextBook) H. L. Royden, Macmillan; Pub. Co. Inc.; 4th Edition

Reference Books

- 1.Principles of Mathematical Analysis Walter Rudin, Mc Graw Hill, Kogakusha Mathematical Analysis
2. T. M. Apostol; Narosa Publishing House, New Delhi, 1985
- 3.Measure Theory and Integration G. de. Barra; Wiley Eastern Limited, 1981
- 4.Theory of Functions of a Real Variable, Vol. I I. P. Natanson

Course Name: Theory of Ordinary Differential Equations**Course Code: 11206102****Prerequisite:** Basic Knowledge of Derivatives and Differential equations**Rationale:** The Theory of Ordinary Differential Equations is essential for modeling and analyzing dynamic systems, providing a mathematical framework to understand how quantities change over time in various scientific and engineering applications.**Course Objectives:**

This course will help the learner to

COBJ1:	Grasping the basic concepts, terminology, and classifications of ordinary differential equations.
COBJ2:	Applying differential equations to model and describe real-world phenomena in different disciplines, such as physics, biology, engineering, and economics.
COBJ3:	Learning and applying techniques for solving linear and nonlinear ordinary differential equations, including initial and boundary value problems.
COBJ4:	Gaining insight into the qualitative behavior of solutions, stability, and phase plane analysis.
COBJ5:	Exploring applications of ordinary differential equations in diverse fields, emphasizing their significance in understanding dynamic systems.

Course Learning Outcome:

After completion of course student will be able to,

CLO1	Expresses the existence-uniqueness theorem of differential equations.
CLO2	Expresses the basic existence theorem for higher- order linear differential equations.
CLO3	Solve systems of linear differential equations.
CLO4	Determines the type of a linear differential equation systems.
CLO5	Solve the linear system in normal form
CLO6	Solves the homogeneous linear systems with constant coefficients.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	-	-	4	20	20	-	60	-	100

L- Lectures; T- Tutorial; P- Practical; C- Credit; MSE- Mid-Semester Evaluation, CE- Continuous Evaluation, ESE- End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit-1	Existence and Uniqueness of Solutions: Introduction, Preliminaries, Picard's Successive Approximations, Picard's theorem, Continuation and dependence on initial conditions, Existence of solution, Existence and Uniqueness for System, Fixed point techniques. Existence Theorem, Extremal Solutions, Upper and Lower Solutions, Monotone Iterative Method	25%	15
Unit-2	System of Linear differential equations: Systems of First order equations, Matrices and Eigen values Two Dimensional System of Linear first order ODE, Stability		

	of homogeneous linear system: Unequal real Eigen values, equal real Eigen values, complex Eigen values, Model for Arms Competition between two nations, Existence and Uniqueness Theorem, Fundamental matrix, Non Homogeneous linear system, Linear system with constant coefficients, Linear system with periodic coefficients, Variation of Parameters (A nonlinear version), Phase Portrait	25%	15
Unit-3	Solutions in Power Series: Introduction, Second order linear equations with ordinary points, Legendre Equation and polynomials, Second order Equation with regular singular points, Bessel's Functions Boundary Value Problems: Introduction, Strum-Liouville Problem, Green Functions, Application of BVP	26%	16
Unit-4	Asymptotic behavior and Stability Theory: Introduction, Critical points of nonlinear systems, Linear system with constant and variable coefficients, Stability of nonlinear system, Stability of Autonomous System, Stability of Non-Autonomous Systems.	24%	14
	Total	100	60

Text Book

Theory of Ordinary Differential Equations (TextBook) Earl A. Coddington and Norman Levinson; Tata Mcgraw-Hill Publication

Reference Books

1. Text Book of Ordinary Differential Equations (TextBook) Deo, S.G., Lakshmikantham, V., and Raghvendra, V; Tata McGraw Hill; 2nd Edition
2. Differential Equations with Applications and Historical Notes Simmons G.F; Tata McGraw Hill; 2nd Edition
3. A Text Book on ordinary Differential Equations Shair Ahmad, Antonia Ambrosetti, Springer

Course Name: Advanced Numerical Analysis**Course Code:11206103****Prerequisite:** Knowledge of functions, Algebraic Operations.

Rationale: The rationale for advanced numerical analysis lies in its ability to provide sophisticated techniques for solving complex mathematical problems that may be analytically intractable.

Course Objectives:

This course will help the learner to

COBJ1	Equip students with a deep understanding of advanced numerical methods, including finite element analysis, spectral methods, and numerical optimization, to solve complex mathematical problems.
COBJ2	Enable students to apply advanced numerical analysis techniques to address real-world engineering, scientific, and mathematical problems, fostering practical problem-solving skills.
COBJ3	Instruct students on the critical role of numerical methods in validating and verifying theoretical models against experimental data, ensuring the accuracy and reliability of computational simulations.
COBJ4	Encourage innovative thinking by guiding students in the application of advanced numerical analysis for exploring new ideas, simulating novel concepts, and contributing to cutting-edge research in their respective fields.
COBJ5	Develop expertise in using numerical optimization techniques for parameter estimation in scientific studies, enhancing students' ability to optimize solutions with multiple parameters.

Course Learning Outcome:

After completion of course student will be able to,

CLO1	Bring out role of approximation theory in the process of developing a numerical recipe for solving an engineering problem
CLO2	Introduce geometric ideas associated with the development of numerical schemes
CLO3	Familiarize with ideas of convergence analysis of numerical methods
CLO4	Study analytical aspects associated with numerical computation
CLO5	Analyze and evaluate the accuracy of common numerical methods.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	-	-	4	20	20	-	60	-	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Numerical Optimization: Necessary and Sufficient conditions for constrained and unconstrained optimization, Minimization of a function of One variable, Nelder-Mead and Powell's Methods, Gradient and Newton's Methods	25%	15
Unit:2	Numerical Methods for Ordinary Differential Equations: Introduction to differential equations, Initial Value problem, Euler's Method, Heun's Method, Taylor Series Method, Runge- Kutta Methods, Predictor- Corrector Methods	25%	15
Unit:3	Boundary –Value Problems for Ordinary Differential Equations: Implicit and Explicit functions in boundary value problem, The Linear Shooting Method, The Shooting Method for Non Linear Problem, Finite Difference Method for Linear Problems, Finite Difference methods for nonlinear problems, The Rayleigh-Ritz Method	20%	12
Unit:4	Approximating Eigenvalues: Linear Algebra and Eigenvalues, The Power and Inverse Power Methods, Jacobi's Method, Householder's method, The QR Algorithm, Nonlinear System of Equations: Fixed point for functions of several variables, Newton's Method, Quasi Newton Methods	30%	18
	Total	100	60

Text Book

1. Numerical Analysis Richard L. Burden, J. Douglas Faires

Reference Books

2. Numerical Methods Using Matlab John Mathews, Kurtis D. Fink
3. Mathematical Methods S.R.K. Iyenger, R.K. Jain; Narosa Publication
4. Numerical Methods and Applications E. Ward Cheney, David R. Kincaid

Course Name: Topology

Course Code:11206104

Prerequisite: Linear Algebra & Real Analysis

Rationale: Topology provides a mathematical framework to study spatial properties preserved under continuous deformations. Focusing on global characteristics rather than local details, it classifies spaces based on shared topological features.

Course Objectives:

This course will help the learner to

COBJ1:	Gain a deep comprehension of fundamental topological concepts such as continuity, convergence, open and closed sets, compactness, and connectedness.
COBJ2:	Learn essential techniques used in topology, including homeomorphisms, quotient spaces, and the use of fundamental groups.
COBJ3:	Enhance problem-solving abilities by applying topological methods to analyze and solve mathematical problems in various contexts.
COBJ4:	Delve into advanced topics such as homotopy theory, homology, and differential topology, expanding the understanding of abstract and complex spaces.
COBJ5:	Understand the practical applications of topology in diverse fields, including physics, engineering, and biology.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Understand terms, definitions and theorems related to topology.
CLO2:	Demonstrate knowledge and understanding of concepts such as open and closed sets, interior, closure and boundary.
CLO3:	Create new topological spaces by using subspace, product and quotient topologies.
CLO4:	Use continuous functions and homeomorphisms to understand structure of topological spaces.
CLO5:	Demonstrate knowledge and understanding of metric spaces.
CLO6:	Apply theoretical concepts in topology to understand real world applications.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	-	-	4	20	20	-	60	-	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Metric Spaces: The definition and some examples, Open sets, Closed sets, Convergence, Completeness, and Baire's theorem, Continuous mappings, Spaces of continuous functions, Euclidean and unitary spaces.	16%	10
Unit:2	Topological Spaces: The definition and some examples, Elementary concept, Open bases and open sub-bases, Homeomorphism, Weak topologies, The function algebras $C(X, \mathbb{R})$ and $C(X, \mathbb{C})$	17%	10
Unit:3	Compactness: Compact spaces, Products of spaces, Tychonoff's theorem and locally compact spaces, Compactness for metric spaces, Ascoli's theorem Separation: T1- spaces and Hausdroff spaces, Completely Regular and Normal Spaces, Urysohn's Lemma and the Tietze Extension Theorem, The Urysohn imbedding theorem, The Stone-Cech compactification.	34%	21
Unit:4	Connectedness: Connected spaces, Totally disconnected spaces, locally connected spaces. Approximation: The Weierstrass approximation theorem, The Stone-Weierstrass theorem, Locally compact Hausdroff spaces, The Extended Stone- Weierstrass theorem	33%	19
	Total	100	60

Text Book

Introduction to Topology and Modern Analysis (TextBook) Simmons, G. F; McGraw Hill.

Reference Books

1. Topology Munkres, J. R; PHI.; 2nd Edition
2. Topology Dugundji, James; Prentice Hall of India.

Course Name: Matlab Programming**Course Code: 11206106****Prerequisite:** Basic Knowledge of Programming

Rationale: MATLAB programming is essential for its robust numerical computing capabilities, facilitating efficient implementation of mathematical algorithms and data analysis. Its user-friendly syntax and extensive toolbox ecosystem make it a versatile tool across diverse disciplines, while its widespread adoption in academia and industry further underscores its significance.

Course Objectives:

This course will help the learner to

COBJ1:	Develop a strong understanding of MATLAB's syntax, data structures, and basic programming constructs to efficiently manipulate data and solve mathematical problems.
COBJ2:	Learn to use MATLAB's built-in functions and toolboxes for numerical computing, enabling proficiency in tasks such as linear algebra, optimization, and signal processing.
COBJ3:	Acquire skills in data manipulation, statistical analysis, and visualization using MATLAB, empowering the ability to analyze and interpret data in diverse scientific and engineering applications.
COBJ4:	Gain hands-on experience in implementing algorithms and solving engineering and scientific problems using MATLAB, emphasizing coding efficiency and best practices.
COBJ5:	Apply MATLAB skills to complete hands-on projects, encouraging problem-solving and practical application of programming concepts.

Course Learning Outcome:

After completion of course student will be able to,

CLO1	Understand the need for simulation/implementation for the verification of mathematical functions.
CLO2	Understand the main features of the MATLAB program development environment to enable their usage in the higher learning.
CLO3	Implement simple mathematical functions/equations in numerical computing environment such as MATLAB.
CLO4	Interpret and visualize simple mathematical functions and operations thereon using plots/display.
CLO5	Analyze the program for correctness and determine/estimate/predict the output and verify it under simulation environment using MATLAB tools.
CLO6	Solve numerical problems using MATLAB tools.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Introduction to MATLAB Programming: This module will introduce the students to MATLAB programming through a few examples. Students who have used MATLAB are still recommended to do this module, as it introduces MATLAB in context of how we use it in this course 1 Basics of MATLAB programming 2 Array operations in MATLAB 3 Loops and execution control 4 Working with files: Scripts and Functions Plotting and program output	30%	18
Unit:2	Approximations and Errors: Taylor's / Maclaurin series expansion of some functions will be used to introduce approximations and errors in computational methods 1 Defining errors and precision in numerical methods 2 Truncation and round-off errors Lecture Error propagation, Global and local truncation errors	20%	12
Unit:3	Numerical Optimization: Methods of numerical Optimization MATLAB functions for optimization will be discussed. 1 Minimization of a function of One variable 2 Nelder-Mead 3 Powell's Methods Gradient and Newton's Methods	25%	15
Unit:4	Ordinary Differential Equations (ODE): Explicit ODE solving techniques in single variable will be covered in this module 1 Introduction to ODEs; Implicit and explicit Euler's methods 2 Second-Order Runge-Kutta Methods 3 MATLAB ode45 algorithm in single variable 4 Higher order Runge-Kutta methods Error analysis of Runge-Kutta method	25%	15
	Total	100	60

Text Book

Applied Numerical Analysis Using MATLAB Fausett L.V.; Pearson Education

Reference Books

1. Numerical Methods Using Matlab ,John Mathews, Kurtis D. Fink
2. Mastering Matlab, A Comprehensive tutorial and reference Duane Hanselman and Bruce Littlefield,
3. Numerical Methods with Programs in BASIC, FORTRAN, Pascal and C++
4. S. Balachandra Rao, C. K. Shantha Introduction to Numerical Analysis C.E. Froberg; Addison- Wesley

Course Name: Transform Theory

Course Code: 11206107

Prerequisite: Knowledge of Integration, ODE, PDE.

Rationale: The rationale for transform theory lies in its ability to simplify the analysis and manipulation of signals, functions, and data by converting them from one domain to another.

Course Objectives:

This course will help the learner to

COBJ1:	Develop a comprehensive understanding of various transform techniques, including Fourier, Laplace, and Z transforms, and their applications in converting signals or functions between different domains.
COBJ2:	Master the skill of problem-solving by translating problems from one domain to another, leveraging the advantages of different representations for easier analysis and manipulation.
COBJ3:	Acquire proficiency in using transforms to solve differential equations, transforming complex differential problems into more manageable algebraic problems for analysis and solution.
COBJ4:	Understand the application of transform theory in control systems, allowing for the analysis of system behaviour in different domains and the design of effective control strategies.
COBJ5:	Learn how to use transform methods for noise filtering and data compression, emphasizing key components in transformed domains to enhance signal quality and reduce data size.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Understand and apply Fourier transform methods to one-dimensional and multi-dimensional problems
CLO2:	Understand band limited functions, sampling, and aliasing.
CLO3:	Understand the relationships between various discrete versions of the Fourier transform.
CLO4:	Explain briefly the historical development of the fractional calculus from the time of Euler to the present.
CLO5:	State sufficient conditions under which the fractional integrals and derivatives exist.
CLO6:	Solve linear fractional differential equations using the Laplace transform.
CLO7:	Investigate some applications of the fractional calculus to the real world.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Fourier Transform: Basic Concepts and Definitions of Integral Transform, The Fourier Integral Formulas, Definition of the Fourier Transform and Examples, Fourier Transforms of Generalized Functions, Basic Properties of Fourier Transforms, Poisson's Summation Formula	25%	15
Unit:2	Application of Fourier Transform: Applications of Fourier Transforms to Ordinary Differential Equations, Solutions of Partial Differential Equations, Fourier Cosine and Sine Transforms with Examples, Properties of Fourier Cosine and Sine Transforms, Applications of Fourier Cosine and Sine Transforms to Partial Differential Equations, Evaluation of Definite Integrals	25%	15
Unit:3	Discrete Fourier Transform: Fourier transforms, Inverse Fourier transform Z-Transform: Z- Transform, Linearity, Z- transform of elementary functions, Shifting theorem, initial and final value theorem, Convolution theorem, inversion of Z- transform, solution of difference equations by Z- Transforms	25%	15
Unit:4	Introduction of Laplace Transform: Definition of Laplace Transform and Examples using definition, Existence conditions for Laplace Transform, First Shifting Theorem and examples, Scaling Property and examples, Laplace transform of periodic functions	25%	15
	Total	100	60

Text Book

Integral Transforms and their applications Lokenath Debnath, Dambaru Bhatta; Chapman and Hall/CRC

Reference Books

Integral Transforms for Engineers Larry S. Andrews, Bhimsen K. Shivamoggi

Semester – 2

Course Name: Complex Analysis

Course Code: 11206151

Prerequisite: Basics Number System and Calculus

Rationale: Complex analysis provides a powerful mathematical framework for studying functions of complex numbers, offering insights into intricate mathematical structures and phenomena.

Course Objectives:

This course will help the learner to

COBJ1:	Develop a comprehensive understanding of complex numbers and functions, including properties like continuity, differentiability, and integration in the complex plane.
COBJ2:	Learn and apply analytic techniques, including contour integrals, residue calculus, and conformal mappings, for solving complex mathematical problems and understanding the behavior of complex functions.
COBJ3:	Develop problem-solving skills by applying complex analysis methods to diverse mathematical and scientific problems, fostering the ability to approach and solve complex challenges.
COBJ4:	Study special functions, such as the exponential, logarithmic, and trigonometric functions in the complex plane, understanding their properties and applications.
COBJ5:	Develop the ability to visualize and interpret complex functions and geometric transformations in the complex plane, enhancing insight into mathematical structures and relationships.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Explain the fundamental concepts of complex analysis and their role in modern Mathematics and applied contexts
CLO2:	Demonstrate accurate and efficient use of complex analysis techniques
CLO3:	Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from complex analysis
CLO4:	Apply problem-solving using complex analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts.
CLO5:	Use the residue theorem to compute several kinds of real integrals.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Functions of Complex Variables: Functions and Mappings, Limit, Continuity, derivatives, Cauchy- Riemann equations, C.R. equation in polar coordinates and Complex form, analytic functions, harmonic functions, Uniquely Determined Analytic Functions, elementary Functions	25%	15
Unit:2	Line Integration of Complex Valued function: Contours, contour integrals, antiderivative, Complex Integration, Line integral and its fundamental properties, Cauchy's theorem, Simply and multiply connected domains and Cauchy's Integral Formula, Cauchy inequality, Liouville's Theorem and Fundamental theorem of Algebra, Cauchy's Theorem and simple connectivity, Morera's theorem, Goursat's theorem. Gauss Mean Value theorem, Principle of deformation of paths, Maximum Modulus principle.	25%	15
Unit:3	Power Series and its Application: Power series, Taylor's theorem, Laurent series, absolute and uniform convergence of power series. Zeros of an analytic functions, Classification of singularities, residues, residues theorem, re sidues at poles, Rouché's theorem, evaluation of improper real integrals, definite integrals with sine and cosine function	34%	20
Unit:4	Conformal Mapping: Transformations or Mapping, linear Transformation, Bilinear transformation, Jacobian of Transformation, Mapping of Half plane on Circle, Conformal Mapping, Riemann's Mapping Theorem, Fixed or Invariant Point of Transformation, The Schwarz Christoffel transformation	16%	10
	Total	100	60

Text Book

Complex Variables and Applications Churchill, R.V., Brown, J. and Verle, R.; McGraw-Hill Publ. Co., 1974.

Reference Books

1. Complex variables, Schaum's outlines series Mc. Graw Hill
2. Functions of One Complex Variable (Second Edition) Conway, J.B.; Narosa Publ. House, New Delhi, 1994.
3. Foundations of Complex Analysis Ponnusamy, S.; Narosa Publ. House, New Delhi, 1995.
4. Elements of Complex Analysis, (Second Edition) Choudhary, B.; The Wiley Eastern Ltd., New Delhi, 1992

Course Name: Applied Partial Differential Equations**Course Code: 11206152****Prerequisite:** Basics of differential equations

Rationale: They are essential in fields like physics, engineering, and biology to predict and analyze complex systems, guiding decisions in diverse areas such as fluid dynamics, heat transfer, and structural mechanics.

Course Objectives:

This course will help the learner to

COBJ1:	Develop the ability to formulate partial differential equations (PDEs) that accurately represent physical processes in fields such as physics, engineering, and biology.
COBJ2:	Acquire analytical skills to solve and manipulate PDEs, employing various mathematical techniques and methods to find solutions that provide insights into the behavior of dynamic systems.
COBJ3:	Apply PDEs to model and analyze real-world problems, ranging from heat conduction and fluid dynamics to wave propagation, fostering the application of mathematical concepts in practical scenarios.
COBJ4:	Gain proficiency in numerical methods for solving PDEs, enabling the implementation of computational approaches to address complex problems and simulate dynamic systems with practical significance.
COBJ5:	An understanding of how PDEs transcend disciplinary boundaries, encouraging students to integrate mathematical modeling with diverse scientific and engineering applications, promoting a holistic approach to problem-solving.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Formulate boundary value problems using appropriate coordinates.
CLO2:	Classify the fundamental principles of partial differential equations (PDEs) to solve hyperbolic, parabolic and elliptic equations.
CLO3:	Transform an equation or operator from one geometry to another.
CLO4:	Solve one and two dimensional partial differential equations of the heat, wave, and Laplace type in both Cartesian and polar coordinates.
CLO5:	Produce a graphical representation of the analytical solutions

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	First Order Scalar quasilinear equations: Introduction, Cauchy data, Characteristics, Linear and semi linear equations, Domain of definition and blowup, Quasilinear equations, Solutions with discontinuity Introduction to Second order Scalar Equations Cauchy problem for semi linear equations, Characteristics, Canonical form of Semi Linear Equations: Hyperbolic Equation, Parabolic Equation, Elliptic Equation	24%	14
Unit:2	Heat Equation: Introduction, Derivation of the conduction of heat in one dimensional Rod, Boundary Conditions, Equilibrium Temperature distribution, Derivation of heat equations in two or three dimensions	26%	16
Unit:3	Method of Separation of Variables: Introduction, Linearity, Heat Equation with zero temperature at finite ends, Worked examples with heat equations, Laplace equations: Solution and qualitative Properties	25%	15
Unit:4	Vibrating Strings and Membrane: Introduction, Derivation of a vertically Vibrating String, Boundary conditions, vibrating strings with fixed ends, Vibrating Membranes	25%	15
	Total	100	60

Text Book

Applied Partial Differential Equations John Ockendon; Oxford University Press

Reference Book

1. Elementary Applied Partial Differential Equations With Fourier Series and Boundary Value Problems Richard Haberman; Prentice Hall
2. Introduction to Partial Differential Equations with Applications Zachmanoglou, E.C., Thoe, D.W.; Dover Publications.
3. Introduction to Partial Differential Equations Rao.K. S.; PHI Learning Pvt. Ltd

Course Name: Advanced Abstract Algebra**Course Code: 11206153****Prerequisite:** Basics of Group theory

Rationale: This course aims to cultivate a higher level of mathematical sophistication, enabling students to engage with and contribute to abstract algebraic theories. By delving into advanced topics such as group theory, ring theory, and field theory, students develop analytical and problem-solving skills crucial for applications in diverse areas like cryptography, coding theory, and algebraic geometry.

Course Objectives:

This course will help the learner to

COBJ1:	Attain a profound understanding of advanced algebraic structures, including groups, rings, and fields, grasping the underlying principles and abstract concepts that govern these mathematical entities.
COBJ1:	Develop a high level of theoretical rigor in abstract algebra, enabling students to construct and analyze sophisticated mathematical arguments and proofs related to algebraic structures and their properties.
COBJ1:	Explore the applications of advanced abstract algebra in various branches of mathematics, such as algebraic geometry, number theory, and mathematical logic, fostering connections between abstract concepts and their practical implications.
COBJ1:	Hone problem-solving skills by working on challenging abstract algebraic problems, equipping students with the ability to apply advanced theoretical concepts to novel mathematical situations.
COBJ1:	Prepare students for advanced mathematical research by encouraging independent exploration, critical thinking, and the ability to contribute to the development and understanding of abstract algebraic theories.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Understand concept of irreducible polynomial.
CLO2:	Introduce to and have knowledge of many mathematical concepts like splitting field, normal extension and Galois theory.
CLO3:	Understand the connection and transition between previously studied mathematics and more advanced mathematics.
CLO4:	Recognize and interpret theorems to prove properties about specific algebraic structure.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; T- Tutorial; P- Practical; C- Credit; MSE- Mid-Semester Evaluation, CE- Continuous Evaluation, ESE- End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Algebraic Extensions of Fields: Irreducible polynomials Eisenstein criterion, Adjunction of roots, Algebraic extensions, Algebraically closed field.	25%	15
Unit:2	Normal and separable extensions: Splitting fields, Normal extensions, Multiple roots, Finite fields, Separable extensions	25%	15
Unit:3	Galois Theory: Automorphism groups and fixed fields, Fundamental theorem of Galois theory, Fundamental theorem of algebra	25%	15
Unit:4	Applications of Galois theory to classical problems: Roots of unity and cyclotomic polynomials, Cyclic extensions, Polynomials solvable by radicals, Symmetric functions, Ruler and compass constructions	25%	15
	Total	100	60

Text Book

Topics in Algebra Herstein, I. N.; John Wiley & Sons.; 2nd

Reference Book

1. A First Course in Abstract Algebra Fraleigh, J. B.; Pearson Education; 7th
2. Contemporary Abstract Algebra Gallian J. A.; Cengage; 8th
3. Basic Abstract Algebra P.B. Bhattacharya; Cambridge University Press; 2nd
4. Artin M. Algebra; Prentice Hall, Englewood, Cliffs NJ

Course Name: Advanced Linear Algebra

Course Code: 11206154

Prerequisite: Basics of Linear Algebra

Rationale: This course builds upon foundational topics, delving into advanced theories and techniques essential for applications in various scientific and mathematical disciplines.

Course Objectives:

This course will help the learner to

COBJ1:	Develop a thorough understanding of abstract vector spaces, emphasizing properties and structures beyond basic vector operations, enabling students to handle more complex mathematical spaces.
COBJ2:	Explore advanced aspects of linear transformations, including diagonalization, canonical forms, and applications in diverse areas such as physics, engineering, and computer science.
COBJ3:	Study eigenvalues, eigenvectors, and spectral decompositions in a broader context, providing a deeper insight into the behavior of linear transformations and their applications in various mathematical and scientific domains.
COBJ4:	Extend matrix analysis to advanced topics, covering concepts like singular value decomposition, matrix norms, and positive definite matrices, with an emphasis on their relevance in applications such as optimization and data analysis.
COBJ5:	Apply advanced linear algebraic concepts to contemporary scientific and technological problems, including but not limited to applications in computer graphics, machine learning, quantum mechanics, and signal processing.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Apply techniques from the course to various problems in mathematics and physics
CL02:	Use visualization, spatial reasoning, as well as geometric properties and strategies to model, solve problems, and view solutions, especially in R^2 and R^3 , as well as conceptually extend these results to higher dimensions.
CL03:	Critically analyze and construct mathematical arguments that relate to the study of introductory linear algebra.
CL04:	Use technology, where appropriate, to enhance and facilitate mathematical understanding, as well as an aid in solving problems and presenting solutions.
CL05:	Explain the fundamental concepts of advanced algebra and their role in modern Mathematics and applied contexts.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Polynomials and Theory of Single Linear Operator: Algebra of Polynomials, Roots of Polynomial, Invariant Subspaces of a n Operators, Cyclic Operator, maximal Vectors, Indecomposable Operators, Invariant Factors and Elementary Divisors, Canonical Forms, Operators on Real and Complex Vector Space	17%	10
Unit:2	Inner Product Spaces: Inner Products, Geometry in Inner Product Spaces, Orthonormal and Gram Schmidt process, Orthogonal Complement and Projections, Dual Subspaces, Adjoint	33%	20
Unit:3	Linear Operators on Inner Product Spaces: Self-adjoint and Normal Operator, Spectral theorems, Normal Operators on Real Inner Product spaces, Unitary and Orthogonal Operators, Polar Decomposition and Singular Value Decomposition, Trace of Linear operator, Determinant of Linear Operator and Matrix	25%	15
Unit:4	Modules: Review of basic properties of modules, rank of a free module and epimorphosis, Noetherian module, Hilbert basis theorem, free module over a principal ideal domain, torsion free and free modules, primary decomposition, cyclic decomposition of a primary module, the invariant factor decomposition.	25%	15
	Total	100	60

Text Book

Advanced Linear Algebra Bruce Cooperstein, CRC Press, Taylor and Francis Group

Reference Book

1. Linear Algebra Hoffman, K. and Kunze R; Pearson Education (Asia) Pvt. Ltd. Prentice Hall of India
2. Applied Linear Algebra Olver P.J. and Shakiban C.; Prentice Hall
3. Linear Algebra and its Applications Strang G.; Thomson Learning Asia Pvt. Ltd
4. Linear Algebra with Applications Leon S. J.; Pearson Education

Course Name: Python Programming**Course Code: 11206156****Prerequisite:** Basic knowledge of programming

Rationale: The rationale of Python Programming lies in its versatility, simplicity, and widespread use across diverse domains. As a high-level, interpreted language, Python is accessible for beginners and powerful for professionals, making it an ideal choice for programming education.

Course Objectives:

This course will help the learner to

COBJ1:	Understand the basic syntax and fundamental concepts of Python programming, including variables, data types, control structures, and functions.
COBJ2:	Develop problem-solving skills and the ability to think algorithmically, applying Python to solve real-world problems through the design and implementation of efficient algorithms.
COBJ3:	Learn to use Python's programming constructs such as loops, conditionals, and modular programming, fostering the development of organized and maintainable code.
COBJ4:	Explore data structures in Python, including lists, dictionaries, and tuples, and gain proficiency in manipulating and analyzing data to solve practical problems.
COBJ5:	Familiarize yourself with the principles of Object-Oriented Programming in Python, understanding classes, objects, inheritance, and polymorphism.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Apply techniques from the course to various problems in mathematics and physics
CLO2:	Use visualization, spatial reasoning, as well as geometric properties and strategies to model, solve problems, and view solutions, especially in R2 and R3, as well as conceptually extend these results to higher dimensions.
CLO3:	Critically analyze and construct mathematical arguments that relate to the study of introductory linear algebra.
CLO4:	Use technology, where appropriate, to enhance and facilitate mathematical understanding, as well as an aid in solving problems and presenting solutions.
CLO5:	Explain the fundamental concepts of advanced algebra and their role in modern Mathematics and applied contexts.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Introduction: Need for Python, Basic programming fundamentals Basics: Data variables, Operators, First Python program, Control Structures String Inbuilt functions, Code flow, Indentation in Python	17%	5
Unit:2	Data Structures: Knowledge about Python data structures with strings, lists, set, tuples and dictionaries Packages and its elements: User-defined Functions, modules, packages Errors and Exception handling: Python errors, exceptions, raising the exception and debugging concept	36%	11
Unit:3	Standard Library and Regular Expression: Standard library modules introduction with examples. Re-Module, usage with functions like split, search, find all, compile, etc. File Operations: Need of a file. Opening, closing and read/write operations on the file.	23%	7
Unit:4	Object-Oriented Programming: Basic OOP concepts, Creating classes and objects, Class variables and Object Variables, Method Invocation, Static, Class and Instance. Methods, Relationships, Overloading methods, Data Hiding.	24%	7
	Total	100	60

Text Book

Introducing Python Lubanovic Bill, O' ReILLY

Reference Book

1. Beginning Python: Using Python 2.6 and Python 3.1 by James Payne, Wrox Publication

Course Name: Mechanics

Course Code: 11206157

Prerequisite: Basics of Calculus

Rationale: Mechanics serves as a cornerstone in the understanding of the natural world, providing a framework to analyze the forces, motion, and energy interactions that govern objects.

Course Objectives:

This course will help the learner to

COBJ1:	Understand and apply fundamental principles of mechanics, including Newton's laws of motion, equilibrium, and the conservation of energy and momentum.
COBJ2:	Develop proficiency in analyzing the motion of objects, covering concepts of displacement, velocity, acceleration, and the forces influencing motion.
COBJ3:	Study the mechanics of both individual particles and rigid bodies, applying principles to analyze the motion and forces acting on these systems.
COBJ4:	Gain insight into linear and angular motion, understanding the rotational dynamics of objects and their connection to translational motion.
COBJ5:	Study the principles of collisions and impulse, exploring the effects of forces during short time intervals and their impact on the motion of objects.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Concentrate on the mechanical aspects of problems.
CL02:	Get a firm basis in mechanics, and a good basis in mathematics, numeric and informatics
CL03:	Update knowledge within one of the main specializations of the programme: fluid, solid or continuum mechanics.
CL04:	Get good knowledge of a broad range of methods and techniques based on mechanics and can use them for analysis and problem solving.
CL05:	Comprehend complicated practical problems, specify the problem mathematically and identify suitable analytical and/or numerical solution methods, and prospective experimental methods.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Plane Statics: Fundamental laws of Newtonian Mechanics, Equilibrium of a particle and system of particles, The moment of a vector about a line, Varignon's Theorem , Conditions of equilibrium of a system of particles, Equipollent system of forces, Couples, Reduction of a general plane force system, Work and potential energy, The principle of virtual work	25%	15
Unit:2	Application in Plane Statics: Introduction, Velocity and acceleration, Gradient vectors, Mass centers and center of gravity, Theorems of Pappus, Gravitation, Friction, Flexible cable and its differential equation, The suspension bridge, The common catenary	25%	15
Unit:3	Motion of Particle: The ingredients of Mechanics, Frames of reference, Velocity and acceleration gradient vector, Fundamental laws of Newtonian Mechanics, Newtonian frame of reference. Tangential and normal components of velocity and acceleration, radial and transverse components of velocity and acceleration, The Hodograph, Motion of a particle and a system of particles, Principle of energy, D'Alembert's principle, Frames of reference with uniform translational velocity and acceleration, Frames of reference relating with constant angular velocity.	27%	16
Unit:4	Lagrange's Equations: Lagrange equations for unconstrained motion, Constrained systems; an example, Proof of Lagrange equations with constraints, Generalized momenta and ignorable coordinates, Lagrange equations for magnetic forces, Lagrange multipliers and constrained forces	23%	14
	Total	100	60

Text Book

Mechanics Sunil Dutta; Prentice Hall of India

Reference Book

1. Principles of Mechanics John L. Synge and Byron A. Griffith; Mc Graw Hill Book Company
2. Classical Mechanics John R. Taylor; University Science Books

Semester – 3

Course Name: Functional Analysis

Course Code: 11206201

Prerequisite: Linear Algebra & Real Analysis

Rationale: Functional analysis provides tools and techniques that have applications in various areas of mathematics, physics, engineering, and other disciplines.

Course Objectives:

This course will help the learner to

COBJ1:	Develop a thorough understanding of infinite-dimensional spaces, including normed spaces, Banach spaces, and Hilbert spaces, and appreciate the mathematical structures that arise in these contexts.
COBJ2:	Gain proficiency in working with topological vector spaces, understanding the concepts of continuity, convergence, and completeness in more general settings beyond finite-dimensional spaces.
COBJ3:	Study various function spaces, including spaces of continuous functions, L_p spaces, and Sobolev spaces. Understand the concept of Banach algebras and their significance in mathematical analysis.
COBJ4:	Investigate the spectral theory of operators, including the spectral decomposition theorem, and understand its applications in solving differential equations and analyzing linear operators.
COBJ5:	Develop the ability to work with abstract concepts and generalize mathematical ideas, fostering a deeper understanding of the underlying structures in functional analysis.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Explain the fundamental concepts of functional analysis and their role in modern mathematics and applied contexts.
CL02:	Demonstrate accurate and efficient use of functional analysis techniques.
CL03:	Demonstrate capacity for mathematical reasoning through analyzing proving and explaining concepts from functional analysis.
CL04:	Apply problem-solving using functional analysis technique applied to diverse situations in physics, engineering and other mathematical context.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Normed Space and Banach Space: Vector Space, Normed Space, Banach Space Further Properties of Normed Spaces, Finite Dimensional Normed Spaces and Subspaces, Compactness and Finite Dimension, Riesz Lemma, Linear Operators, Bounded and Continuous Linear Operators, Linear Functional, Linear Operators and Functional on Finite Dimensional Spaces, Normed Spaces of Operators, Algebraic dual space and reflexivity, Dual Space.	25%	15
Unit:2	Inner Product space and Hilbert Space: Inner Product Space, Hilbert Space, Further Properties of Inner Product Spaces Orthogonal Complements and Direct Sums, Orthonormal Sets and Sequences, Series Related to Orthonormal Sequences and Sets, Total Orthonormal Sets and Sequences, Legendre, Hermite and Laguerre Polynomials, Representation of Functionals on Hilbert Spaces, Hilbert-Adjoint Operator, Self-Adjoint, Unitary and Normal Operators.	25%	15
Unit:3	Fundamental Theorems for Normed and Banach Spaces: Zorn's Lemma, Hahn-Banach Theorem, Hahn-Banach Theorem for Complex Vector Spaces and Normed Spaces, Application to Bounded Linear functionals on $C[a, b]$, Adjoint Operator, Reflexive Spaces, Category Theorem. Uniform Boundedness Theorem, Strong and Weak Convergence, Convergence of Sequences of Operators and Functionals, Application to Summability of Sequences, Numerical Integration and Weak* Convergence, Open Mapping Theorem, Closed Linear Operators, Closed Graph Theorem	28%	17
Unit:4	Applications to Banach Fixed Point Theorem: Banach Fixed Point Theorem, Application of Banach's Theorem to Linear Equations, Applications of Banach's Theorem to Differential Equations, Application of Banach's Theorem to Integral Equations	22%	13
	Total	100	60

Text Book

Introductory Functional Analysis with Applications Erwin Kreyszig; John Wiley & Sons; 2004

Reference Book

1. Functional Analysis B. V. Limaye; Wiley

Course Name: Mathematical Modelling**Course Code: 11206202****Prerequisite:** Knowledge of ODE, PDE, MATLAB**Rationale:** Mathematical modeling serves as a powerful tool for understanding, analyzing, and predicting the behavior of systems in various fields.**Course Objectives:**

This course will help the learner to

COBJ1:	Develop the ability to identify real-world problems that can be addressed using mathematical modeling, recognizing situations where mathematical techniques can provide valuable insights.
COBJ2:	Acquire skills in formulating mathematical models to represent and describe complex systems, translating real-world phenomena into mathematical equations or algorithms.
COBJ3:	Learn techniques for analyzing and validating mathematical models, including sensitivity analysis, parameter estimation, and comparison of model predictions with experimental or observational data.
COBJ4:	Enhance communication skills to effectively convey mathematical modeling results to both technical and non-technical audiences, emphasizing clarity, accuracy, and the interpretation of findings.
COBJ5:	Gain experience in implementing mathematical models using computational tools, programming languages, or simulation software, allowing for practical application and analysis.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Create mathematical models of empirical or theoretical phenomena in domains such as the physical, natural, or social science.
CL02:	Create variables and other abstractions to solve college-level mathematical problems in conjunction with previously-learned fundamental mathematical skills such as algebra.
CL03:	Draw inferences from models using college-level mathematical techniques including problem solving, quantitative reasoning, and exploration using multiple representations such as equations, tables, and graphs.
CL04:	Take an analytical approach to problems in their future endeavors.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Compartment Models: Mathematical models, Some modeling approaches, Modelling for Decision Making, Exponential decay and radioactivity, Lake pollution models, Drug assimilation into blood, Equilibrium points and its stability	25%	15
Unit:2	Model of Single Populations & Numerical Solution of Differential Equations: Exponential Growth, Density dependent growth, Limited growth with harvesting, Discrete Population Growth and chaos, Time Delayed regulation Basic Numerical schemes, Computer Implementation using MATLAB. Instability	25%	15
Unit:3	Interacting population Models & Phase-plane Analysis: Interacting population Models An epidemic model for influenza, Predators and Prey, Competing Species, Model of battle Phase-plane analysis of epidemic model, Analysis of a battle model, Analysis of Predator Prey model, Analysis of Competing species model, Closed trajectories for the predator-prey.	28%	17
Unit:4	Formulating Basic Heat Models: Some basic physical Laws, Model for a hot water heater, Heat Conduction and Fourier's Law, Heat Conduction through a wall, Radial Heat Conduction, The cooling coffee problem.	22%	13
	Total	100	60

Text Book

Mathematical Modelling with case studies Belinda Barnes and Glenn Robert Fulford; CRC Press

Reference Book

1. Mathematical Modelling with case studies Belinda Barnes and Glenn Robert Fulford; CRC Press

Course Name: Integral Equations and Calculus of Variation**Course Code: 11206203****Prerequisite:** Integration, Differential Equation**Rationale:** The study of Integral Equations and Calculus of Variation is motivated by the need to address complex mathematical problems arising in diverse scientific and applied fields.**Course Objectives:**

This course will help the learner to

COBJ1	Understand the formulation and classification of integral equations, distinguishing between Fredholm and Volterra equations and recognizing their significance in various mathematical and applied contexts.
COBJ2:	Acquire proficiency in solving different types of integral equations using analytical methods, numerical techniques, and transform methods, gaining insights into the behavior of solutions.
COBJ3:	Explore applications of integral equations in diverse fields such as physics, engineering, biology, and economics, understanding how integral equation models describe real-world phenomena.
COBJ4:	Study different types of kernel functions and their impact on integral equations, with a specific focus on singular integral equations and techniques for handling their singularities.
COBJ5:	Develop skills in implementing numerical methods, such as finite element methods or boundary element methods, to approximate solutions of integral equations in practical scenarios.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Learn variation principles.
CL02:	Develop the knowledge in the path of the rocket trajectory, optimal economic growth.
CL03:	Gain the vast knowledge by using the applications of calculus of variations in biological and medical field.
CL04:	Learn easier & systematic way to ordinary and differential equations and partial differential equations.
CL05:	Develop the skills while doing/solving the various problems by using integral equations in all engineering sciences and etc.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Preliminary Concepts: Definition and classification of linear integral equations. Conversion of initial and boundary value problems in to integral equations. Conversion of integral equations in to differential equations. Integro- differential equations.	20%	12
Unit:2	Fredholm Integral Equations: Solution of integral equations with separable kernels, Eigen values and Eigen functions. Solution by the successive approximations, Neumann series and resolvent kernel. Classical Fredholm Theory: Fredholm method of solution and Fredholm theorems.	30%	18
Unit:3	Volterra Integral Equations: Successive approximations, Neumann series and resolvent kernel. Equations with convolution type kernels. Solution of Integral Equations by Transform Methods: Singular integral equations, Laplace-transform	20%	12
Unit:4	Calculus of Variations: Basic concepts of the calculus of variations such as functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum, Euler's equation with the cases of one variable and several variables, Variational derivative Invariance of Euler's equations. Variational problem in parametric form.	30%	18
	Total	100	60

Text Book

Introduction to Integral Equations with Applications Jerry, A. J.; Wiley Publishers

Reference Book

1. Calculus of Variations (TextBook) Gelfand, I.M., Fomin, S. V.; Dover Books

Course Name: Inferential Statistics**Course Code: 11206210****Prerequisite:** Basic knowledge of Calculus, Statistics, Probability

Rationale: Inferential statistics provides a framework for making predictions, generalizations, and informed decisions about large groups when it is impractical or impossible to study the entire population.

Course Objectives:

This course will help the learner to

COBJ1:	Gain a comprehensive understanding of sampling distributions and their role in making inferences about population parameters, providing a foundation for statistical reasoning.
COBJ2:	Learn different methods for estimating population parameters, including point estimation and interval estimation, to quantify the uncertainty associated with sample-based estimates.
COBJ3:	Develop proficiency in hypothesis testing, including formulating null and alternative hypotheses, conducting statistical tests, and interpreting results, enabling informed decisions about population characteristics.
COBJ4:	Understand the concept of statistical significance and its application in determining whether observed effects or relationships in sample data are likely to exist in the larger population.
COBJ5:	Learn to construct and interpret confidence intervals, providing a range of plausible values for population parameters and conveying the precision of sample-based estimates.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Summarize data visually and numerically.
CL02:	Build and assess data-based models.
CL03:	Learn and apply the tools of formal inference
CL04:	Learn mathematical and probabilistic foundations of statistical inference.
CL05:	Execute statistical analyses with professional software.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Probability Distribution and Sampling Techniques: Introduction to Geometric, Negative Binomial, Exponential Distribution, Gamma Distribution, Beta Distribution (1st Kind and 2nd Kind), Chebyshev's inequality, Mean of sampling distribution, Central Limit Theorem, Small samples and large samples, sampling techniques, Simple random sampling with and without replacement, Stratified sampling	30%	18
Unit:2	Estimation and Testing of Hypothesis: Estimation of confidence intervals for mean and variance, Chi-square test of goodness of fit, students t-test (paired and unpaired), F- test, Contingency tables, One population case, two population case, testing of hypotheses	30%	18
Unit:3	Regression Analysis: Curve fitting, Correlation, Regression and multiple regression using least square techniques	20%	12
Unit:4	Control Charts: Control charts for variables and attributes, acceptance sampling by attributes, simple, double and sequential sampling plans, Design of experiments.	20%	12
	Total	100	60

Text Book

Contemporary Statistics, a computer approach S.P. Gordon and F.S. Gordon

Reference Book

1. An Introduction to Probability Theory and Its Applications William Feller; John Wiley inc; (Vol. I & II)

Course Name: Fluid Dynamics**Course Code: 11206207**

Prerequisite: Some background in solving ordinary and partial differential equations, basic physics/mechanics, multivariable calculus.

Rationale: The field is important in various scientific and engineering applications, ranging from understanding weather patterns to designing aircraft and optimizing industrial processes.

Course Objectives:

This course will help the learner to

COBJ1:	Understand the basic principles and concepts of fluid mechanics, including fluid properties, fluid statics, and fluid dynamics.
COBJ2:	Derive and apply the governing equations of fluid flow, such as the continuity equation, Navier-Stokes equations, and energy equation.
COBJ3:	Learn how to formulate and solve mathematical models that describe fluid flow problems in various physical scenarios.
COBJ4:	Classify and analyze different types of fluid flow, including laminar and turbulent flow, steady and unsteady flow, and compressible and incompressible flow.
COBJ5:	Understand the concept of boundary layers and their significance in fluid dynamics, especially in relation to viscous flows and aerodynamics.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Explain the physical properties of a fluid and the consequence of such properties on fluid flow.
CL02:	Identify the fundamental kinematics of a fluid element.
CL03:	State the conservation principles of mass, linear momentum, and energy for fluid flow.
CL04:	Apply the basic applied-mathematical tools that support fluid dynamics
CL05:	Create models of inviscid, steady fluid flow over simple profiles and shapes.
CL06:	Determine the basic forces and moments acting on simple profiles and shapes in an inviscid, steady fluid flow.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Governing Equations of Fluid Motion: Lagrangian and Eulerian descriptions, Continuity of mass flow, circulation, rotational and irrotational flows, boundary surface, streamlines, path lines, streak lines, vorticity, inviscid case, Bernoulli's theorem, compressible and incompressible flows, Kelvin's theorem, constancy of circulation	25%	15
Unit:2	Inviscid Incompressible Flows: Stream function, Complex-potential, source, sink and doublets, circle theorem, method of images, Theorem of Blasius, Strokes stream function, Motion of a sphere. Helmholtz's vorticity equation, vortex filaments, vortex pair.	25%	15
Unit:3	Viscid Incompressible Flows: Navier-Stokes equations, dissipation of energy, diffusion of vorticity, Steady flow between two infinite parallel plates through a circular pipe (Hagen-Poiseuille flow), Flow between two coaxial cylinders, Energy equation, Dynamical similarity	25%	15
Unit:4	Flow at large Reynold's numbers: Dimensional analysis, large Reynold's numbers; Laminar boundary layer equations, Similar solutions; Flow past a flat plate, Momentum integral equations, Solution by Karman Pohlhausen methods, impulsive flow, Reyleigh problem, dynamical similarity, Thermal boundary layer equation for incompressible flow; Temperature distribution in Coutte flow and in flow past a flat plate.	25%	15
	Total	100	60

Text Book

An Introduction to Fluid Dynamics G.K.Batchelor; Cambridge Press

Reference Book

1. Analytical Fluid Dynamics G Emanuel; CRC Press
2. Mathematical introduction to Fluid Mechanics Chorin; Springer Verlag
3. Fundamental Mechanics of Fluids G.Currie; McGraw-Hill

Semester-4

Course Name: Operator Theory

Course Code: 11206251

Prerequisite: Functional Analysis

Rationale: The rationale for studying operator theory lies in its ability to provide a powerful and abstract framework for understanding and analyzing linear operators on different mathematical spaces.

Course Objectives:

This course will help the learner to

COBJ1:	Gain a solid understanding of fundamental concepts in operator theory, including linear operators, bounded and unbounded operators, and linear functionals.
COBJ2:	Develop a foundation in functional analysis, which provides the mathematical framework for studying operators on various function spaces.
COBJ3:	Study Hilbert spaces and understand their role in operator theory. Explore properties of Hilbert spaces, such as completeness and orthonormal bases.
COBJ4:	Introduce spectral theory for both bounded and unbounded operators. Understand concepts like spectrum, resolvent, and spectral decomposition.
COBJ5:	Learn about compact operators and their properties. Understand the compactness criterion and applications of compact operators in operator theory.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Use different methods of estimating action of a given operator T, depending on the chosen model.
CL02:	Apply information on the spectrum of T and its parts.
CL03:	Recognize structures related to systems of commuting operators, by using Banach and Hilbert space techniques.
CL04:	Know basic methods of investigating linear operators in various situations and knows their relations to other branches of mathematics.
CL05:	Know basic results from spectral theory of bounded (as well as unbounded) linear operators on Hilbert spaces and examples of their applications

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Spectral theory of linear operators in Normed spaces:: Spectral theory in finite dimensional normed spaces, Eigen values, Eigen vectors, Eigen spaces, Spectrum and resolvent set of matrix- definitions, Eigen values of an operator, Definition of Regular value, Point, Continuous and Residual spectrum, Spectral properties of bounded linear operators, Properties of Resolvent and Spectrum, Holomorphy and Local holomorphy, Use of complex analysis in spectral theory.	25%	15
Unit:2	Compact Linear Operators on Normed Spaces and their Spectrum:: Compact linear operators on normed spaces and their properties, Spectral properties of compact linear operators on normed spaces. Spectral Theory of Bounded Self Adjoint Linear Operators: Spectral properties of bounded self-adjoint linear operator, Theorem on eigenvalues and eigenvectors, Theorems on resolvent set and spectrum, Residual spectrum theorem, Positive operators, Product of positive operators, Projection operators and their properties.	25%	15
Unit:3	Spectral Theory of Bounded Self Adjoint Linear Operators:: Spectral properties of bounded self-adjoint linear operator, Theorem on eigenvalues and eigenvectors, Theorems on resolvent set and spectrum, Residual spectrum theorem, Positive operators, Product of positive operators, Projection operators and their properties.	25%	15
Unit:4	Unbounded Linear operators on Hilbert Space:: Unbounded linear operators and their Hilbert adjoint operators, Symmetric and self adjoint linear operators, Closed linear operators Closure of Hilbert adjoint, Spectral properties of Hilbert adjoint, Spectral representation of unitary operators and self-adjoint operators, Multiplication and Differential operators, Riesz' s theorem, Sequilinear form and Riesz's representation theorem, Hilbert adjoint operator and its properties, Self adjoint, Unitary and Normal operators.	25%	15
	Total	100	60

Text Book

Introductory Functional Analysis with Applications Erwin Kreyszig; John Wiley & Sons; 2004

Reference Book

Introductory Functional Analysis with Applications Erwin Kreyszig; John Wiley & Sons; 2004

Course Name: Finite Element Method**Course Code: 11206252****Prerequisite:** Basic knowledge of Calculus**Rationale:** The rationale for employing the Finite Element Method is rooted in several key advantages and practical considerations:**Course Objectives:**

This course will help the learner to

COBJ1:	Gain a fundamental understanding of the basic principles and concepts of the Finite Element Method, including discretization, interpolation, and variational principles.
COBJ2:	Learn about different types of finite elements (e.g., truss, beam, plane stress, and solid elements) and understand how to derive and use shape functions for each element type.
COBJ3:	Develop skills in dividing complex geometries into finite elements and generating finite element meshes. Understand the impact of mesh quality on the accuracy of solutions.
COBJ4:	Understand the matrix formulation of the finite element method, including the assembly of element stiffness matrices and the construction of the global stiffness matrix.
COBJ5:	Study how to apply boundary conditions to the finite element model and understand their influence on the solution. Learn to handle essential and natural boundary conditions.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Understand the concepts behind variational methods and weighted residual methods in FEM.
CL02:	Identify the application and characteristics of FEA elements such as bars, beams, plane and iso-parametric elements, and 3-D element.
CL03:	Develop element characteristic equation procedure and generation of global stiffness equation will be applied.
CL04:	Able to apply Suitable boundary conditions to a global structural equation, and reduce it to a solvable form.
CL05:	Able to identify how the finite element method expands beyond the structural domain, for problems involving dynamics, heat transfer, and fluid flow.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Introduction: Advantages of FEM over other methods, Basic steps in FEM, Springs in series analogy, Understanding about weak solution, Relay Ritz Method, Different approaches in FEM formulation, Variational and Galerkin's approach. Discretization of problem, Discretization of geometry	25%	15
Unit:2	Line Elements and Applications: Element types, Shape functions, Element equations, Assembly procedure, Imposition of Essential boundary conditions, Properties of assembled matrix, Methodology for solving system of equations.	25%	15
Unit:3	Formulation of the FEM: Formulation of the FEM for elliptic problems, Variational and Galerkin formulation	20%	12
Unit:4	Finite element discretization: Finite element discretization in 1D, Finite element discretization in 2D, A FEM for Poisson's equation, steady state heat equation, General second order pde, Galerkin approach, Second order pde in different domain with physical parameter's description. FEM as a tool for solving boundary value problems.	30%	18
	Total	100	60

Text Book

Numerical solution of Partial Differential Equations: Finite Difference Methods G.D Smith; Oxford University Press

Reference Book

1. Concepts and Applications of Finite Element Analysis R D Cook, D S Malkus, M E Plesha, and R J Witt, Wiley

Course Name: Operations Research**Course Code: 11206258****Prerequisite:** Basics of Multi-variable Calculus, Linear Algebra, Formulation of Mathematical Modeling and its solution techniques**Rationale:** Operational Research (OR), also known as Operations Research, is a discipline that applies scientific and mathematical methods to decision-making and problem-solving in complex systems.**Course Objectives:**

This course will help the learner to

COBJ1:	Teach students how to formulate real-world problems into mathematical models suitable for analysis within the framework of Operations Research.
COBJ2:	Introduce optimization techniques, including linear programming, integer programming, and nonlinear programming. Teach students how to formulate and solve optimization problems
COBJ3:	Explore queuing models to analyze waiting lines and optimize service systems. Provide insights into the design and management of queues.
COBJ4:	Cover simulation techniques for modeling and analyzing complex systems. Provide hands-on experience in constructing and running simulations.
COBJ5:	Extend optimization skills to integer programming problems, with applications in project scheduling, network design, and discrete resource allocation.

Course Learning Outcome:

After completion of course student will be able to,

CLO1:	Identify and develop operational research models from the verbal description of the real system.
CLO2:	Understand the mathematical tools that are needed to solve optimization problems.
CLO3:	Use mathematical software to solve the proposed models
CLO4:	Develop a report that describes the model and the solving technique, analyses the results and propose recommendations in language understandable to the decision-making processes in Management Engineering.
CLO5:	Develop linear programming (LP) models for shortest path, maximum flow, minimal spanning tree, critical path, minimum cost flow, and transshipment problems.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Duality Theory: Overview of Simplex Method, Dual Simplex Method, Sensitivity Analysis, Parametric Linear Programming Integer Programming: Cutting Plane and Branch and Bound Techniques, for all Integer and Mixed Integer Programming Problems	25%	15
Unit:2	Non-linear programming: Lagrangian method, Kuhn-Tucker conditions, Quadratic programming, Wolfe's method, Beale's method.	20%	12
Unit:3	Queuing Theory: Introduction, Queueing components, Models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited space, M/G/1.	20%	12
Unit:4	Inventory theory: Concept, classification of inventory models, EOQ model, EPQ model, EOQ model with shortages, EOQ model with constraints Project Management (CPM and PERT): Network Concepts Components, Rules for Network Construction, Critical Path Method (CPM), Project Evaluation Techniques (PERT)	35%	21
	Total	100	60

Text Book

Operation Research: Theory and Application J.K.Sharma; Macmillan India Ltd

Reference Book

1. Operation Research: Theory and Application J.K.Sharma; Macmillan India Ltd

Course Name: Dynamical Systems and Control**Course Code: 11206259****Prerequisite:** Basic concepts from Linear Algebra and Ordinary Differential Equations**Rationale:** The study of Dynamical Systems and Control is crucial in various engineering disciplines and scientific fields due to its wide-ranging applications and importance in understanding and influencing the behavior of dynamic systems.**Course Objectives:**

This course will help the learner to

COBJ1:	Provide an overview of dynamical systems, emphasizing the study of how systems evolve over time. Introduce concepts such as state, state space, and trajectories.
COBJ2:	Teach students how to formulate mathematical models for physical systems, emphasizing the use of ordinary differential equations (ODEs) and partial differential equations (PDEs).
COBJ3:	Introduce the fundamental components of control systems, including sensors, actuators, controllers, and feedback loops. Emphasize the importance of closed-loop control for stability and performance.
COBJ4:	Introduce state-space representation for dynamic systems. Cover concepts such as controllability, observability, and the state-space realization of systems.
COBJ5:	Introduce observer design for state estimation, covering concepts such as full-state observers and reduced-order observers. Discuss the implications of observer design on system performance.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Demonstrate and understand various mathematical models, such as differential equation and transfer function models.
CL02:	Formulate state-space models of dynamic systems.
CL03:	Demonstrate the ability to linearize the dynamic model of nonlinear systems
CL04:	Develop students' understanding of stability, transient, and steady-state behavior of linear dynamic systems.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Introduction: Formulation of physical systems, Existence and uniqueness theorems, Linear systems, Solution of linear systems, Fundamental Matrix, Fundamental matrices for non-autonomous systems, Solution of non-homogeneous systems.	25%	15
Unit:2	Stability of Systems: Stability of systems: Equilibrium points, Stability of linear autonomous systems, Stability of weakly non-linear systems, Stability of non-linear systems using linearization, Properties of phase portrait, Properties of orbits, Phase portrait: Types of critical points, Phase portrait of linear differential equations, Poincare Bendixson Theorem, Limit cycle, Lyapunov stability, and Lyapunov stability.	25%	15
Unit:3	Controllability and Observability: Introduction to Control Systems, Controllability of Autonomous Systems, Controllability of Non-autonomous Systems, Observability, Results on Controllability and Observability, Companion Form, Feedback Control, State Observer, Stabilizability.	28%	17
Unit:4	Discrete Systems: Introduction to Discrete Systems, Lyapunov Stability Theory, Optimal Control, Optimal Control for Discrete Systems, Controllability of Discrete Systems, Observability of Discrete Systems, Stability for Discrete Systems, Relation between Continuous and Discrete Systems.	22%	13
	Total	100	60

Text Book

Dynamical Systems and Control Firdaus E. Udwadia, H.I. Weber, George Leitmann

Reference Book

1. Introduction to Mathematical Control Theory Stephen Barnett, Oxford University Press

Course Name: Computational Fluid Dynamics**Course Code: 11206256****Prerequisite:** Basic knowledge of Calculus, Numerical Methods, Fluid Dynamics**Rationale:** Computational Fluid Dynamics (CFD) plays a crucial role in engineering and scientific research by providing a powerful and versatile tool for analyzing and simulating fluid flow phenomena.**Course Objectives:**

This course will help the learner to

COBJ1:	Understand the basic principles of fluid mechanics and how they are translated into mathematical equations governing fluid flow.
COBJ2:	Gain proficiency in the numerical methods and algorithms used for solving the governing equations of fluid dynamics, including finite difference, finite volume, and finite element methods.
COBJ3:	Acquire hands-on experience with CFD software tools commonly used in industry and research. This may include understanding the user interface, mesh generation, solver settings, and post-processing.
COBJ4:	Learn how to formulate and define fluid flow problems for numerical simulation, considering boundary conditions, initial conditions, and appropriate simplifications or assumptions.
COBJ5:	Develop skills in creating suitable computational grids or meshes for different types of fluid flow problems, ensuring accuracy and efficiency in simulations.

Course Learning Outcome:

After completion of course student will be able to,

CL01:	Understand solution of aerodynamic flows. Appraise & compare current CFD software. Simplify flow problems and solve them exactly.
CL02:	Define and setup flow problem properly within CFD context, performing solid modelling using CAD package and producing grids via meshing tool.
CL03:	Understand both flow physics and mathematical properties of governing Navier-Stokes equations and define proper boundary conditions for solution.
CL04:	Use CFD software to model relevant engineering flow problems. Analyze the CFD results. Compare with available data, and discuss the findings.

Teaching and Examination Scheme

Teaching Scheme				Evaluation Scheme					
L	T	P	C	Internal Evaluation			ESE		Total
				MSE	CE	P	Theory	P	
4	0	0	4	20	20	0	60	0	100

L- Lectures; **T-** Tutorial; **P-** Practical; **C-** Credit; **MSE-** Mid-Semester Evaluation, **CE-** Continuous Evaluation, **ESE-** End Semester Examination

Course Content

	Content	Weightage	Teaching Hours
Unit:1	Basic Philosophy of CFD and Governing Equations: Introduction to CFD, Applications Governing equations and assumptions, Equation types, Model equations, potential flow, Heat conduction, Wave equation, Burgers equation, Euler equations.	25%	15
Unit:2	Mathematical Properties of the Fluid Dynamic Equations: Finite Differences, Algorithms, Errors and Accuracy, Consistency, Stability and Convergence, Finite Volumes, Explicit algorithms, Implicit algorithms, Numerical boundary conditions, Method of lines, Shock Jump Relations, Shock capturing.	25%	15
Unit:3	One Dimensional Equations: One dimensional Euler equations, Lax – Wendroff Scheme, Mc- Cormack Scheme, Implicit - method, Pseudo One Dimensional Euler Equations, boundary conditions, Flux – Splitting, Artificial viscosity, Flux limiters.	25%	15
Unit:4	Multi-Dimensional Equations: Multidimensional Euler equations, Lax- Wendroff and Mc-Cormack schemes, stability of multidimensional schemes, Operator splitting Implicit algorithms, Beam - Warming algorithm.	25%	15
	Total	100	60

Text Book

Computation Fluid dynamics J. D. Anderson; Mc-Graw – Hill, New York

Reference Book

1. Computation Fluid dynamics J. D. Anderson; Mc-Graw – Hill, New York