Adamas University
School of Basic and Applied Sciences
Department of Mathematics

Syllabus of

B.Sc. (Mathematics)

Programme Code: MTH3401
Duration: 4 Years Full Time
Academic Year: 2024-25

Vision of the University

To be an internationally recognized university through excellence in inter-disciplinary education, research and innovation, preparing socially responsible well-grounded individuals contributing to nation building.

Mission of the University

- Improve employability through futuristic curriculum and progressive pedagogy with cutting-edge technology
- Foster outcomes-based education system for continuous improvement in education, research and all allied activities
- Instill the notion of lifelong learning through culture of research and innovation
- Collaborate with industries, research centers and professional bodies to stay relevant and up-to-date
- Inculcate ethical principles and develop understanding of environmental and social realities

Core Values

- Respect
- Positivity
- Commitment
- Accountability
- Innovation

Vision of the School

To be recognized globally as a provider of education in Basic and Applied Sciences, fundamental and interdisciplinary research.

Mission of the School

- Develop solutions for the challenges in sciences through value-based science education.
- Conduct research leading to innovation in sciences.
- Nurture students into scientifically competent professionals in the usage of modern tools.
- Foster in students, a spirit of inquiry and collaboration to make them ready for careers in teaching, research and corporate world.

Vision of the Department

To create a Centre of academic excellence in Mathematics and Statistics through active teaching-learning and collaborative research

Mission of the Department

- Deliver graduates with considerable Mathematical and Statistical skills along with real-world problem-solving ability.
- Create a framework to nurture students through outcome-based education towards building a strong foundation in mathematical sciences for academia and industry.
- Conduct fundamental and cutting-edge collaborative research on mathematical and interdisciplinary fields.
- Contribute towards development of mathematical foundation in pan-university level.

Programme Educational Objectives (PEO) of B.Sc. (Mathematics):

PEO 01 Graduates will pursue higher education/research in recognized national/international institutes.

PEO 02 To prepare students with knowledge, abilities and insight in mathematics and related fields.

PEO 03 Graduates will work effectively as individuals and as team members in multidisciplinary projects.

PEO 04 Be able to formulate, investigate and analyze scientifically real life problems along with ethical attitude.

PEO 05 To facilitate students to recognize the need for and the ability to engage in life-long learning.

Programme Outcomes (POs) and Programme Specific Outcomes (PSOs) of B.Sc. (Mathematics)

Students of all undergraduate general degree Programmes at the time of graduation will be able to have

PO1	**Academic Excellence**	Apply theoretical knowledge of Mathematics for the solution of different problems related to science and technology.
PO2	**Contextualized Understanding**	Develop mathematical concepts in all the fields of learning and recognize the need in science and technology.
PO3	**Critical Thinking and Problem-Solving Skills**	Investigate various problems with effective solutions or techniques to crack competitive examinations and higher studies.
PO4	**Problem Analysis**	Identify, formulate and analyze complex problems using mathematical principles.
PO5	**Modernization and Tools Usage**	Design and solve critical problems using sophisticated mathematical modelling with modern tools and programming skills.
PO6	**Societal Implication**	Analyze complex social elements, their interrelation and its impact on geographically different society.
PO7	**Environment and Sustainability**	Design a system, component, or process to meet desired needs within realistic constraints such as environmental, health, safety, manufacturability, and sustainability.
PO8	**Ethics**	Understand ethical principle and commit to professional ethics, responsibly and norms in the society.
PO9	**Individual and Team Work**	Work as an individual or in teams on multi-disciplinary projects in research organizations, industries and participate in academic discussion.
PO10	**Communication**	Build up effective communication skills, both written and verbal, to specialized and non-specialized audiences.
PO11	**Leadership Skills**	Undertake a major, individual, mathematics-related project and discuss the results in a full scientific report with a presentation.
PO12	**Life Long Learning**	Develop the ability to reasoning, abstract thinking, critically evaluate theories, methods, principles, and applications of pure and applied science.
PSO1		Understand basic concepts of mathematics to develop problem solving skills which are required for higher education and get placed in gov./ private organizations.
PSO2		Develop deeper understanding and expanded knowledge in pure mathematics.
PSO3		Apply mathematical methods to other disciplines such as physics, engineering, computer science.

Course Title	**Algebra**
Course Code	**MTH101**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand different methodologies used for solving an algebraic equation
- To make students understand the concept of inequalities and their applications
- To enable students to solve various problems related to integers
- To make students understand the concept of group theory

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Build the concept of algebraic equations of higher degree

CO2: Extend the knowledge of simple Inequalities

CO3: Explain different properties of integers and related theorems

CO4: Define group and subgroup with examples and discuss their properties along with the concept of cyclic group and permutation group

Course Description:

This course provides an in-depth exploration of key concepts in algebra and number theory, focusing on the theory of equations, inequalities, integers, and algebraic structures. Throughout the course, students will develop critical thinking and problem-solving skills, preparing them for advanced studies in mathematics and related fields. The course combines theoretical insights with practical applications, ensuring a comprehensive understanding of the material.

Course Content:

Module I: Theory of Equations

Relation between the roots and coefficients of general polynomial equation of one variable, fundamental theorem of classical algebra, nature of roots, Descartes rule of signs and its applications, transformation of equations, multiple roots, symmetric functions of roots, reciprocal equations, special roots, Cardan's method and Ferrari's method.

Module II: Inequality

Cauchy-Schwarz inequality, inequality involving A.M. (including weighted), G.M., H.M. and their applications, m^{th} power theorem.

Module III: Integers

Divisibility of integers, the greatest common divisor (gcd) of integers a, b, existence and uniqueness of gcd, prime integers, Euclid’s first and second theorems, congruence, Euler’s function, Fermat’s theorem and their applications.

Module IV: Algebraic structure

Concept of algebraic structure, groupoid, semigroup, monoid, Group and its properties, order of an element of a group, order of a group, subgroups and relevant results, concept of cyclic groups, permutation groups and their properties.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. S. K. Mapa, Classical Algebra, Sarat book house.
T2. John B Fraleigh, First course in abstract algebra, Pearson.
T3. Sen, Ghosh and Mukhopadhyay, Topics in abstract algebra, University press
T4. S. K. Mapa, Higher Algebra, Sarat book house.
T5. Ghosh and Chakroborty, Higher algebra, U N Dhur & Sons.

Reference Books:

R1. I. N. Hernstein, Topics in algebra, Wiley India Pvt Ltd.
R2. Burnside and Panton, The theory of equations, Vol. 1, Hodges Figgis and Company.
R3. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
R4. M.R. Adhikari, A. Adhikari, Basic Modern Algebra with Applications, Springer Verlag.
R5. Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.

Course Title	**Calculus**
Course Code	**MTH102**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand the concept of differentiation.
- To enable students to solve definite and indefinite integrals.
- To make students understand the concept of improper integrals, criteria of convergency, and Beta-Gamma functions.
- To make students understand the application of differentiation and integration.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Define the concept of differentiation and different types of integration

CO2: Explain different tools and techniques under differentiation and integration

CO3: Solve different problems arising from engineering and science through various techniques

CO4: Estimate different things related to curves through the applications of integration and differentiation

Course Description:

This course provides an in-depth exploration of key concepts in differentiation and integration. Throughout the course, students will develop critical thinking and problem-solving skills, preparing them for advanced studies in mathematics and related fields. The course combines theoretical insights with practical applications, ensuring a comprehensive understanding of the material.

Course Content:

Module I: Differentiation

Successive differentiation, Leibnitz's rule, Mean Value Theorem, Taylor’s and Maclaurin’s theorems with the remainder term, indeterminate form, Convexity, Concavity, point of inflexion, Maximum and minimum of functions for a single variable.

Module II: Integrals

Indefinite integrals, Definite integrals, Reduction formulae, techniques of integration, differentiation under integral sign, Fundamental theorem of integral calculus.

Module III: Improper Integration

Definition, types of improper integration, necessary and sufficient condition for convergence; Comparison and M-test, Absolute and non-absolute convergence and inter-relations, Abel's and Dirichlet's test for convergence (statement only), Beta and Gamma function.

Module IV: Applications

Cartesian and polar forms of asymptotes, envelope, evolute, involute, curvature, Curve tracing; Length of plane curves, evaluation of area, area included between two curves, area in polar coordinates.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. Shanti Narayan, Differential Calculus. S. Chand publishers
T2. Shanti Narayan, P.K. Mittal, Integral Calculus, S. Chand
T3. K. C. Maity and R. K. Ghosh, Differential Calculus, an Introduction to Analysis
T4. K. C. Maity, R. K. Ghosh, Integral Calculus, New Central Book Agency.

Reference Books:

R1. B. N. Mukherjee, B. C. Das, Key to Differential Calculus, U N Dhur & Sons
R2. S. C. Malik and S. Arora, Mathematical Analysis, New Age International (P) Ltd.

Course Title	**Real Analysis**
Course Code	**MTH103**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand the concept of real line with its core properties
- To make students understand the concept of series and sequences

Course Outcomes:

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

CO1: Define fundamental concepts of real line

CO2: Explain the underlying concepts of sequence and series of real numbers

CO3: Develop the problem-solving ability using properties of real numbers

CO4: Utilize the concept of convergence and divergence to tackle real life problems

Course Description:

This course provides a depth knowledge of real numbers with its various properties which helps us to understand the applicability in various fields. Here student can learn the core techniques of sequence and series which they can apply in other aspects of mathematics.

Course Content:

Module I: Real number system

Mapping, Functions, Field Axioms, ordered field, bounded set, least upper bound (supremum) and greatest lower bound (infimum), completeness axiom, Characterization of $\mathbb{R}$ as a complete ordered field, Archimedean property of $\mathbb{Q}$ and $\mathbb{R}$

Module II: Sets in $\mathbb{R}$

Countable, Uncountable sets; Intervals, the neighborhood of a point, interior point, open set, limit point and isolated point, closed set, closure of a set, Bolzano-Weierstrass theorem on limit point.

Module III: Sequences of real numbers

Definition, bounded sequence, limit of a sequence, convergence and non-convergence, algebra of limits, subsequence, limit supremum and limit infimum, monotone sequences and their convergence.

Module IV: Series of real numbers

Definition, Cauchy convergence criterion, positive term series, geometric series, comparison test, limit form, convergence of p-series, various test for convergence of a series, alternating series, Leibnitz's test (statement only), Absolute and conditional convergence with related results; Power series

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. S.K. Mapa, Introduction to Real Analysis, 7th Edition, Sarat Publishers, India
T2. S.C. Malik and S Arora, Mathematical Analysis, New Age International Private Limited
T3. S. Bandyopadhyay, Mathematical Analysis, Academic Publishers

Reference Books:

R1. R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis (3rd Edition), John Wiley and Sons (Asia) Pvt. Ltd., Singapore
R2. R.K. Ghosh and K.C Maity, An Introduction to Analysis: Differential Calculus: Part I

Course Title	**Ordinary Differential Equation**
Course Code	**MTH104**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objective of this course are as follows:

- To provide students the basic concept of differential equations
- To develop skill for solving and applying first order ordinary differential equations.
- To provide skill related to solve higher order ordinary differential equations.
- To aware student about series solution of differential equations.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Explain the concept of first order differential equation and its different methods of solutions

CO2: Apply the concept of first order differential equation in real life applications

CO3: Solve problem based on second order ordinary differential equations

CO4: Apply the concept of series solution for some ordinary differential equation

Course Description:

This course is design in such a way that students will develop their concept infundamental as well as applications of first order linear and non-linear differential equations. The course deals with different types of first order differential equation and their solutions with applications in biological, physical and engineering problems. This course also deals with second and higher order ordinary differential equations and its series solutions have been also included in this syllabus. After the successful completion of this course student may formulate some physical models in the form of ordinary differential equation and may solve by suitable method.

Course Content:

Module I: First order linear differential equation

Overview of differential equation, First order ordinary differential equation, Existence and Uniqueness theorem, exact differential equations, integrating factors; first order linear differential equation and Bernoulli’s equations; Applications

Module II: First order non-linear differential equation

Differential equation of first order but not first degree; equations solvable for *p*, *y*, *x*; Clairaut's equation; singular solutions and its geometric meaning; orthogonal trajectories and related problems

Module III: Higher order linear differential Equation

Higher order linear differential equations with Constant Coefficients, Wronskian, Complementary function, Particular integral, method of variation of parameters, Undetermined coefficient, Linear differential equations with variable coefficients, Cauchy-Euler's equation, real life applications; Systems of first order linear differential equations

Module IV: Power series solution of differential equations

Ordinary point, singular point and regular singular point, power series, power series solution about an ordinary point.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. R.K. Ghosh ad K.C. Maity, An Introduction to Differential Equations, New Central Book Agency.

T2. M.D. Raisinghania, Ordinary and Partial Differential Equations, S Chand Publishing.

T3. V Sundarapandian, Ordinary and Partial Differential Equations (With Laplace transforms, Fourier series and applications), TMH Educational Pvt Limited, 2013.

T4. S. L. Ross, Differential Equations, John Wiley and Sons, India, 2004.

Reference Books:

R1. William E. Boyce and Richard C. Di-Prima, Elementary Differential Equations and Boundary Value Problems, 7th edition, John Wiley & Sons, Inc.

R2. C. H. Edwards and D. E. Penny, Differential Equations and Boundary Value Problems: Computing and Modeling, Pearson Education, India, 2005.

R3. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies

R4. H.T.H. Piaggio, Differential Equations, G.Bell& Sons Ltd. 1921

Course Title	**Linear Algebra**
Course Code	**MTH201**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

1. To help the students to acquire the knowledge of vector spaces
2. To enable the students to get an idea of linear independence, span, and basis
3. To give the idea about the solution procedures for solving system of linear equations and matrix equations
4. To help the students to understand the concepts of row space, column space and null space of a matrix
5. To give knowledge of linear transformations and their various properties
6. To enable the students to evaluate the eigen values and eigen vectors of a matrix.
7. To give an idea about the General Quadratic form and definiteness of matrices
8. To enable the students to inner products space, associated norms and the operators on Inner product spaces.

Course Outcomes:

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

CO1: Define real vector spaces, subspaces and develop the idea of linear independence, span, basis along with the concept of row space, column space, and solution space of a system of linear equations

CO2: Define linear transformation and its various properties, matrix representation including the concept of rank and nullity of a linear transformation

CO3: Summarize the concept of matrix polynomial, diagonalizability, Real quadratic form involving three variables and definiteness.

CO4: Extend the concept of vector spaces to inner products space including associated norms and the operators on Inner product spaces.

Course Description:

This course is intended to provide the concept of vector spaces. This course is also intended to provide some tools for performing basic operations on matrices and use those tools for solving system of linear equations and matrix equations. Furthermore, some basic ideas about row-space, column-space, and null-space are there. Concepts of eigen values and eigen vectors of a matrix and their applications in real world will be discussed in this course. Some basic ideas about linear transformation and its relationship with matrix algebra can be found in this course. Also, an idea about of general quadratic form and the definiteness of the associated matrices is provided through this course.

Course Content:

Module I: Vector/linear space

Definitions and examples of vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, generators of vector space, linear independence, basis and dimension, replacement theorem, extension theorem, deletion theorem, extraction of basis, dimension of a vector space, finite dimensional vector space, dimension of subspaces.

Module II: Systems of Linear Equations

Row space and column space of matrix, elementary operations on matrices, echelon matrix, rank of a matrix, determination of rank of a matrix, elementary matrices, statements and application of results on elementary matrices, normal form of a matrix under congruence. row rank and column rank of matrix, equality of row rank, column rank and rank of a matrix, systems of linear equations, solutions of system of equations by Matrix method, the invariance of solution set of systems of linear equations under row-equivalence, solution space, applications of linear systems.

Module III: Linear transformations

Definition and related results, null space, range space, rank and nullity of a linear transformation, Rank-Nullity theorem, algebra of linear transformations and related properties, composition of linear transformation, and isomorphism between two finite-dimensional vector spaces. Matrix representation of a linear transformation, various properties of matrix representation, matrix of composite mapping, inverse mapping, basis change, linear space of linear mappings, linear operator and properties.

Module IV:

Eigen Values and Eigen Vectors: Eigenvalues and eigenvectors of square matrices, Cayley-Hamilton theorem, simple properties of eigenvalues and eigenvectors, AM and GM., Eigen spaces of a linear operator, the minimal polynomial for a linear operator, similar matrix, diagonalizability and Jordan Canonical form.

Quadratic Form: Real quadratic form involving three variables, reduction to normal form (Statements of relevant theorems and applications), general quadratic form, index, signature, characteristics of quadratic forms (positive definite, positive semi-definite, negative definite, negative semi-definite, indefinite).

Module V: Inner product spaces

Inner product spaces and norms, various results of inner product spaces, Orthogonal projections and Spectral theorem, Gram-Schmidt orthogonalization process, Bessel's inequality, the adjoint of a linear operator, normal and self-adjoint operators, orthogonal complements.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
T2. S. K. Mapa, Higher Algebra- Abstract and Linear, revised Ninth Edition, Sarat Book House, 2003.
T3. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
T4. Hoffman and Kunze, Linear algebra, Pearson.
T5. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, Pearsons

Reference Books

R1. R.K. Jain and S.R.K. Iyenger, Advanced Engineering Mathematics, Narosa Publishing House.
R2. B. S. Vaatsa, Theory of matrix, New age publication.
R3. A Kurosh, Higher Algebra, Mir Publisher
R4. D.T. Finkbeiner, Introduction to matrices and linear transformations, CBS Publishers, New Delhi.
R5. John Smith, Modern Engineering Mathematics, 5th Edition, Pearson Education.

Course Title	**Analytical Geometry**
Course Code	**MTH202**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

To give students the knowledge of two-dimensional and three-dimensional geometry which is useful to study several real-life phenomena.

Course Outcomes:

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

CO1: Choose appropriate transformation of the coordinate axes and explain the concept of pair of straight lines

CO2: Explain the concepts of tangent & normal, pole & polar to a conic and the idea the polar equations of the conics.

CO3: Build the knowledge of straight lines in three-dimensional space, shortest distance of skew lines and transformation of axes.

CO4: Build the knowledge of three-dimensional shapes namely plane, sphere, ellipsoid, hyperboloid, cone, cylinder, etc.

Course Description:

This course includes the basic and advanced topics of two-dimensional and three-dimensional geometry. Analytic geometry is also known as coordinate geometry or Cartesian geometry. It is used in modern fields of geometry, including algebraic, differential, discrete and computational geometry, physics, engineering, and also in aviation, rocketry, space science, and spaceflight. In analytic geometry, the plane is given a coordinate system, by which every point has a pair of real number coordinates. In polar coordinates, every point of the plane is represented by its distance r from the origin and its angle θ. This course describes transformation of axes, pair of straight lines, general second-degree equation, tangent, normal, pole, polars, etc. This course describes coordinates in space, equation of plane, straight line in space, direction cosines, shortest distance of two skew lines, equation of sphere, cone, cylinders, surfaces of revolution, etc.

Course Content:

Module I: Coordinate Geometry

Transformation of rectangular axes, Invariants, pair of straight lines, reduction of the general second-degree equation to canonical form, classification of conics

Module II:

Pole and polar with respect to a non -singular conic, polar equations of straight lines, circle and conics (with a focus as pole) and tangent, normal, chord of contact

Module III: Three- dimensional Geometry

Rectangular Cartesian coordinates in space, direction cosines and direction ratios of a directed line, projection, angle between two lines, equations of a plane, the sides of a plane, bisectors of the angles between two planes, parallelism and perpendicularity of two planes, straight lines in the space, skew lines

Module IV:

Sphere, cone, cylinder, surfaces of revolution, ruled surface, transformation of rectangular axes in the space, reduction of the general second-degree equation in three variables to canonical form, classification of quadrics, standard equations and shapes of ellipsoid, hyperboloid and paraboloid

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. S.L. Loney, The Elements of Coordinate Geometry, McMillan and Company, London.
T2. J. G. Chakravorty and P.R. Ghosh, Advanced Analytical Geometry, U.N.Dhur & Sons Pvt Ltd, 2018

Reference Books

R1. R.J.T. Bell, Elementary Treatise on Coordinate Geometry of Three Dimensions, McMillan India Ltd., 1994
R2. P.K.Jain and K.Ahmad, Analytical Geometry of Two Dimensions, New Age International (P) Ltd., 1996
R3. R M Khan, Analytical Geometry and Vector Algebra, New Central Book Agency (P) Limited, 2013

Course Title	Modern Algebra
Course Code	MTH203
Credit	4
Contact Hours (L-T-P)	3-1-0
Course Type	Theory

Course Objectives:

The objectives of this course are as follows:

- To make students understand the basic concept of group theory with its core properties
- To make students understand the basic concept of ring theory with its core properties

Course Outcomes:

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

CO1: Explain the concept of cosets, Lagrange's theorem, normal subgroup and quotient groups with some related results.

CO2: Explain the concept of group homomorphism, automorphism, characteristic, commutator subgroups and study some applications.

CO3: Explain the concept of rings, subrings, ideals, and study some properties.

CO4: Extend the concept of group homomorphism to ring homomorphism and study related results.

Course Description:

This course provides a depth knowledge of group structure and ring structure with its various properties which helps us to understand the applicability in various fields. Here student can learn the core concept of ideal and homomorphism which they can apply in other aspects of mathematics.

Course Content:

Module I

Cosets with its properties, Lagrange's theorem and its applications, Normal subgroup, quotient group

Module II

Group homomorphisms, Cayley's theorem, properties of isomorphisms, first, second and third isomorphism theorems, automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, commutator subgroup, group action

Module III

Rings and fields: rings, zero divisors, integral domains, division rings, fields, Subrings, characteristic of a ring, ideals, quotient ring, ring homomorphisms, kernel and image of a homomorphism

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
T2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
T3. Sen, Ghosh and Mukhopadhyay, Topics in abstract algebra, University press
T4. S. K. Mapa, Higher Algebra, Sarat book house.

Reference Books

R1. Joseph A. Gallian, Contemporary Abstract Algebra (8th Edn.), Narosa Publishing House, New Delhi
R2. Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.
R3. I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
R4. M.R. Adhikari, A.Adhikari, Basic Modern Algebra with Applications, Springer Verlag

Course Title	**Introduction to Linear Programming and Game Theory**
Course Code	**MTH204**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To develop the concept of formulation of linear programming problem (LPP) and solution procedure of LPP by using Graphical method, simplex method.
- To acquire the knowledge of special classes of LPPs such as Transportation problem, Assignment problem and Travelling salesman problem
- To build up the concept of application procedures of LPP to Game Theory.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Find the mathematical form of real-world problems in the form of LPP and find the solution by using Graphical method

CO2: Illustrate the concept of Simplex method and Duality of LPP

CO3: Choose appropriate techniques for solving problems related to transportation, assignment and travelling salesman

CO4: Build the concept of application procedures of LPP to Games and strategies

Course Description:

Linear Programming Problem (LPP) deals with the problem of minimizing or maximizing a linear function in the presence of linear equalities/inequalities. Since the development of the simplex method, linear programming has been extensively used in the military, industrial, governmental, and urban planning fields, among others. A large class of optimization problems are solved by techniques under the heading mathematical programing. There are several other techniques to solve the optimization problems but LPP concerned with only solving the linear programing models in an iterative procedure which yields an exact solution in a finite number of steps. LPP is useful to solve the allocation problems. These problems require the allocation of limited available resources to the jobs that are to be done. There is a class of games which are intimately related to linear programing.

Course Content:

Module I: Introduction to LPP

Introduction, definition of linear programming problem (LPP), formation of LPP, graphical Method, basic solutions and basic feasible solution (BFS), degenerate and non-degenerate BFS, Hyperplane, convex set, extreme points, convex hull and convex polyhedron, supporting and separating hyperplane, reduction of a feasible solution (FS) to a BFS, optimality condition, unboundedness, alternate optima, infeasibility

Module II: Simplex method

Theory of simplex method, optimality and un-boundedness, the simplex algorithm, two-phase method, Big-M method, Duality, formulation of the dual problem, primal-dual relationships, Duality theorem, interpretation of the dual economically

Module III: Transportation problem

Transportation problem and its mathematical formulation, north-west corner method, least cost method and Vogel approximation method for determination of initial basic feasible solution, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem, travelling salesman problem

Module IV: Game Theory

Concept of game theory, rectangular games, pure strategy and mixed strategy, saddle point, optimal strategy and value of the game, concept of dominance, formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, S. Chand and Co. Pvt. Ltd.

T2. Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice Hall India, 2006.

T3. G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

Reference Books:

R1. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.

R2. N.V.R. Naidu, G. Rajendra and T. Krishna Rao-Operations Research, I.K. International Publishing House Pvt. Ltd., New Delhi, Bangalore.

R3. D. C. Sanyal, K. Das, Linear Programming and Game Theory, U. N. Dhur and sons Pvt Ltd, 2008.

Course Title	**Multivariate Calculus**
Course Code	**MTH205**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To develop the concept of differential and integral calculus for multiple variables
- To acquire the knowledge vector calculus
- To build up the concept different tools and techniques used in multivariate calculus

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Define various terms related to Calculus and Vector

CO2: Explain the underlying concepts of partial differentiation and multiple integral

CO3: Apply different tools and techniques from calculus for solving several types of problems

CO4: Analyse complex problems with the help of vector calculus

Course Description:

This course offers an in-depth exploration of multivariable calculus and vector calculus, focusing on functions of several variables and their applications. In **Unit I**, students will learn to define and analyze key concepts such as limits, continuity, and partial differentiation. They will investigate differentiability conditions and apply the chain rule, while gaining a solid understanding of vector fields, gradients, divergence, and curl. The geometric interpretations of these concepts, including tangent planes and normal lines, will be emphasized through Taylor's theorem for functions of two variables. By the end of this course, students will have developed a robust understanding of multivariable calculus and vector calculus, preparing them for advanced studies in mathematics, engineering, and the sciences.

Course Content:

Module I:

Functions of several variables, Limit and Continuity, Partial differentiation, Differentiability, Sufficient condition for differentiability, Chain rule, Homogeneous function and Euler’s theorem, Directional derivatives, level curves and level surfaces, vector field, Gradient, Divergence and

Curl, Maximal and normal property of the gradient, Geometric interpretation, Tangent planes and Normal lines, Linear approximation, Taylor's theorem for functions two variables

Module II:

Extrema of a function - two or more variables, local and global extrema, Stationary points, Saddle point, method of Lagrange multipliers, constrained optimization problems, Variable transformations and Jacobian

Module III:

Line integral, Conservative field, Double integrals over rectangles, iterated integrals, Fubini's theorem, double integrals over general regions, change of order of integration, evaluation of triple integrals, applications of Double and Triple integrals, area by double integration, surface area, surface integral, volume of solids as double integrals, volume as triple integral, Surface area and volume of solids of revolution, Green's theorem, Gauss Divergence theorem, Stokes' theorem

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. G.B. Thomas Jr., M.D. Weir and J.R. Hass, Thomas Calculus, Pearson Education, 2009
T2. S. C. Mallik and S. Arrora, Mathematical Analysis, S. Chand.
T3. G.B. Thomas and R. L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
T4. S. Bandyopadhyay, Mathematical Analysis, Academic Publishers.

Reference Books:

R1. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007
R2. E Marsden, A. J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005
R3. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks/Cole, Thomson Learning, USA, 2001

Course Title	**Numerical Methods**
Course Code	**MTH301**
Credit	**4**
Contact Hours (L-T-P)	**3-0-1**
Course Type	**Hybrid**

Course Objectives:

To introduce the numerical approaches for solving various mathematical problems.

Course Outcomes

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

CO1: Find the errors in numerical methods, and numerical solutions of nonlinear equations with single variable

CO2: Illustrate the solution procedure of system of linear algebraic equations

CO3: Develop the basic knowledge of finite differences, interpolation and divided differences

CO4: Demonstrate the concept of numerical differentiation and integration

CO5: Solve the ordinary differential equations by several numerical methods

Course Description:

Numerical analysis is the subject of study to find the numerical solutions of mathematical problems by computational methods. Numerical techniques are effective tools for providing solutions to mathematical problems which are not solved by analytical methods. It studies the numerical solutions to the problems involving nonlinear equations, system of linear algebraic equations, interpolation and approximation, empirical laws for curve fitting, differences, integrals, ordinary and partial differential equations, finite differences, etc. Numerical methods are normally being used to find the solution to a problem whose analytical solution is difficult to achieve, thus it is felt that a study in applied sciences and engineering is essential and found wide applications in all areas of science, technology and economics.

Course Content:

Module I:

Errors: Relative, Absolute, Round off, Truncation errors, Propagation of errors;

Roots of algebraic and transcendental equations: Bisection method, Regular-Falsi method, Secant method, Fixed point iteration method, Newton-Raphson method; Rate of convergence

Module II:

System of linear algebraic equations: Gauss Elimination method, LU factorization, Ill-conditioned system and its solution, Gauss-Jacobi method, Gauss-Seidel method

Module III:

Interpolation: Finite difference operators and their relations, Newton's forward and backward difference formulae, Lagrange's interpolation formula, Divided difference, Newton's divided difference interpolation formula

Module IV:

Numerical integration: Newton-Cotes quadrature formula, Trapezoidal rule, Simpson's rules, Weddle's rule

Numerical Solutions of ODE: Euler's method, Modified Euler's method, Second and fourth order Runge-Kutta methods.

Practical/Lab to be performed on a computer using MATLAB/C programming:

Write and execute C/MATLAB-code for the following programs:

Name of the experiment:

1. Find a root of non-linear equation using Bisection method.
2. Find a root of non-linear equation using false position method.
3. Find a root of non-linear equation using Newton-Raphson method.
4. Solve the system of equation using Gauss-Elimination Method.
5. Solve the system of equation using Gauss-Seidel iteration method.
6. Interpolate values using Newton‘s forward interpolation.
7. Interpolate values using Newton‘s backward interpolation
8. Interpolate values using Lagrange‘s method.
9. Evaluate the integral using Trapezoidal rule.
10. Evaluate the integral using Simpson‘s rule.
11. Evaluate the integral using Weddle‘s rule.
12. Evaluate the differential equation by Euler's method.
13. Evaluate the differential equation by Runge-Kutta methods

Evaluation:

Mode of Evaluation	Theory		Practical	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination	Comprehensive and Continuous Assessment	End Semester Examination
	25%	25%	25%	25%

Text Books:

T1. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New age International Publisher, India, 5th edition, 2007.

T2. S. A. Mollah, *Numerical Analysis* and Computational Procedures, Books & Allied (P) Ltd, 2020.
T3. B. S. Grewal, Numerical Methods in Engineering & Science with Programs in C & C++, Khanna Publications, 2013.

Reference Books:

R1. T. Veerarajan, T. Ramachandran, Numerical Methods with Programs in C, Tata McGraw Hill Publications.
R2. S. Dey, S. Gupta, Numerical Methods, McGraw Hill Education.
R3. S. S. Sastry, Introductory Methods of Numerical Analysis. PHI Learning Pvt. Ltd, 2012.
R4. S. S. Ray, Numerical Analysis with Algorithms and Programming. Chapman and Hall/CRC, 2018.
R5. A Gupta and S C Bose, Introduction to Numerical Analysis, Academic Publishers, 2009.

Course Title	**Dynamics of a Particle**
Course Code	**MTH302**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course is to develop concept of kinematics of particles and rigid bodies with respect to fixed and moving coordinate systems.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Understand motion of a particle in a straight line

CO2: Relate Newton's law to determine the forces acting on an object

CO3: Explain motion in a plane curve, impulse, momentum, velocities after impact

CO4: Determine velocities of a point on a rigid body and planar motion

Course Description:

This course will teach students about force and motion, work-energy, impulse-momentum in view of Newton's laws of motion and its integration over time and displacement. The course also discusses the motion under central force, planetary motion, and collision of two elastic bodies. The class activities include lectures, tutorials, assignments, quizzes, and interactions. Moreover, the students will actively participate in discussion, problem solving in class and workout on board. The course will help the students to develop the fundamental knowledge of dynamics, and in addition, to enhance the problem solving, interaction and presentation skills.

Course Content:

Module I:

Principles of dynamics, Laws of motion, Motion in a straight line under variable acceleration, Motion under inverse square law, Simple harmonic motion, Composition of two Simple harmonic motions of nearly equal frequencies, Motion of particle tied to one end of elastic string, Damped oscillation, damped forced oscillation, Motion in resisting medium where the resistance varies as some integral (nth) power of velocity, Terminal Velocity

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Module II:

Impulse and impulsive forces, Work, Power and Energy, Conservative field of force, Principles of Conservation of energy and momentum, Impact of elastic bodies, Newton's Experiment Law of impact Direct and indirect impact of two elastic spheres, Loss of kinetic energy in both direct and indirect impact of two spheres, Angle of deflection

Module III:

Expressions for velocity and acceleration of a particle moving on a plane in cartesian and polar coordinates (Radial and Cross-radial components of velocity and acceleration), Motion of a projectile in a resisting medium in which the resistance varies as some integral power of velocity

Module IV:

Central forces and central orbits, Characteristics of central orbits, Apes on a central orbit, Stability of nearly circular orbits, motion under inverse square law, Planetary motion and Kepler's laws, Time of describing an arc of the orbit

Module V:

Expressions for tangential and normal component and velocity and accelerations, Circular motions, Simple cases of constrained motion of a particle on a smooth and rough curve (such as circle, parabola, ellipse, cycloid, etc)

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. S. L. Lony, Dynamics of Particle and Rigid Bodies, G. K. Publication
T2. S. Ganguly and S. Saha, Analytical Dynamics of Particle including Elements of Statistics, 2016, New Central Book Agency (P) Ltd
T3. N. Dutta and R. Jana, Dynamics of Particle, Shreedhar Prakashani, 2016

Reference Books:

R1. Anil Rao, Dynamics of Particle and Rigid Bodies: A Systematic Approach
R2. E, T. Whittaker, A Treatise on the Analytical Dynamics of Particles and Rigid Bodies
R3. Joseph Whittington - Elementary dynamics, a textbook for engineers-University Press (1920)

Course Title	**Probability and Statistics**
Course Code	**MTH303**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To introduce the fundamental concepts of probability and statistics.
- To explain key statistical concepts such as random variables, expectation, correlation, and hypothesis testing.
- To equip students with the knowledge of probability distributions and their applications in real-life scenarios.
- To develop analytical skills for solving complex problems using probabilistic models and statistical methods.
- To enable students to make informed decisions based on data analysis and statistical reasoning.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Define basic components of probability and statistics

CO2: Explain the concepts of random variable, expectation, correlation, testing of hypothesis etc.

CO3: Utilize the knowledge of different distributions for solving real-life problems related to chance

CO4: Analyse a complex problem and take satisfactory decision with the knowledge of probability and statistics

Course Description:

This course introduces the essential concepts and principles of probability and statistics, focusing on their practical applications in various fields. Students will explore basic probability rules, random variables, distributions, and expected values. The course covers statistical methods like hypothesis testing, correlation, and real-world data analysis. By the end of the course, students will be equipped with the knowledge to analyze complex problems and make informed decisions in situations involving randomness and uncertainty. Through theoretical learning and practical examples, the course aims to bridge the gap between abstract mathematical theory and real-life problem-solving.

Course Content:

Module I: Introduction to Probability Theory

Review of Probability concepts, Conditional probability, independent events, multiplication rule, Baye's theorem and its applications.

Module II: Random Variables and Mathematical Expectation

Random variables and its types, distribution function, probability mass function, probability density function, discrete and continuous distribution functions, Mathematical expectation of a random variable and function of random variable, properties of expectation, moments, central moments, moment generating function and its limitations, properties and uniqueness theorem of moment generating function

Module III: Probability distributions:

Discrete uniform, Bernoulli, Binomial, Poisson, Geometric, Hyper-geometric, Uniform, exponential, and Normal distributions and their moment generating functions and properties.

Module IV: Correlation and Regression Analysis

Correlation analysis, Pearson's correlation coefficient, Spearman's rank correlation, linear regression analysis, two regression equations, logistic regression.

Module IV: Law of Large Number

Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance

Module IV: Testing of Hypothesis

Basic concepts, one- and two- tailed tests, test statistic, confidence interval and confidence limit, types of error, p-values for decision making testing hypotheses, pre-selection of a significance level, test for population mean, difference in means, population variance

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. S C Gupta and V K Kapoor, Fundamentals of Mathematical Statistics, S Chand & Sons.

T2. Vijay K. Rohatgi, A.K. Md. Ehsanes Saleh, An Introduction to Probability and Statistics, 2nd edition, Wiley.

T3. Amritava Gupta, Groundwork of Mathematical Probability and Statistics, Academic Publishers, 2015

Reference Books:

R1. R. V. Hogg, J Mckean, A T Craig, Introduction to Mathematical Statistics, 7e, Pearson Education India.

R2. S. Ross, A First Course in Probability, Pearson Education.

R3. S. Ross, Introduction to probability models, Academic Press, Indian Reprint 2007.

R4. Parimal Mukhopadhyay, An Introduction to the Theory of Probability, World Scientific, 2012.

Course Title	Internship (Summer Project)
Course Code	**MTH350**
Credit	**4**
Contact Hours (L-T-P)	
Course Type	**Internship**

Course Objectives:
To apply the knowledge of statistics and data science in relevance to practical solutions.

Course Outcomes:
On completion of this course, the students will be able to:

CO1: Apply techniques using different methods of applying skills and knowledge acquired in the classroom

CO2: Understand the professional requirements for access to and success in the field

CO3: Realize the work ethic and skills required for success in the field

Course Description:
Summer internship allows the student an opportunity to bridge theory and practice. It is a learning experience that permits students to apply knowledge acquired in the academic classroom within the professional setting. Such experiential learning supplements academic theory, helps the student to identify personal strengths and guides her/him into specialized fields within the profession (Research and development, teaching, Engineering, financial management, data analysis etc.). Perhaps equally as important is the chance for the student to begin to establish the professional network so essential for access to, and movement within, the profession. The student may personally research internship opportunities and interview for any opportunity that furthers the student's professional aspirations in the field.

Evaluation:

Mode of Evaluation	Presentation and Report
Weightage	End Semester Examination
	100%

Course Title	**Complex Analysis**
Course Code	**MTH304**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand complex numbers and learn complex functions along with limit, continuity and differentiability. Also, to make them familiar with analytic functions and their properties.
- To make students understand the concept of complex integration and learn how to compute complex integrations using Cauchy's integral formula.
- To make students understand the convergence of an infinite series, learn about Laurent series, singularities, and residue theory, applying them to solve integrals and problems in complex analysis. Also, to gather knowledge about bilinear transformations and conformal mappings.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Build the concept of Complex functions, limit, continuity, differentiability and analytic functions.

CO2: Illustrate the idea of complex integration along with Cauchy-Goursat theorem and Cauchy's integral formula with their applications.

CO3: Explain the infinite series (Taylor series, Laurent series etc.) expansion along with the region of convergence.

CO4: Build the knowledge of bilinear transformations and conformal mappings.

Course Description:

This Complex Analysis course provides a thorough introduction to the theory of functions of a complex variable. It begins with the study of complex numbers and their geometric representation, followed by a detailed examination of analytic functions, including the Cauchy-Riemann equations and power series expansions. Key results like Cauchy's Integral Theorem and Cauchy's Integral Formula are explored in-depth. The course also covers Laurent series, singularities, and residue theory, focusing on their applications in evaluating integrals and solving complex problems. By the end, students will gain a strong foundation in the fundamental techniques and theorems of complex analysis.

Course Content:

Module I: Complex Functions

Exponential form, product and powers in exponential form, Stereographic Projection, Point Sets and regions in the complex plane.
Functions of complex variable, Branch Points and Branch Lines, Mapping, mapping by exponential functions, limits, Uniform Continuity, Derivatives, Analytic Functions, Cauchy–Riemann Equations, Harmonic Functions, uniquely determined analytic functions, Orthogonal Families.

Module II: Complex Integration

Line Integrals, Change of Variables, Simply and Multiply Connected Regions, Contour integral, Upper bound for moduli of contour integrals, Jordan Curve Theorem, Convention Regarding Traversal of a Closed Path, Cauchy–Goursat Theorem, Morera's Theorem, Liouville's Theorem and the fundamental theorem of algebra.

Module III: Infinite Series, Residue Theorem and its Application

Infinite Series: Power Series, Taylor's Theorem, Laurent's Theorem, Convergence, Singularities, Meromorphic Functions;

Residue and its application: Isolated singular points, Residues, Cauchy's Residue theorem, Residue at infinity and poles, Zeros of analytic function, Zeros and poles.

Evaluation of Definite Integrals using Residue theorem, Special Theorems Used in Evaluating Integrals.

Module IV: Bilinear Transformations

Bilinear transformations their properties and classifications, principle of conformal mapping, bilinear of fractional transformations, Schwartz-Christoffel transformation, physical applications of conformation mapping. Analytic continuation, direct analytic continuation, Poisson integral formula.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.

T2. Murray. R. Spiegel, Complex Variables, Schaum's outline series, Second Edition.

T3. S. Ponnusamy, Foundations of Complex Analysis, Narosa Pub. House.

Reference Books:

R1. J.B. Conway, Functions of One Complex Variable, 2nd Edition, Narosa, New Delhi, 1978.

R2. A.R. Shastri, An Introduction to Complex Analysis, Macmilan India, New Delhi, 1999.

Course Title	**Integral Transform and Partial Differential Equations**
Course Code	**MTH305**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students gain a strong understanding of Fourier and Laplace transforms and their application in solving differential equations and boundary value problems.
- To make students learn to classify partial differential equations (elliptic, parabolic, and hyperbolic) and apply methods such as separation of variables for their solution.
- To make students utilize integral transforms to model and solve problems in heat conduction, wave propagation, and fluid dynamics.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Build the concept of Laplace transform and its application in real life.

CO2: Acquire the knowledge of Fourier Series and Fourier transform to solve complex problems.

CO3: Define and form several types of partial differential equations and illustrate the solutions to first order linear and nonlinear partial differential equations with two or more independent variables using Lagrange's and Charpit's method.

CO4: Solve second order reducible and irreducible partial differential equations with constant coefficients to obtain integral surfaces.

CO5: Solve one dimensional wave equation and heat equations, and two-dimensional Laplace equation using separation of variables method.

Course Description:

The course on Integral Transforms and Partial Differential Equations (PDEs) introduces students to methods for solving complex differential equations that arise in physics, engineering, and applied mathematics. The course covers Laplace and Fourier transforms, which are powerful tools for converting PDEs into simpler algebraic equations. These techniques are used to solve boundary value problems and initial value problems in various fields such as heat conduction, wave propagation, and fluid flow. Key topics include classification of PDEs (elliptic, parabolic, and hyperbolic), separation of variables, and Green's functions. The course also delves into the application of Fourier series in solving PDEs and how integral transforms aid in simplifying problems in both time and frequency domains. By the end of the course, students will be able to apply integral transforms effectively to solve linear PDEs, providing insight into real-world phenomena across multiple scientific disciplines.

Course Content:

Module I: Laplace Transform

Definition, Existence conditions for Laplace transform, Linearity property, Shifting theorems, Laplace transform of derivatives and integrals, Initial and final value theorem, Laplace transform of periodic functions, Laplace transform of some special functions, Inverse Laplace transform and their properties, convolution theorem, solution Initial/Boundary value problems using Laplace transform.

Module II: Fourier Series and Fourier Transform

Fourier series: Periodic function, Trigonometric Fourier series, Dirichlet's condition, Fourier series of even and odd functions, Fourier half-range series, Parseval`s identity, Complex form of Fourier series.
Fourier Transforms: Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties.

Module III: Partial Differential Equation

Formation of first order partial differential equations (PDE), linear and non-linear PDE of first order, special types of first-order equations, solutions of linear first order PDE, Lagrange's method of solving Lagrange's linear equations, integral surfaces passing through a given curve, nonlinear first order PDE, Charpit's method.

Linear second order homogeneous and non-homogeneous PDE with constant coefficients, method of finding the complementary function and particular integral for homogeneous and nonhomogeneous PDE, separation of variable (Product Method), Non-linear equation of the second order.

Module IV: Solutions of Laplace Equation, Wave Equation, and Heat Equation

Laplace equation, Solution of Laplace equation by separation of variables, One dimensional wave equation, Solution of the wave equation by the method of separation of variables, Diffusion equation, solution of one-dimensional diffusion equation by the method of separation of variables.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. A R Vasishtha and R K Gupta, Integral Transforms, Krishna Prakashan Media (P) Ltd.

T2. Sudhir K Pundir, Integral Transforms Methods in Science & Engineering, CBS Publishers & Distributions Pvt. Ltd.

T3. M.D. Raisinghania, Advanced Differential equations, S. Chand.

Reference Books:

R1. E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons, 2011.

R2. S. L. Ross, Differential equations, 3rd Ed., John Wiley and Sons, India, 2004.

R3. I.N. Sneddon, Elements of partial differential, McGraw-Hill book.

Course Title	**Project**
Course Code	**MTH351**
Credit	**4**
Contact Hours (L-T-P)	
Course Type	**Project**

Course Objectives:

- To address the real-world problems and find the required solution.
- To fabricate and implement the mini project intended solution for project-based learning
- To improve the team building, communication and management skills of the students

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Identify the requirements for the real-world problems.

CO2: Demonstrate and build the project successfully by reviewing and analysing the results.

CO3: Study and enhance Mathematical skills.

CO4: Explain the findings of the study conducted in the preferred domain

Course Description:

The role of Projects in life of science students are very crucial. Minor Project helps you to explore and strengthen the understanding of fundamentals through practical application of theoretical concepts. Every phenomenon around you is being justified by our greatest Mathematicians to date. In this article we, will be covering what is Mathematics and mini-projects that can be done by mathematicians during their academics. It acts like a beginners guide to do larger projects later in their career. It not just affects the grades of learner but also matter a lot for good CV/Resume. So before choosing the minor and major project, you should explore the options and pick the correct domain where the opportunities are immense.

Evaluation:

Mode of Evaluation	Presentation and Report
Weightage	End Semester Examination
	100%

Course Title	Continuum Mechanics
Course Code	MTH306
Credit	4
Contact Hours (L-T-P)	3-1-0
Course Type	Theory

Course Objectives:
The objectives of this course is to equip students with a rigorous foundation-level understanding to support their efforts in the theory, modelling and analysis of problems arising in the Solid Mechanics and Fluid Mechanics.

Course Outcomes:
On completion of this course, the students will be able to:

CO1: Define deformation and flow, material and spatial time derivative, learn the Lagrangian and Eulerian descriptions of flow

CO2: Establish the concept of Strain tensors, Finite strain tensors, Principal Strain, and various topics on Strain

CO3: Know the body force, Surface Force, Stress tensors and various concepts on Stress

CO4: Learn the Principle of conservation of mass and other dynamical principles.

CO5: Build up the concept of Classical Elasticity, Generalized Hook's Law, establish the constitutive equations for elastic solids, Strain Energy function and compatibility equations

CO6: Deduce path lines, Stream lines and different properties of flow mechanics, different properties of Waves in water and Complex Potential.

Course Description:
This course provides an in-depth exploration of key concepts in the mechanics of continuous media. It covers the kinematics of deformation, the concept of stress, and the conservation laws for mass, momentum and energy. This is followed by an introduction to constitutive theory with applications to well-established models for viscous fluids and elastic solids. The course combines theoretical insights with practical applications, ensuring a comprehensive understanding of the material.

Course Content:

Module I: Theory of Strain

Body, Configuration, Deformation and Flow, Material and spatial time derivative, Lagrangian and Eulerian Descriptions, Deformation gradient tensors, Finite strain tensors, small deformation, Infinitesimal strain tensor, Principal strains, Strain Invariants, Strain quadric, Compatibility equations for linear strains

Module II: Theory of Stress

Body and Surface forces, Stress tensor, Stress Components, Equations of Equilibrium, Symmetry of stress tensor, Normal and shearing stress, Maximum shearing stress, Principal stresses, Invariants of stress tensors, Stress quadric

Module III: Motions of Continuum

Principle of Conservation of mass, The Continuity equation, Principle of Conservation of linear and angular momentum, Conservation of energy

Module IV: Theory of Elasticity

Ideal material, Classical Elasticity, Generalized Hooke's Law, Isotropic materials, Constitutive equation (Stress-Strain relations) for isotropic elastic solids, Strain- Energy Function, Beltrami-Michel Compatibility Equation for Stresses, Saint-Venant's Principle

Module V: Fluid Media

Path lines, Stream lines and Streak lines, Bounding Surface, Lagrange's criterion for bounding Surface

Module VI: Waves

General Features, Phase Velocity, Group Velocity, Wave Packet, Surface Condition of gravity Waves, Cisotti's Equation, Complex Potential, Energy and Path of particles for Progressive waves and Stationary waves, Group Velocity

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. A, C. Eringen: Mechanics of Continua, Wiley,1967.

T2. I. S. Sokolnikoff: Mathematical theory of Elasticity, Tata Mc Grow Hill Co, 1977.

T3. J. L. Bansal: Viscous Fluid Dynamics, Oxford and IBH Publishing Co, 1977.

Reference Books:

R1. R. N. Chatterjee: Mathematical Theory of Continuum Mechanics, Narosa Publishing House, New Delhi, 1999.

R2. D. S. Chandrasekharaiah and L. Debnath: Continuum Mechanics, Academic Press, 1994.

Course Title	**Discrete Mathematics and Graph Theory**
Course Code	**MTH307**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To develop an in-depth understanding of combinatorics, generating function, Recurrence relation, Graphs and Trees.
- To develop the ability using the above mathematical tools in computer science related courses.

Course Outcomes:

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

CO1: Define fundamental concepts of combinatorics

CO2: Explain the underlying concepts of Lattice and Boolean algebra for the discrete structures

CO3: Develop the problem-solving ability using the concept of mathematical logic

CO4: Utilize the concept of graph theory to find the solution of real-life problems in computer science and other relevant fields

Course Description:

This course helps to understand and use (abstract) discrete structures and advance algebraic structure that are backbones of computer science. In particular, this course is meant to introduce logic, proofs, sets, relations, functions, counting, recurrence relation and graphs, with an emphasis on applications in computer science.

Course Content:

Module I: Combinatorics

Diagonalization and Pigeonhole Principle, Multinomial theorem, principle of inclusion exclusion; Recurrence relations- classification, summation method, extension to asymptotic solutions from solutions for subsequences; Linear homogeneous relations, characteristic root method, general solution for distinct and repeated roots, non-homogeneous relations and examples, generating functions and their application to linear homogeneous recurrence relations, non-linear recurrence relations, exponential generating functions, Polya theory of counting

Module II:

Lattice: Relation, Poset, Hasse diagram, Lattice as Poset Properties of lattices, Lattice as an algebraic system, Duality.

Boolean Algebra: Definition and properties, Boolean Expression and Boolean Function, Identities of Boolean Algebra, Duality

Module III:

Logic: propositions and connectives, syntax, semantics, truth assignments and truth tables, validity and satisfiability, tautology; adequate set of connectives; Equivalence and normal forms; Compactness and resolution; Formal reducibility - natural deduction system and axiom system; Soundness and completeness. Introduction to Predicate Calculus: Syntax of first order language; Semantics: structures and interpretation; Formal deductibility; First order theory, models of a first order theory (definition only), validity, soundness, completeness, compactness (statement only), outline of resolution principle

Module IV:

Graph Theory: Graphs and digraphs, complement, isomorphism, connectedness and reachability, adjacency matrix, Eulerian paths and circuits in graphs and digraphs, Hamiltonian paths and circuits in graphs and tournaments, trees; Minimum spanning tree, rooted trees and binary trees, planar graphs, Euler's formula, statement of Kuratowski's theorem, dual of a planer graph, independence number and clique number, chromatic number, statement of Four-color theorem, dominating sets and covering sets

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. Kenneth H. Rosen, Discrete Mathematics and its Applications, Tata McGraw – Hill.

T2. C L Liu and D P Mohapatra, Elements of Discrete Mathematics A Computer Oriented Approach, 3rd Edition by, Tata McGraw – Hill.

T3. Susanna S. Epp, Discrete Mathematics with Applications,4th edition, Wadsworth Publishing Co Inc.

Reference Books

R1. J.P. Tremblay and R. Manohar, Discrete Mathematical Structure and It’s Application to Computer Science”, TMG Edition, Tata McGraw- Hill.

R2. Schaum’s Outlines Series, Seymour Lipschutz, Marc Lipson, Discrete Mathematics, Tata McGraw - Hill.

R3. Norman L. Biggs, Discrete Mathematics, 2nd Edition, Oxford University Press.

Course Title	**Applied Statistics**
Course Code	**MTH308**
Credit	**4**
Contact Hours (L-T-P)	**3-0-2**
Course Type	**Hybrid**

Course Objectives:

The objectives of this course are as follows:

- To teach the concepts of trend and forecasting
- To guide the students with the concepts of theory and uses of index numbers
- To give the students a perspective to the various tools useful for process and quality control
- Be acquainted with the interdisciplinary nature of demography, and population studies

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Define several statistical terms used in industry

CO2: Explain the underlying mathematical concepts of different statistical methods

CO3: Apply statistical methods for analyzing different types of data sets

CO4: Analyze complex real-life problems with the help of different statistical tools and techniques

Course Description:

The course is designed to make the students familiar with the applied statistical and forecasting techniques. The focus of this paper is to enable the students to apply relevant tools in forecasting, quality control, economy, and population studies. As a part of the curriculum, students will be exposed to relevant tools to be applied in real life situations. At the end students are expected to identify the methods and tools to be used for real life economic, business, climate, industrial, and demographic data analysis.

Course Content:

Module I:

Time Series data, Characteristics, Illustrations, Different models - merits and demerits, Measurement of Trend by method of free-hand curve, method of Moving Averages and method of least squares (linear, quadratic and modified exponential), Measurement of Seasonal Variations by methods of Ratio to Moving Average and Ratio to Trend

Module II:

Index Numbers**,** types, Construction of Index Numbers of prices and quantities, Paasche, Laspeyres and Fisher indices, Link and changes of base periods, Consumer Price Index Number, Uses and limitations of Index Numbers

Module III:

Introduction to Demographic Methods, measurement of population, Rates and Ratios of Vital Events; Measurement of Mortality: CDR, SDR (w.r.t. Age and sex), STDR, IMR; Life (Mortality) tables; Measurement of Fertility and Reproduction: CBR, GFR, SFR, TFR; Measurement of Population Growth: GRR, NRR

List of experiments (to be executed using Scientific Calculators and/or MS Excel/R)

Sl. No.	Name of the Experiment
1	Plotting a real-life Time Series and detecting various features (Trend, periodic behaviors etc.)
2	Fitting and plotting of mathematical curves: Linear, Quadratic, Exponential and Modified Exponential
3	Fitting of Trend by Moving Average Method.
4	Measurement of Seasonal indices Ratio-to-Moving Average method.
5	Measurement of Seasonal indices Ratio-to-Trend method.
6	Calculation of Price and Quantity Index Numbers.
7	Applications on Chain Index Numbers.
8	Applications on Consumer Price Index Number.
9	To calculate CDR and Age Specific Death Rate for a given set of data.
10	To find Standardized Death Rate by: a. Direct method b. Indirect method.
11	To construct a Complete Life Table.
12	To fill in the missing entries in a Life Table.
13	To calculate CBR, GFR, SFR, TFR for a given set of data.
14	To calculate GRR and NRR for a given set of data and compare them.

Evaluation:

Mode of Evaluation	Theory		Practical	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination	Comprehensive and Continuous Assessment	End Semester Examination
	25%	25%	25%	25%

Text Books:

T1. P. Mukhopadhyay, Applied Statistics, New Central Book Agency, Calcutta, 1999

T2. S C Gupta, and V K Kapoor, Fundamentals of Applied Statistics, 4th Edition, Sultan Chand & Sons, 2008

Reference Books:

R1. A M Gun, M K Gupta, and B Dasgupta, Fundamentals of Statistics, Vol. II, 9th Edition World Press, Kolkata, 2008

R2. S M Ross, Introduction to Probability and Statistics for Engineers and Scientists. Elsevier Academic Press, UK., 2009

Course Title	Mathematical Modelling
Course Code	**MTH401**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course to give students the lessons of solving biological problems mathematically after converting it to a mathematical model

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Define a mathematical modelling with its various properties and limitations

CO2: Demonstrate the nature of dynamical system and their stability

CO3: Apply mathematical tools for different kind of mathematical models

CO4: Choose various numerical solver for solving mathematical model effectively

Course Description:

This course is a modern course of Mathematics. Mathematical Modelling plays an important role between real life problems and mathematics quite effectively. Biological, fluid etc. concepts can be interpreted as a formulation of Mathematical Model. One of the main goals of this course is to study Stability Analysis of a mathematical model. For understanding stability analysis, linear algebra is a must needed pre-requisite. Also, for understanding the nature of the model Ordinary Differential Equation is also very much needed. Students will be encountering many graphs in this course to understand the geometry of the model equations. Along with the tutorial and real-life problems, students will be able to apply the theoretical concepts in life.

Course Content:

Module I: Modelling

Definition and properties, dynamical systems, autonomous and non-autonomous dynamical system, equilibrium point and its classification, linearization, Stability Analysis

Module II:

Continuous Model: Numerical solvers of systems of differential equations: stiff equations, delay differential equations, compartment models: population dynamics, infectious disease models

Discrete Models: Definition, Fixed point, stability analysis, Growth models, Decay models, Drug Delivery Problem, Discrete Prey-Predator models, Density dependent growth models with harvesting

Module III:

Bifurcation: Fixed points, saddle node, pitchfork, trans-critical bifurcation, Hopf bifurcation,
Limit Cycle: Introduction of Limit Cycle, Stable and Unstable limit cycle, existence of closed orbit

Module IV:

Simulation: Monte Carlo Simulation, Random Number generation, Queuing Models, Harbour system, Morning rush hour model, Optimization modelling, Sensitivity analysis

Evaluation:

Mode of Evaluation	Theory and Lab	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. Strogatz, S. Nonlinear Dynamics and Chaos, CRC press
T2. Murrey, J.D., Mathematical Biology I-An introduction, Springer.
T3. Barnes B and Fulford GR, Mathematical Modeling with Case Studies. CRC Press.

Reference Books:

R1. TynMyint-U and LokenathDebnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006.
R2. Mattheij RMM, Rienstra SW, ten ThijeBoonkamp JHM, Partial differential Equations, Modeling Analysis, Computation. SIAM (Dimensional analysis)

Course Title	**Fluid Dynamics**
Course Code	**MTH402**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The primary objective of this course are as follows:

- To introduce students to the principal concepts of fluid motion.
- To make understand the concept of two-dimensional motion and doublets.
- To provide concept of stress and strain and its importance in Newtonian and non-Newtonian fluids flow.
- To discuss the concept of Navier-Stokes equations of motion of a viscous fluid and energy equations
- To make understand about boundary layer concept in fluid dynamics.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Develop the concept of equation of continuities in different coordinate systems and rotational and irrotational motion.

CO2: Acquire the knowledge of Euler equation of motion, Lagrange's equation, Bernoulli's equation and Torricelli's theorem.

CO3: Built the idea of fluid motion in two dimensions, source, sink, vortex motion and Blasius theorem

CO4: Explain the underlying concept of Newtonian and non-Newtonian fluids, Navier-Stokes equations of motion and Boundary layer concept

Course Description:

This course is designed to provide students a fundamental concepts, properties and methods of fluid dynamics. Topics covered in the course include equation of fluid, conservation of mass and momentum, fluid motion in two dimension, and kinematics of deformation of fluid parcel. The course also deals with fluid motion in two dimension and Kinematics of Deformation. This course also includes Navier-Stokes equations and boundary layer theory which help students to understand flow study of fluid in different medium. Moreover, the students will actively participate in discussion, problem solving in class and workout on board. The course will help the students to develop the fundamental knowledge of fluid dynamics, and in addition, to enhance the problem solving, interaction and presentation skills.

Course Content:

Module I: Equation of continuity

Physical properties of fluids, concept of fluids, continuum hypothesis, density, specific weight, specific volume, Kinematics, Equation of continuity: Eulerian and Lagrangian equations, velocity of a fluid particles, material, local and convective derivatives, equation of continuity in Cartesian, cylindrical and spherical coordinates, streamline, streak line, vortex line, rotational and irrotational motion, Kinematics of vorticity and circulation.

Module II: Equations of Motions

Euler's equations of a motion in Cartesian, cylindrical and spherical coordinates, Lamb's hydrodynamical equations, Impulsive action, the energy equation, Lagrange equations and Helmholtz equation of motion, integration of Euler's of motion, Bernoulli's equation, Bernoulli's theorem for steady motion with no velocity potential and conservation field of force, Torricelli's theorem.

Module III: Motion in two dimensions

Stream function, Irrotational motion, Velocity and Complex potentials, Cauchy-Riemann's equations, Sources and Sinks, Doublets; Image system of a simple source and a doublet with respect to a plane and a circle, Milne-Thomson Circle Theorem, Blasius Theorem, Motion of circular cylinders and sphere, Vortex motion.

Module IV: Kinematics of Deformation

Newton's Law of viscosity, Newtonian and non-Newtonian fluids, Theory of stress and Rate of strain, Body and Surface forces, Navier-Stokes equations of motion of a viscous fluid and energy equations, Diffusion of vorticity and equation, Laminar flow of viscous incompressible fluid, Similarity of flows: Reynolds and other numbers, Boundary layer concept, 2-dimensional boundary layer equations, separation phenomena; boundary layer on a semi-infinite plane, Blasius solution, boundary layer thickness.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. F. Charlton, Text book of Fluid Dynamics, CBS Publishers.
T2. M D Raisinghania, Fluid Dynamics, S. Chand

Reference Books

R1. W.H. Besant and A.S. Ramsey, A Treatise on Hydrodynamics, CBS Publishers.
R2. P. K. Kundu, I M Cohen, Fluid Mechanics, Academic press, Elsevier.
R3. E. Rathakrishnan, Fluid Mechanics An introduction, PHI Learning Private Limited, Delhi
R4. R. K. Rathy, An introduction to fluid dynamics, Oxford and IBH Publishing Co. 1976.
R5. L. N. Milne Thomson, Theoretical Hydrodynamics, Macmillan and Co. Ltd.
R6. Z.U.A. Warsi, Fluid Dynamics, CRC Press, 1999.

Course Title	**Advanced Abstract Algebra**
Course Code	**MTH403**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand the advance concept of group theory with its core properties
- To make students understand the advance concept of ring theory with its core properties and various forms.

Course Outcomes:

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

CO1: Explain the concept of cosets, Lagrange's theorem, normal subgroup and quotient groups with some related results.

CO2: Explain the concept of group homomorphism, automorphism, characteristic, commutator subgroups and study some applications.

CO3: Explain the concept of rings, subrings, ideals, and study some properties.

CO4: Extend the concept of group homomorphism to ring homomorphism and study related results.

Course Description:

This course provides the core concept of internal and external direct product of groups, Caley theorem and Sylow theorems with its important results. This course also gives the concept of ring embedding, polynomial ring, irreducibility and other important aspect with its significant results.

Course Content:

Module I:

External direct product and internal direct product of groups, direct product of cyclic groups, semi direct products, classification of all groups of order ≤ 12, group actions, Cayley's theorem, extended Cayley's theorem, Burnside theorem, conjugacy classes, class equation.

Module II:

Cauchy's theorem on finite groups, p-group, Centre of p-groups. Sylow's theorems, some applications of Sylow's theorems, Simple groups, non-simplicity of groups of order $p^n (n > 1)$,

$pq, p^2q, p^2q^2 (p, q$ are primes), determination of all simple groups of order less than equal to 60, nonsimplicity of $A_n (n \geq 5)$.

Module III:

Ring embeddings, Euclidean domain, principal ideal domain, prime elements and irreducible elements, maximal ideals, maximal ideals in some familiar rings of functions, maximal ideals space of a ring, prime ideals, primary ideals.

Module IV:

Polynomial ring and factorization of polynomials over a commutative ring with identity, the division algorithm in $K[x]$ where K is a field, $K[x]$ as Euclidean domain, unique factorization domain (UFD), if D is UFD then so are $D[x]$ and D$[x_1, x_2, \dots, x_n]$. Eisenstein's criterion of irreducibility, Noetherian and Artinian rings.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. Malik, Mordeson and Sen; Fundamentals of Abstract Algebra; McGraw-Hill, 1997.
T2. T. W. Hungerford; Algebra; Springer, 1980.
T3. I. N. Herstein; Topics in Algebra; Wiley Eastern Ltd. New Delhi, 1975

Reference Books

R1. D. S. Dummit, R. M. Foote; Abstract Algebra, 2nd edition; Wiley Student edition.
R2. Michael Artin; Algebra; PHI. (Eastern Economy Edition) Prentice Hall.
R3. S. Lang; Algebra (2nd ed.); Addition-Wesley.

Course Title	Fuzzy Sets and Its Applications
Course Code	MTH404
Credit	4
Contact Hours (L-T-P)	3-1-0
Course Type	Theory

Course Objectives:

The objectives of this course are as follows:

- To acquire the basic notion of fuzzy set theory, several operations of fuzzy sets, fuzzy numbers, arithmetic operations of fuzzy numbers, fuzzy relations.
- To demonstrate the application of fuzzy logic and approximate reasoning to the real-world decision-making problems.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Explain the basic notion of fuzzy set theory, several operations of fuzzy sets and fuzzy relations

CO2: Illustrate the knowledge of fuzzy numbers, arithmetic operations of fuzzy numbers and linguistic variables

CO3: Build the knowledge of fuzzy logic and approximate reasoning

CO4: Analyse the multi-criteria decision-making problem under fuzzy environment.

Course Description:

The notion of a fuzzy set provides a convenient point of departure for the construction of a conceptual frame-work which parallels in many respects the framework used in the case of ordinary sets, but is more general than the crisp set. Fuzzy set theory provides a strict mathematical framework in which vague conceptual phenomena can be precisely and rigorously studied. It deals several aggregation operations of fuzzy sets, fuzzy numbers. Basic concept of fuzzy relations, fuzzy graphs, fuzzy inference rules are also discussed here. Fuzzy logic has been used in numerous applications such as pattern recognition, washing machines, vacuum cleaners, control systems, knowledge-based systems, multi-objective optimization, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, image processing, power engineering, industrial automation, robotics, consumer electronics, etc.

Course Content:

Module I: Fuzzy Set Theory

Crisp sets, Basic concept of Fuzzy sets, Operations on fuzzy sets e.g. union, intersection, complement, t-norms, t-conorms, fuzzy negations. A-cut, support, height and kernel of a fuzzy set, normal fuzzy sets, convex fuzzy sets, Scalar cardinality of a fuzzy set, Representations of fuzzy sets, Extension principle for fuzzy sets and related results.

Module II: Fuzzy Number and Fuzzy Relations

Fuzzy numbers (triangular and trapezoidal fuzzy numbers), Generalized fuzzy numbers, arithmetic operations on fuzzy numbers, Crisp and fuzzy relations, Binary fuzzy relations, Fuzzy equivalence relations, Composition of fuzzy relations, Fuzzy graph.

Module III: Fuzzy logic and Approximate Reasoning

Classical logic, multivalued logic, fuzzy propositions, fuzzy quantifiers, linguistic variables, linguistic hedges, Fuzzy inference, Fuzzy mapping rules and fuzzy implication rules, Fuzzy rule-based models for function approximation, Types of fuzzy rule-based models (Mamdani, TSK and Tsukamoto models), Fuzzy implications and approximate reasoning.

Module IV: Decision making in Fuzzy environment

Multi-criteria decision making, Fuzzy Multi criteria analysis, Decision making using Fuzzy ranking methods, Fuzzy Linear programming (Zimmerman's approach, Werner's approach), Fuzzy goal programming, Fuzzy Multi-objective decision making.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. G. J. Klir, B. Yuan, Fuzzy sets and fuzzy logic, theory and applications, Prentice Hall, 2006.

T2. H. J. Zimmermann, Fuzzy Set Theory and its Applications, Kluwer Academic Publishers, Boston, 1991.

Reference Books:

R1. K. H. Lee, First Course on Fuzzy Theory and Applications, Springer, 2005

R2. D. C. Sanyal, K. Das, Linear Programming and Game Theory, U. N. Dhur and sons Pvt Ltd, 2008

Course Title	**Operations Research**
Course Code	**MTH405**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are:

1. To provide the basic concept of the mathematical model formulation of an optimization problem
2. To help the students to learn different methodology for solving Linear programming and Integer programming problem
3. To enable students to acquire the knowledge of dynamic programming model and methodology
4. To give the students in-depth knowledge of different models related to the inventory problem

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Construct Operations Research (OR) models for real-life problems
CO2: Explain the underlying concepts of different solution procedures used in OR
CO3: Make use of different solution procedures for solving OR models
CO4: Analyse a real-life problem from the experience of case studies in OR

Course Description:

To become a very good decision-maker, one needs to have a strong foundation in Operations Research (OR). To provide that foundation, this course is designed. It covers the topics related to linear programming, Dynamic programming, Network analysis, Replacement model, and Inventory model. All the lectures will be devoted on discussions of basic and advanced topics, focusing on practical implementation of knowledge. Classes will be conducted by lecture as well as power point presentation. The tutorials will familiarize the students with practical problem-solving techniques led by the course coordinator. Students will strongly grab the basic concepts of the subject via exercise and discussions with the coordinator.

Course Content:

Module I:

Introduction to Operations Research: Origin & Development of Operations Research (OR), Basic definition, Scope, Objectives, Phases, and limitations of OR, Mathematical Modeling of Real-Life Problems

Linear Programming Problem: Duality theorems, Dual simplex method, Primal-dual Algorithm, Revised Simplex method, infeasibility, alternate optimum, degeneracy and unbound solutions, Post optimal analysis, Changes in objective function coefficients, Changes in b_i and a_{ij} values, Introduction to Interior-Point Methods. (Ellipsoid Method, Karmarkar's Method)

Module II:

Integer Linear Programming Problem: Integer linear programming, Pure and mixed integer programming, Gomory's cutting plane method, Branch and bound method, E-Bala's Algorithm for 0-1 programming problem, Real life applications of linear Integer Programming Problem, Application of Branch and Bound Algorithms for solving Travelling Salesman problem

Module III:

Dynamic Programming: Introduction, the recursive Equation Approach, Characteristics of Dynamic Programming, Developing Optimal decision Policy, Additive and Multiplicative Separable returns for objective as well as constraints functions. Discrete Dynamic programming Problems, Dynamic Programming Approach for solving Linear Programming Problem, Applications of Dynamic programming

Module IV:

Deterministic Inventory models: Inventory costs. Models with deterministic demand, Inventory model with (a) demand rate uniform and production rate infinite, (b) demand rate non-uniform and production rate infinite, (c) demand rate uniform and production rate finite, Price-break model, Multiple Items Inventory, Inventory models with constraints

Probabilistic Inventory Models: Probabilistic EOQ Model, No-Setup Model (Newsvendor Model), Setup Model

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. G Srinivasan, Operations Research: Principles and Applications, PHI Learning Private Limited, Third Edition, 2017

T2. J K Sharma, Operations Research Theory & Applications, Macmillan India Ltd, Third Edition, 2007

T3. H A Taha, Operations Research-An Introduction, Pearson, 10th edition, 2017

Reference Books

R1. P K Gupta and D S Hira, Operations Research, S. Chand & Co., 2007

R2. S D Sharma, Operations Research: Theory and Applications, 4th edition, Laxmi Publications

R3. Frederick S Hillier and G J Lieberman, Introduction to Operations Research, McGraw-Hill Science

R4. S. S. Rao, Optimization: Theory and Applications, Wiley Eastern.

R5. W. L. Winston, Operation Research: Application and algorithm, Cengage Learning; 4thedition, 2003.

R6. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.

Course Title	**Topology and Metric Space**
Course Code	**MTH406**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand the basic concept of metric space with its various properties
- To make students understand the basic and advance concept of topology with its core properties and various aspects.

Course Outcomes:

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

CO1: Define different notions related to metric space and topological space

CO2: Extend the concept of metric space and related notions to more general topological space

CO3: Develop different countability and separation axioms in topological space

CO4: Formulate sufficient conditions for metrizability of a topological space through the notions of regularity and normality

Course Description:

This course provides basic concepts of metric spaces. Here the analysis of metric spaces have been shown. Few important topics like Banach fixed point theorem is also described here. This course also includes basic and advance concept of point set topology. In this course students can learn the concept of topology along with its various properties like continuity, compactness, connectedness and related theorems. Here they can able to know the concept of Cartesian Product of topological spaces.

Course Content:

Module I: Metric spaces

Definition and examples, some important spaces like l_p , $C[a, b]$. Open and closed balls, neighborhood of a point in a metric space, open set, interior of a set. limit point of a set, closed set, diameter of a set, sequences in metric spaces, Cauchy sequence, complete metric space, Cantor's theorem

Module II:

Subspaces, dense sets, separable spaces, equivalence of two metrics, Continuous mappings, sequential criterion and other characterizations of continuity, Uniform continuity, contraction and weak contraction mapping, Banach fixed point theorem

Module III:

Topological spaces, Definition of topology through open set axioms, Basis for a topology, The order topology, product topology, Subspace topology, Closed sets, countability axioms, limit points, Continuous functions and homeomorphism

Module IV:

Separation axioms, T_o, T_1, T_2, regular, normal and completely normal spaces, their comparison and examples, Uryshon's lemma, Uryshon's metrization theorem, Tietz extension theorem. Compactness and Connectedness in topological spaces

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. J. R. Munkres, Topology, Pearson Education India, 2001.
T2. P. K. Jain and K. Ahmad, Metric Spaces, Narosa Publishing House, New Delhi, 1996.

Reference Books

R1. G.F. Simmons, Topolgy and Modern analysis, Kreiger 2004.
R2. K.D. Joshi, Introduction to General Topology, New Age International, 2002.
R3. B. K. Tyagi, First Course in Metric Spaces, Cambridge University Press.
R4. Satish Shirali and H.Vasudeva, Metric Spaces, Springer.

Course Title	**Classical Mechanics**
Course Code	**MTH407**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To provide a foundation in classical mechanics necessary for further study in science, engineering and technology
- To develop the concept of Lagrangian and Hamiltonian formulations and their applications.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Apply variational principles and Hamilton's principle in different systems

CO2: Explain the kinematics of rigid body motion

CO3: Solve rigid body problems and the Euler equations of motion

CO4: Learn canonical transformations and application of Hamilton-Jacobi theorem

Course Description:

This course provides an in-depth exploration of key concepts in the classical mechanics. Classical mechanics is concerned with the set of physical laws describing the motion of bodies under the influence of a system of forces. It covers the topics include dynamics of particles and rigid bodies, rotating reference frames, conservation laws, gravitational fields and potentials, planetary motion, wave motion, oscillations, Lagrangian and Hamiltonian equations

Course Content:

Module I:

Mechanics of a system of particles, D'Alembert's principle and Lagrange's equations, Velocity-dependent potentials and the dissipation function, Variational principles and Lagrange's equations.

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Module II: The kinematics of rigid body motion

The independent coordinates of a rigid body, Orthogonal transformations, The Euler angles, The Cayley-Klein parameters and related quantities, Euler's theorem on the motion of a rigid body, Finite rotations, Infinitesimal rotations, Rate of change of a vector, The Coriolis force.

Module III:

The rigid body equations of motion: Angular momentum and kinetic energy of motion about a point, Tensors and dyadic, the inertia tensor and the moment of inertia, The eigenvalues of the inertia tensor and the principal axis transformation, Methods of solving rigid body problems and the Euler equations of motion

The Hamilton equations of motion: Legendre transformations and the Hamilton equations of motion, Cyclic coordinates and conservation theorems, Routh's procedure and oscillations about steady motion, The Hamiltonian formulation of relativistic mechanics, The principle of least action

Module IV:

Canonical transformations: Poisson brackets and other canonical invariants, Equations of motion, infinitesimal canonical transformations and conservation theorems in the Poisson bracket formulation, The angular momentum Poisson bracket relations, Symmetry groups of mechanical systems, Liouville's theorem

Hamilton-Jacobi theory: The Hamilton-Jacobi equation for Hamilton's principal function, Separation of variables in the Hamilton-Jacobi equation

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. Herbert Goldstein, Classical mechanics, Second Edition, Addison-Wesley Publishing Company.

Reference Books:

R1. K.C. Gupta, Classical Mechanics, New Age Int. Pub

R2. N. C. Rana and P. S. Jog, Classical Mechanics, Tata McGraw-Hill

Course Title	**Research Methodology**
Course Code	**MTH450**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives

To equip students with a comprehensive understanding of research methodologies to formulate effective research questions and objectives. It emphasizes the improvement of scientific writing and communication skills for creating persuasive research papers, proposals, and presentations. Students will explore ethical considerations, including the avoidance of scientific misconduct and the promotion of responsible conduct, to maintain integrity in research. Additionally, the course will focus on effectively utilizing indexing and citation databases and mastering tools for scientific writing and reference management to ensure accurate documentation of sources.

Course Outcomes

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

CO1. Identify the nature and significance of several types of research, objectives for doing research.

CO2. Develop skills in scientific writing and present research effectively.

CO3. Apply ethical principles in research, ensuring responsible conduct and treatment of human subjects.

CO4. Select the appropriate research quality journal based several criteria for publishing the research.

Course Description:

This course on Research Methodology covers essential concepts in research, including various approaches, ethical considerations, and the formulation of research questions. Students will learn to structure research papers, improve scientific writing, and deliver presentations. The course also addresses ethics in research, scientific misconduct, and explores indexing databases, research metrics, and tools like LaTeX for effective writing.

Course Content:

Module I: Introduction to Research Methodology:

Understanding the nature and significance of research, Different approaches to research - Basic, Applied, Interdisciplinary, Multidisciplinary, difference between quantitative and qualitative research, identifying research objectives and formulating research questions, exploring ethical considerations and responsible conduct of research.

Module II: Research communication and scientific writing:
Structuring and organizing research papers and reports, enhancing scientific writing skills for research articles and proposals, preparing effective research presentations (oral and poster), developing communication skills for scientific conferences and collaborations

Module III: Ethics in research:
Definition, moral philosophy, scientific conduct, intellectual honesty, and research integrity, scientific misconducts, falsification, fabrication and plagiarism, Redundant publications, duplication, overlapping publications, and salami slicing.

Module IV:
Databases, Indexing databases, Citation databases: Web of Science, Scopus, etc. Research Metrics, Impact factor, SNIP, SJR, IPP, Cite Score, h-index, g-index, i10 index, altmetrics. Scientific writing, References and citations (Medley, Jabref), plagiarism, intellectual property rights, copyrights, preprints (arXiv), open access.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. Research Design and Methods – A Process Approach, Bordens, K. S. and Abbott, B. B., Eighth Edition, McGraw-Hill, 2011.

T2. Research Methodology – Methods and Techniques, C. R. Kothari, Second Edition, New Age International Publishers, 2004.

T3. Philosophy of Science, Bird A, Routledge, 2006.

T4. Ethics in Competitive Research: Do not get scooped; do not get plagiarized, Praveen Chaddah, 2018.

T5. Research Methodology and Scientific Writing, C. George Thomas, Springer Nature, 2015.

Reference Books

R1. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar

R2. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches; John W. Creswell and J. David Creswell

R3. Writing for Science, Robert Goldbort

R4. Ethics in Research: Continuum Research Methods, Margaret Adolphus

R5. Scientific Papers and Presentations, Davis, M., Davis K., and Dunagan M., Third Edition, Elsevier

R1. Research Methods for Science, Michael P. Marder, Cambridge University Press, 2011

Course Title	**Computational Matrix Theory**
Course Code	**MTH408**
Credit	**4**
Contact Hours (L-T-P)	**3-0-2**
Course Type	**Hybrid**

Course Objectives:

The objectives of this course are as follows:

- The course gives classical algorithms to solve linear system of equations by different methods, and to find the eigenvalues of a matrix.
- The course details the mathematical theory behind numerical algorithms for solving a linear system and eigenvalue problems.
- Focus on iterative methods suitable for large-scale problems arising in real-life models

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Explain the stability of algorithms, algorithmic complexity, and conditioning of problem

CO2: Demonstrate different types of matrix factorization techniques and apply them for solving system of linear equations

CO3: Develop an idea to compute eigen values and eigen vectors of a matrix

CO4: Apply Krylov subspace methods for solving large and sparse system of equations

Course Description:

Linear Algebra is one of the most widely used topics in the mathematical sciences. At under-graduate level the standard techniques for basic linear algebra tasks including the solution of linear systems, finding eigenvalues/eigenvectors and orthogonalization of bases are taught. However, these techniques are usually computationally too intensive to be used for the large matrices encountered in practical applications. Numerical linear algebra will introduce students to these practical issues and will present, analyses, and apply algorithms for these tasks which are reliable and computationally efficient.

Numerical linear algebra lab is companion course to this course in which a significant lab work using MATLAB is to be done. The theoretical material is assessed in a closed book examination.

Course Content:

Module I: Stability and Conditioning [8 Lecture hours]

Floating point arithmetic, Stability of algorithms, Conditioning of a problem, Perturbation analysis, algorithmic complexity.

Module II: Matrix decomposition and solution of system of equations [14 Lecture hours]
LU factorization using Gaussian elimination, Gaussian elimination with partial pivoting, LU factorization method for solving system of equations $Ax = b,$ Cholesky decomposition - sensitivity analysis, QR factorization, Solution of $Ax = b$ Using QR Factorization, Projections Using QR Factorization, Singular value decomposition (SVD), Least-Squares Solutions to Linear Systems, normal equations, Rank deficient least-squares problems, Sensitivity analysis of least-squares problems.

Module III: Computing eigenvalues and eigenvectors [15 Lecture hours]
Localization of the Maximal Eigenvalue, matrices in superdiagonal block form, eigenvalues and eigenvectors of a few classes of nonnegative matrices. Perturbation of eigenspaces, a perturbation bound for eigenvalues. Numerical methods to compute eigenvalues and eigenvectors: the Power Method, Jacobi Method, the Inverse Iteration, and the Rayleigh Quotient Iteration.

Module IV: Applications [8 Lecture hours]
Krylov Subspace Methods for Linear Systems, Lanczos, Arnoldi, GMRES, Conjugate Gradient, and QMR.

List of experiments. Write and execute MATLAB-code for the following programs:

1. LU factorization method
2. Cholesky decomposition method
3. QR factorization method
4. SVD
5. Power method
6. Jacobi method
7. Inverse Iteration method
8. Rayleigh Quotient Iteration method
9. Conjugate Gradient method
10. Arnoldi Process method
11. GMRES
12. Lanczos Method

Evaluation:

Mode of Evaluation	Theory		Practical	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination	Comprehensive and Continuous Assessment	End Semester Examination
	25%	25%	25%	25%

Text Books:

T1. James W. Demmel, Applied Numerical Linear Algebra, Publisher: Society for Industrial and Applied Mathematics, Year: 1997

T2. Biswa Nath Datta, Numerical Linear Algebra and applications, 2nd Edition, Publisher: Society for Industrial and Applied Mathematics, Year: 2010

T3. Alan J. Laub, Computational Matrix Analysis, SIAM, 2012

T4. Rajendra Bhatia, Matrix Analysis, Springer.

Reference Books:

R1. Henryk Minc, Nonnegative Matrices. New York: Wiley, 1988.

R2. G. H. Golub & C. F. Van Loan, Matrix Computations, 3rd Ed., Publisher: John Hopkins University Press, Year: 1996

R3. N. Trefethen & David Bau III, Numerical Linear Algebra, Publisher: Society for Industrial and Applied Mathematics, Year: 1997

R4. Richard A. Brualdi and Herbert J. Ryser, Combinatorial Matrix Theory. Cambridge University Press.

R5. Roger A. Horn and Charles R. Johnson, Topics in Matrix Analysis. Cambridge University Press.

Course Title	**Stochastic Methods in Industry**
Course Code	**MTH451**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- Gain insights into stochastic processes and apply queueing models like M/M/1 and M/M/c to evaluate system performance.
- Understand the core concepts of reliability and develop models for system reliability in different configurations.
- Master quality control techniques and implement statistical tools for maintaining industrial quality standards.
- Learn simulation methodologies and apply Monte Carlo techniques for analyzing and optimizing complex systems.

Course Outcomes:

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

CO1: Define different terms from stochastic processes which are used in industry

CO2: Explain different types of statistic-based methodologies

CO3: Make use of stochastic methods for measuring the performance of a system

CO4: Analyze and control the performance of a system with the help of Simulation, SQC, Reliability etc.

Course Description:

This course comprehensively explains queueing theory, reliability theory, statistical quality control, and simulation techniques. Students will explore stochastic processes, performance analysis of queueing systems, reliability models, quality control methods, and simulation applications to complex systems, equipping them with essential tools for decision-making and system optimization.

Course Content:

Module I: Queueing Theory

Introduction to Stochastic Processes, Discrete-Time Markov Chains, Classification of States and Chains, Continuous-Time Markov Chains, Poisson Process, General concepts of a queueing system, Characteristics of a queueing system, the birth-death Process in Queueing, Performance measures of a queueing system, Little's formula, Queues with finite waiting room, Queues with impatient customer (Balking and reneging), Markovian queues- M/M/1 with finite and infinite waiting space, M/M/c with finite and infinite waiting space

Module II: Reliability Theory

Basics of reliability, hazard rate and mean time before failure (MTBF), failure time distribution functions, Reliability of series, parallel, standby, k out of n, Series-Parallel, Parallel-series configurations and bridge structures, Reliability and Availability models, Time-dependent and independent Replacement policies

Module III: Statistical Quality Control

Overview of quality, History of quality, Competitive Advantage, Industrial Perspective, Total Quality System, Taguchi Loss function concept, Juran's Trilogy, Statistical Quality Control, Statistical Process Control, Introduction to control charts, their construction and use, Acceptance sampling plans, six sigma- features, Introduction to ISO-9000 quality management systems and emerging standards

Module IV: Simulation

Simulation Concepts- Generation of uniform variates, generation of Variates from Standard distributions; Monte Carlo Calculus and variance reduction techniques, Analogue simulation of systems

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. William W. Hines, Douglas C. Montgomery, David M. Goldsman, Connie M. Borror, Probability and Statistics in Engineering, John Wiley & Sons, Inc., Fourth Edition, 2003

T2. K.S. Trivedi: Probability and Statistics with Reliability, Queuing and Computer Science Applications, Second Edition, Wiley, 2013

T3. J K Sharma, Operations Research Theory & Applications, Macmillan India Ltd, Third Edition, 2007

T4. H A Taha, Operations Research An Introduction, Pearson, 10th edition, 2017.

Reference Books:

R1. Donald Gross, John F. Shortle, James M. Thompson, Carl M. Harris, Fundamentals of Queueing Theory, Fourth Edition, 2008

R2. J. Medhi: Stochastic Models in Queueing Theory, Second Edition, 2002

R3. Srinath. L. S., Reliability Engineering, East West Press, New Delhi, 2005

Course Title	**Physical Oceanography**
Course Code	**MTH452**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are

- To introduce the students with different branches and importance of oceanography
- To make students understood the different physical processes in the ocean
- To get students familiar with various instruments and methods used in ocean observation

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Understand the basics and gain fundamental concepts related to the ocean and ocean science

CO2: Understand and explain different properties of ocean water and the oceanic heat budget

CO3: Explain different oceanic processes and physics behind them

CO4: Identify different instrument being used in ocean observations

Course Description:

This course introduces the students to the notion of the oceanography and explores the fundamental principles governing the physical processes of the ocean. Students will learn different aspects and importance of ocean and the oceanography. They will learn about properties of seawater and investigate ocean circulation, waves, tides, and the interactions between the ocean and atmosphere. Through this course, the students will get familiar with the various types of instruments and methods used in ocean observation. By the end of the course, students will develop critical thinking skills and the ability to analyze oceanographic processes and preparing them for further studies or careers in marine science, environmental policy, and related fields.

Course Content:

Module I:

Basics of oceanography: The ocean and oceanography; importance of oceanography; branches of oceanography; dimension, shape and structure of ocean; physical and dynamical properties of ocean water – pressure, temperature, salinity, density, nutrients; oceanic processes – circulation, waves, tides, upwelling, downwelling

Ocean sciences and the scope of physical oceanography: World Ocean, origin, dimension, shape and structure of ocean, History of oceanography, Challenges, Branches of oceanography

Module II:

Seawater and its properties: Temperature, Salinity and Conductivity, Depth, Pressure, Density, Pressure effects on temperature and density. TS Diagrams, water types, and water masses. Sound in the sea, Sound channels, Light in the sea, Colour of seawater. Temperature, Salinity, and density distributions. Transparency of seawater, Thermohaline structure, Stratification.

Heat budget of the oceans: Heat budget terms, Short and Long wave radiation, Evaporation, Heat conduction.

Module III:

Oceanic Processes: Waves, Tides, Coriolis effect, Ekman transport, upwelling, downwelling, Circulation – thermohaline and wind-driven circulation (geostrophic current), Mixing, Estuarine processes

Module IV:

Oceanographic Instruments: Temperature measurements; Protected and unprotected reversing thermometers, MBT, XBT, XCTD, ARGOS, Drifters, Sea Gliders, CTD. Current measurements: Lagrangian and Eulerian methods with examples, Aandhera current meter, ADCP, Position fixing at sea, GPS. Wave and Tide measurements, Research vessels: O.R.V. Sagar Kanya, R.V. Sagar Sampada.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. Descriptive physical oceanography by G.L. Pickard and W.J. Emery

T2. The Ocean: Their Physics, Chemistry and biology, 1962 - Sverdrup, H.U., Johnson, M.W. and Flemming, R.H., Asia Publ. House, New Delhi.

T3. Principles of physical oceanography, 1966 - pierson, W.J. and Newmann, G.S., Prentice Hall, Inc., New Jersey, U.S.A.

Reference Books:

R1. Descriptive physical oceanography by M.P.M. Reddy

R2. Introduction to Physical Oceanography by Bob Stewart, Texas A&M University

Course Title	**Mathematical Modelling in Bio-Sciences**
Course Code	**MTH453**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To give students the lessons of solving biological problems mathematically after converting it to a mathematical model
- To describe a quantitative life science problem, the mathematical approach, solution, and analysis of results.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Solve mathematical problems using analytical methods

CO2: Solve mathematical problems using computational methods

CO3: Classify the behavior of a given physical system based on the analysis of its mathematical model

CO4: Interpret real-world problems mathematically and analyze those models using their mastery of the core concepts

Course Description:

This course is intended to the application of quantitative mathematical methods to the bio sciences. Through specific biological examples, the course will introduce a variety of mathematical modelling approaches and computational programming approaches. Students will be exposed to mathematical modelling techniques commonly used in the life sciences, their implementation using a variety of software systems, and standard procedures for analysis and validation. A non-exhaustive list of the mathematical approaches includes: function approximation, differential and difference equations, combinatorics, stochastic calculus, algebraic-integro-differential systems, linear approximation, model reduction, deep neural networks. Students will be encountering many graphs in this course to understand the geometry of the model equations. Along with the tutorial and real-life problems, students will be able to apply the theoretical concepts in life.

Course Content:

Module I: Dynamical Systems

Basic steps of mathematical modeling, its needs, types of models, limitations, elementary ideas of dynamical systems, autonomous dynamical systems in the plane-linear theory, equilibrium point, node, saddle point, focus, centre and limit-cycle ideas with simple illustrations and figures, linearization of non-linear plane autonomous systems, mathematical modeling in the biological environment.

Module II: Monte Carlo Simulation Modeling

Simulating deterministic behavior (area under a curve, volume under a surface), Generating Random Numbers: middle square method, linear congruence, Queuing Models: harbor system, morning rush hour, Overview of optimization modeling, Linear Programming Model: geometric solution algebraic solution, simplex method, sensitivity analysis.

Module III: Differential equation-based models

Numerical solvers of systems of differential equations: stiff equations, delay differential equations, compartment models: population dynamics, infectious disease models.

Module IV:

Spatial Models: One species model with diffusion, two species model with diffusion, Conditions for diffusive instability, spreading colonies of microorganisms, Blood flow in circulatory system, travelling wave solutions, Spread of genes in a population

Discrete Models: Overview of difference equations, steady state solution and linear stability analysis, Introduction to Discrete Models, Linear Models, Growth models, Decay models, Drug Delivery Problem, Discrete Prey-Predator models, Density dependent growth models with harvesting.

Evaluation:

Mode of Evaluation	Theory and Lab	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. Frank R. Giordano, Maurice D. Weir and William P. Fox, A First Course in Mathematical Modeling, Thomson Learning, London and New York, 2003.

T2. Barnes B and Fulford GR, Mathematical Modeling with Case Studies. CRC Press.

Reference Books

R1. TynMyint-U and LokenathDebnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006.

R2. Mattheij RMM, Rienstra SW, ten ThijeBoonkamp JHM, Partial differential Equations, Modeling Analysis, Computation. SIAM (Dimensional analysis).

R3. Yang X.S,An Introduction to Computational Engineering with Matlab. CISP (Cellular automata).

Course Title	**Measure Theory**
Course Code	**MTH454**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand the basic concept of measure theory with its core properties
- To make students understand the basic concept of Lebesgue integral with its core properties
- To make students understand the basic concept of absolutely continuous function with its properties

Course Outcomes:

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

CO1: Define fundamental concepts of measurable sets

CO2: Explain the underlying concepts of Lebesgue measurable function

CO3: Develop the problem-solving ability using the properties of Lebesgue integral

CO4: Utilize the concept of absolutely continuous function to tackle real life problems.

Course Description:

This course contains the basic concept of Measure theory. Lebesgue integral and related concepts have been discussed here. Measurable function with its various properties discussed here. Detail concept of absolutely continuous function with its properties discussed here.

Course Content:

Module I: Measurable Sets

Lebesgue outer measure, Lebesgue measurable sets, Borel sets, approximation of Lebesgue measurable sets by topologically nice sets, non-measurable sets, Cantor sets

Module II: Measurable Functions

Lebesgue measurable functions, algebra of measurable functions, limit of sequence of measurable functions, simple functions, measurable functions as point-wise limit of sequence of simple functions, approximation of Lebesgue measurable functions by continuous functions, Luzin’s theorem

Module III: Lebesgue integral

Lebesgue integral, monotone convergence theorem, Fatou's lemma, dominated convergence theorem, properties of Lebesgue integrable functions, relation between Lebesgue integral and Riemann integral

Module IV: Absolutely Continuous Function

Absolutely continuous functions, properties of absolutely continuous functions, characterization of absolutely continuous functions in the context of Lebesgue integration (Fundamental theorem of Lebesgue integral)

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. G. De. Barra; Measure Theory & Integration; Wiley Eastern Limited, 1987.

T2. Inder Kumar Rana; An Introduction to measure & Integration; Narosa Publishing House, 1997.

T3. P. K. Jain & V. P. Gupta; Lebesgue Measure & Integration; New Age International(P) limited Publishing Co, New Delhi, 1986.

Reference Books

R1. P. R. Halmos, Measure Theory; D.Van Nostrand Co. inc. London, 1962.

R2. Charles Schwartz, Measure, Integration & Function Spaces; World Scientific, 1994.

R3. T. M. Apostol, Mathematical Analysis; Addison-Wesley Publishing Co. 1957.

Course Title	**Optimization**
Course Code	**MTH455**
Credit	**4**
Contact Hours (L-T-P)	**3-0-2**
Course Type	**Hybrid**

Course Objectives:

The objectives of this course are as follows:

- To develop the concept of unconstrained optimization problems and build up the knowledge of local and global optima
- Able to demonstrate the concept of descent methods, conjugate direction and Quasi-Newton's methods
- To acquire the knowledge of constrained optimization problems and duality

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Choose appropriate techniques for solving univariate and multivariate optimization problems

CO2: Find solutions of nonlinear equations with single variable by using Dichotomous search, Fibonacci search, Golden Section, Newton-Raphson method, Bisection method

CO3: Explain the theoretical aspects and solution techniques of nonlinear optimization, viz., descent methods, conjugate direction and Quasi-Newton's methods

CO4: Build the knowledge of constrained optimization problem and quadratic programming problem.

Course Description:

This course provides a comprehensive overview of introduction to unconstrained and constrained optimizations. It focuses on various optimization techniques and their applications in different settings. Students will develop a deep understanding of optimization principles and strategies for solving complex real-world problems through this course. Throughout the course, practical applications and case studies related to several search techniques will be discussed to provide real-world examples of how these optimization techniques are used in decision-making processes. Students will also have the opportunity to work on assignments and projects to apply the concepts learned in the course.

Course Content:

Module I: Unconstrained optimization for single variable

Introduction to Optimization, Convex and Concave Functions, Minimization and Maximization of Convex Functions, Zero-Order Conditions.

One dimensional unconstrained optimization: Dichotomous search, Fibonacci Search Method, Golden Section Method, Newton-Raphson Method, Bisection Method, Secant Method.

Module II: Unconstrained optimization for multivariate problem

Random search method, Grid search method, Hooke-Jeeves pattern search method, Powell's method, Cauchy's Steepest Descent Method, Conjugate gradient Method, Newton's method, Marquardt's Method, Quasi-Newton method.

Module III: Constrained Optimization

Lagrange Multiplier method, KKT condition, Quadratic programming, Wolfe's modified simplex method, Fritz John optimality condition, interior-point method, penalty method, Barrier method, Portfolio optimization.

Practical/Lab to be performed on a computer using MATLAB/Python programming:

1. Solution of unconstrained optimization problem by Dichotomous search
2. Problem solving by Fibonacci Search Method,
3. Problem solving by Golden Section Method,
4. Solution of unconstrained optimization problem by Bisection Method,
5. Solution of unconstrained optimization problem by Newton-Raphson Method
6. Implement Hooke-Jeeves pattern search method
7. Implement Powell's method
8. Problem based on Cauchy's Steepest Descent Method
9. Problem based on Conjugate gradient Method
10. Problem solving by Newton's method,
11. Problem based on Quasi-Newton method
12. Solution of Quadratic programming problem

Evaluation:

Mode of Evaluation	Theory		Practical	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination	Comprehensive and Continuous Assessment	End Semester Examination
	25%	25%	25%	25%

Text Books

T1. Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, S. Chand and Co. Pvt. Ltd.

T2. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.

T3. D. P. Bertsekas, Nonlinear Programing, 3rd edition, Athena Scientific

Reference Books

R1. Hamdy A. Taha, Operations Research: An Introduction, 8th Ed., Prentice Hall India, 2006.

R2. G.Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

R3. D. Bertsimas, J. N. Tsitsiklis, Introduction to linear optimization, Athena Scientific, 1997.

Course Title	**Ocean Dynamics and Modeling**
Course Code	**MTH456**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are

- To understand fundamental principles of ocean dynamics.
- To analyze physical processes affecting ocean circulation.
- To develop skills in numerical modelling and simulation of ocean systems.
- To apply knowledge to real-world oceanographic problems.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Understand the physical laws and forces behind the oceanic processes

CO2: Explain the equations of motion in ocean

CO3: Explain physical and dynamical properties of waves and tides

CO4: Identify different instrument being used in ocean observations

Course Description:

This course provides an in-depth exploration of the physical processes governing ocean dynamics and introduces various modelling techniques used to simulate oceanic systems. Topics include geophysical fluid dynamics, wave and tides, circulation pattern, numerical modeling approaches, and application of ocean models in to simulate real-world phenomena.

Course Content:

Module I: Fundamentals of Ocean Dynamics

Basic physical laws used in oceanography, forces acting in ocean – gravity, pressure, wind stress, Coriolis force, frictional force; classification of ocean motions; ocean mixing, equation of continuity, stability and stratification, double diffusion, equations of motion, hydrostatic balance and geostrophic flow

Module II: Ocean Circulation

Surface currents, deep water currents, and thermohaline circulation, current without friction, geostrophic currents, impact of wind and Coriolis effect, wind driven currents, west ward intensification of currents, major current system in the world ocean, seasonal currents in North Indian Ocean

Module III: Waves, Tides, and Coastal Processes

Wave generation and propagation, wave characteristics, energy transfer, Kelvin and Rossby waves, tidal cycles and forces, tidal currents, impact of tides on coastal currents, coastal processes

Module IV: Fundamentals of Ocean Modelling: Key concepts in numerical methods, overview of different types of ocean models, gridding, discretization, forcing, initial and boundary conditions, numerical stability, community models, case studies, model validation, data assimilation in ocean modelling, coupled ocean-atmosphere modeling, real-world applications.

Evaluation:

<table>
<tr><td>Mode of Evaluation</td><td colspan="2">Theory</td></tr>
<tr><td rowspan="2">Weightage</td><td>Comprehensive and Continuous Assessment</td><td>End Semester Examination</td></tr>
<tr><td>50%</td><td>50%</td></tr>
</table>

Text Books:

T1. Stephen Pond and George L. Pickard., Introductory Dynamical Oceanography, Second Edition, Pergamon Press Ltd., 1983

T2. Lynne D. Talley, George L. Pickard, William J. Emery, James H. Swift., Descriptive Physical Oceanography: An Introduction, Academic Press.

T3. Pond S. and Bryan, Numerical models for Ocean Circulation

Reference Books:

R1. M.P.M. Reddy, Descriptive Physical Oceanography.

R2. Bob Stewart, Introduction to Physical Oceanography, Texas A&M University

Course Title	**Advanced Differential Equation**
Course Code	**MTH457**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objective of this course are as follows:

- To provide students the basic concept of series solutions of some special differential equations
- To aware students related to special functions involve in the solution of second order differential equations.
- To provide skill to solve Strum-Liouville problem and orthogonality of special functions.

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Develop the concept of series solution of some special differential equation.

CO2: Acquire the knowledge of different properties of some special functions such as Legendre function, Bessel's function, Hermite function and Laguerre function.

CO3: Built the idea of hypergeometric function, some important theorem and Contiguous relationship for confluent hypergeometric function.

CO4: Explain the underlying concept of orthogonal sets of functions and Strum-Liouville problem, Gram-Schmidt process, Orthogonality some special functions.

Course Description:

This course is deals with series solutions of different types of special types of higher order ordinary differential equation. This course also deals with Orthogonal sets of functions and Strum-Liouville problem. After the successful completion of this course student may able to solve some special types of higher order ordinary differential equation and by suitable method.

Course Content:

Module I: Legendre's Polynomials

Review of series solution. Legendre's equation and its solution, Legendre function of the first kind, generating functions, Trigonometric series, Orthogonal properties, recurrence relations, Christoffel's expansion, Rodrigue's formula, Associated Legendre functions, Legendre functions of the second kind.

Module II: Bessel’s and Hermite polynomials

Bessel’s equations and its solution, Bessel’s function of the first and second kind of order *n*, orthogonality property, Bessel’s function of zeroth order, Recurrence relations, generating function, Hermite polynomials and its polynomial of order *n*, Generating function, Rodrigues formula for Hermite polynomials, Orthogonality properties, Recurrence relations with related problems

Module III: Laguerre polynomials and Hypergeometric function

Laguerre equation and its solution, generating function for Laguerre polynomials, Orthogonal properties, Pochhammer symbol, Hypergeometric function, Gauss’s hypergeometric equation and its solution, Gauss theorem, Vandermonde’s theorem, Kummer’s theorem, Contiguous hypergeometric functions and Contiguous relationship for confluent hypergeometric function.

Module IV: Orthogonal and Strum-Liouville problem

Orthogonal sets of functions and Strum-Liouville problem: Introduction, Orthogonal set of functions with respect to a weight function, Gram-Schmidt process of orthonormalization, Strum-Liouville problem, eigen function and eigen values, orthogonality of the Eigen functions, Orthogonality of Legendre polynomials and Bessel functions.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. M.D. Raisinghania, Advanced Differential equations, S. Chand Limited, 1995

T2. V Sundarapandian, Ordinary and Partial Differential Equations (With Laplace transforms, Fourier series and applications), TMH Educational Pvt Limited, 2013.

Reference Books

R1. M.D. Raisinghania; Ordinary and Partial Differential equations, S. Chand.

R2. J. Sinha Roy and S. Padhy, A Course on Ordinary and Partial Differential Equations, Kalyani Publishers, New Delhi, Ludhiana

R3. William E. Boyce and Richard C. Di-Prima, Elementary Differential Equations and Boundary Value Problems, 7th edition, John Wiley & Sons, Inc.

Course Title	**Functional Analysis**
Course Code	**MTH458**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The objectives of this course are as follows:

- To make students understand the basic concept of Normed linear space and Banach space with its core properties
- To make students understand the basic concept of bounded linear functional with its core properties
- To make students understand the idea of Hahn-Banach Theorem and its various applications.

Course Outcomes:

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

CO1: Define different notions related to normed linear spaces, inner product spaces.

CO2: Explain bounded linear operators, bounded linear functionals between two spaces through operator norms and study some of its properties.

CO3: Apply Hahn-Banach theorem, Uniform boundedness principle, open and closed graph theorem to different problems in functional analysis.

CO4: Analyze strong and weak convergence in normed spaces and study the dimension of the underlying space.

CO5: Build the notion of separable and reflexive spaces and study related properties.

Course Description:

This course contains the basic concept of Normed Linear Space and Banach Space. Bounded linear functional and related concepts have been discussed here. Various forms of Hahn-Banach theorems and its applications discussed here.

Course Content:

Module I:

Review of Normed linear spaces, Banach spaces and examples, incomplete normed spaces, completion of normed linear spaces, some properties of Banach spaces, Open and Closed spheres in normed spaces, Quotient spaces of normed linear spaces, comparable norms, Inner product space, best approximation theorem and projection theorem, Bessel's inequality, Gram-Schmidt orthonormalization process.

Module II:
Characterization of finite dimensional normed spaces, bounded linear maps between two normed linear spaces, Examples, linear map on finite dimensional spaces, finite dimensional spaces are isomorphic, operator norm, the space of all bounded linear maps between two normed spaces.

Module III:
Bounded linear functionals, their norms and properties, dual spaces and their examples, Reflexive and separable normed spaces, Properties of reflexive normed spaces, weak convergence and strong convergence, geometric properties of normed spaces, invertibility of an operator, spectrum of an operator.

Module IV:
Hahn-Banach theorems: Geometric and extension forms and their applications, three main theorems on Banach spaces: Uniform boundedness principle, divergence of Fourier series, open mapping theorem, closed graph theorem.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. B.V. Limaye, Functional Analysis, New Age International, 1996.
T2. E. Kreyszig, Introduction to Functional Analysis with Applications, Wiley, 1989.

Reference Books

R4. M.T. Nair, Functional Analysis-a first course, Prentice Hall of India, 2010.
R5. G.F. Simmons, Topology and Modern analysis, Kreiger, 2004.
R6. S. Ponnusamy, Foundations of Functional Analysis, Narosa publishing house, 2008.

Course Title	**Mathematical Finance**
Course Code	**MTH459**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

This course aims to equip students with the foundational knowledge and analytical skills needed to understand financial management principles, solve quantitative finance problems, option pricing problems, and apply portfolio optimization techniques in real-world scenarios.

Course Outcomes:

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

CO1: Define different terminologies of financial management, portfolio analysis and Different types of financial contract.

CO2: Illustrate different measures of financial management, portfolio analysis, Options, and volatility.

CO3: Solve problems related to time value of money, annuities, internal rate of return (IRR) and different numerical methods.

CO4: Interpret the concepts of Mean-variance portfolio optimization, the Markowitz model and the two-fund theorem.

CO5: Solve problems related to types of Option and volatility using Black Scholes model, Single-Period Binomial Model, and multi-period binomial model.

Course Description:

This course provides a comprehensive introduction to financial management and portfolio analysis, equipping students with foundational knowledge and practical skills to navigate the complexities of finance. Key concepts such as financial contracts, options, and volatility will be explored. Students will learn to analyze financial metrics and solve real-world problems involving the time value of money, annuities, and internal rate of return (IRR). The course also covers advanced topics, including mean-variance portfolio optimization, the Markowitz model, and the two-fund theorem, enabling students to develop effective investment strategies. By the end of the course, students will be able to apply both theoretical and quantitative techniques to make informed financial decisions in various scenarios.

Course Content:

Module I:

Financial Management: Financial Management, Goals of Financial Management and main decisions of financial management, Time Value of Money: Interest rate and discount rate. Present value and future value-discrete case as well as continuous compounding case, Annuities and its kinds, Meaning of return. Return as Internal Rate of Return (IRR), Numerical Methods like Newton-Raphson Method to calculate IRR, Measurement of returns under uncertainty situations

Module II:

Meaning of risk, Difference between risk and uncertainty, Types of risks, Measurements of risk. Calculation of security and Portfolio Risk and Return-Markowitz Model, Sharpe's Single Index Model Systematic Risk and Unsystematic Risk, Taylor series and Bond Valuation, Calculation of Duration and Convexity of bonds

Module III:

Introduction to Futures, and Forwards, Characteristics of Futures and Forwards, Theoretical Relationships between Spot, Forward and Future

Introduction to Option, Types of Options, Some Properties of an Option, Speculation with Options and classical strategies, Binomial Model, The Single-Period Binomial Model, multi-period binomial model, Risk-Neutral Valuation, Hedging Options, Trading Options, The Black–Scholes–Merton Model and Its Greeks; Volatility, Types of Volatility, Implied Volatility, Volatility Smiles and Skews

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books

T1. John C. Hull, Options, Futures, and Other Derivatives, Prentice-Hall of India Private Limited.

T2. Alexander, C.(2008): Market Risk Analysis Volume III: Pricing, Hedging and Trading Financial Instruments, John Wiley & Sons Ltd.

T3. Alòs, E., Merino, R. (2023): Introduction to Financial Derivatives with Python, CRC Press.

Reference Books

R1. Aswath Damodaran, Corporate Finance - Theory and Practice, John Wiley & Sons.Inc.

R2. Sheldon M. Ross, An Introduction to Mathematical Finance, Cambridge University Press.

Course Title	**Computational Fluid Dynamics**
Course Code	**MTH460**
Credit	**4**
Contact Hours (L-T-P)	**3-1-0**
Course Type	**Theory**

Course Objectives:

The primary objective of this course are as follows:

- To provide fundamental concepts of fluid flow models with physical boundary conditions
- To understand the basics of Navier-Stokes equations in differential and integral form.
- To make student aware about difference equation, explicit and implicit approaches.
- To provide students a basic concept of Viscous flow.
- To make understand students about boundary layer and its equations with related applications.

Course Outcomes:

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

CO1: Gain underlying concept of continuity equation and Navier-Stokes equation and inviscid incompressible irrotational flow.

CO2: Acquire the knowledge of different classes of partial differential equation, finite difference

CO3: techniques, and some explicit and implicit approaches.

CO4: Develop the idea of Subsonic-supersonic isentropic flow, Prandtl-Mayer expansion wave

CO5: flow field and Couette flow and its numerical solution

CO6: Acquire the underlying concept of boundary layer concept, some advanced topics in modern Computational fluid dynamics

Course Description:

This course provides students a fundamental concept and some important governing equations related to fluid flow. The course deals with some well-known numerical techniques to solve existing mathematical models in fluid flow such as incompressible Couette flow. This course also deals with boundary layer concepts and Linearization of flow equations and their real-life applications.

Course Content:

Module I:

Philosophy of computational fluid dynamics and its impact in real life problems, models of the fluid flow, finite control volume, infinitesimal fluid elements, substantial derivatives, continuity equation, momentum equation, energy equation, physical boundary conditions, Navier-Stokes equations in differential and integral form, Euler equation for Inviscid equations, the full potential equation and inviscid incompressible irrotational flow.

Module II:

Classification of quasi-linear partial differential equations (PDEs), different classes of PDEs, finite difference approach, difference equation, explicit and implicit approaches, The Lax-Wendroff technique, MacCormack's technique, viscous flows, conservation form, relaxation technique, aspect of numerical dissipation and dispersion, artificial viscosity, Alternating-Direction-Implicit technique and pressure correction formula.

Module III:

Viscous flow: Compressible and incompressible flow, stream function, vorticity approach, primitive variable approach, The MAC method, Subsonic-supersonic isentropic flow and it computational fluid dynamics solution, purely subsonic isentropic nozzle flow, numerical solution of Prandtl-Mayer expansion wave flow field, incompressible Couette flow and its numerical solution using implicit Crank-Nicholson technique and pressure correction method.

Module IV:

Physical considerations of boundary layer and its equations, computations of the laminar boundary layer, turbulent boundary layers and related applications, Linearization of flow equations, the beam and warning method, block tridiagonal matrices, flux-vector splitting, Godunov approach and multigrid method.

Evaluation:

Mode of Evaluation	Theory	
Weightage	Comprehensive and Continuous Assessment	End Semester Examination
	50%	50%

Text Books:

T1. J. D. Anderson and J.Wendt, Computational fluid dynamics, (Vol. 206). New York: McGraw-Hill, 1995.

T2. P. Niyogi,S.K. Chakrabarty,.M.K. Laha, Introduction to Computational Fluid Dynamics, Pearson Education, 2005.

Reference Book:

R1. T.J. Chung, Computational Fluid Dynamics, Cambridge University, Press, 2002

R2. Tarit Kumar Bose, Computational Fluid Dynamics, Wiley Eastern Ltd., 1988.

R3. C.A.J. Fletcher, Computational Techniques for Fluid Dynamics, Vol.II, Springer-Verlag, Berlin, 1991.

R4. Pieter Wesseling, Principles of Computational Fluid Dynamics (Springer Series in computational Mathematics), 2001

Course Title	**Project/Dissertation**
Course Code	**MTH499**
Credit	**12**
Contact Hours (L-T-P)	
Course Type	**Dissertation**

Course Objectives:

- To address the real-world problems and find the required solution.
- To fabricate and implement the project intended solution for project-based learning
- To improve the team building, communication and management skills of the students

Course Outcomes:

On completion of this course, the students will be able to:

CO1: Identify a specific area of interest within the domain of Mathematics for the project, demonstrating the ability to select and define a research topic

CO2: Apply theoretical knowledge and research methodology to investigate the chosen project topic, showing practical application of Mathematical concepts.

CO3: Analyze and interpret data collected during the project, using appropriate techniques to draw meaningful conclusions.

CO4: Develop a comprehensive scientific report and presentation, effectively communicating project findings and their significance.

CO5: Evaluate the outcomes of the project, reflecting on the research process and identifying areas for future work or improvement

Course Description:

The role of Projects in life of science students are very crucial. Minor Project helps you to explore and strengthen the understanding of fundamentals through practical application of theoretical concepts. Every phenomenon around you is being justified by our greatest Mathematicians to date. In this article we, will be covering what is Mathematics and mini-projects that can be done by mathematicians during their academics. It acts like a beginners guide to do larger projects later in their career. It not just affects the grades of learner but also matter a lot for good CV/Resume. So before choosing the minor and major project, you should explore the options and pick the correct domain where the opportunities are immense.

Evaluation:

Mode of Evaluation	Presentation and Report
Weightage	End Semester Examination
	100%

CO-PO Correlation Matrix for the Programme

B.Sc (Mathematics)

Course Code	Course Name	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
MTH101	**Algebra**	**CO1**	3	2	2	3	2	-	-	-	-	2	-	-	3	2	2
		CO2	2	2	2	2	-	-	-	-	-	2	-	-	2	-	-
		CO3	3	2	2	2	-	-	-	-	-	2	-	-	3	2	2
		CO4	3	3	2	3	2	-	-	-	-	2	3	2	2	-	-
			2.75	**2.25**	**2**	**2.5**	**2**	**-**	**-**	**-**	**-**	**2**	**3**	**2**	**2.5**	**2**	**2**
MTH102	**Calculus**	**CO1**	3	2	2	3	2	-	-	-	-	2	-	-	3	2	2
		CO2	3	2	2	3	2	-	-	-	-	2	-	-	3	2	2
		CO3	3	3	3	3	2	-	-	-	-	2	-	-	3	2	3
		CO4	3	3	2	3	2	-	-	-	-	2	2	-	2	-	-
			3	**2.5**	**2.25**	**3**	**2**	**-**	**-**	**-**	**-**	**2**	**2**	**-**	**2.75**	**2**	**2.33**
MTH103	**Real Analysis**	**CO1**	3	2	2	2	1	1	1	1	1	2	1	1	3	2	2
		CO2	2	3	2	2	1	1	1	1	1	2	1	1	3	2	2
		CO3	2	2	3	3	2	1	1	1	1	1	1	1	3	3	2
		CO4	2	2	3	3	2	1	1	1	1	1	1	1	3	2	2
			2.25	**2.25**	**2.5**	**2.5**	**1.5**	**1**	**1**	**1**	**1**	**1.5**	**1**	**1**	**3**	**2.25**	**2**
MTH104	**Ordinary Differential Equation**	**CO1**	3	2	2	3	2	-	-	-	-	-	-	-	3	2	2
		CO2	3	2	3	3	2	-	-	-	-	-	-	-	3	2	2
		CO3	3	2	3	3	2	-	-	-	-	-	-	-	3	2	3
		CO4	3	3	3	3	3	-	-	-	-	2	-	-	2	-	-
			3	**2.25**	**2.75**	**3**	**2.25**	**-**	**-**	**-**	**-**	**2**	**-**	**-**	**2.75**	**2**	**2.3**
MTH201	**Linear Algebra**	**CO1**	3	3	2	3	-	-	-	-	-	2	-	-	3	2	2
		CO2	3	3	2	3	-	-	-	-	-	2	-	-	3	2	2
		CO3	3	2	2	2	-	-	-	-	-	2	-	-	2	2	2
		CO4	3	3	2	3	2	-	-	-	-	2	2	-	2	-	-
			3	**2.75**	**2**	**2.75**	**2**	**-**	**-**	**-**	**-**	**2**	**2**	**-**	**2.5**	**2**	**2**

MTH202	**Analytical Geometry**	**CO1**	2	3	2	2	1	-	-	-	1	2	-	-	2	-	2
		CO2	2	3	2	2	1	-	-	-	1	2	-	-	2	-	2
		CO3	2	3	3	3	2	-	-	-	2	2	1	-	3	1	2
		CO4	3	3	2	3	2	-	-	-	2	2	1	2	3	2	3
			2.25	**3**	**2.25**	**2.5**	**1.5**	**-**	**-**	**-**	**1.5**	**2**	**1**	**2**	**2.5**	**1.5**	**2.25**
MTH203	**Modern Algebra**	**CO1**	2	2	2	3	3	1	1	1	1	2	1	1	3	2	2
		CO2	2	2	2	3	2	1	1	1	1	2	1	1	3	2	3
		CO3	1	2	2	2	2	1	1	1	1	1	1	1	2	3	2
		CO4	2	2	2	3	2	1	1	1	1	2	1	1	3	2	2
			1.75	**2**	**2**	**2.75**	**2.25**	**1**	**1**	**1**	**1**	**1.75**	**1**	**1**	**2.75**	**2.25**	**2.25**
MTH204	**Introduction to Linear Programming and Game Theory**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH205	**Multivariate Calculus**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH301	**Numerical Methods**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**

MTH302	**Dynamics of a Particle**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH303	**Probability and Statistics**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH350	**Internship (Summer Project)**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH304	**Complex Analysis**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH305	**Integral Transform and Partial Differential Equations**	**CO1**	3	2	2	3	3	-	1	-	1	-	-	1	3	2	2
		CO2	3	2	3	3	3	-	2	-	1	-	-	1	3	3	2
		CO3	3	3	3	3	3	-	1	-	1	-	-	1	3	3	3
		CO4	2	3	3	3	3	-	1	-	1	-	-	1	3	3	3
		CO5	3	2	3	3	3	-	1	-	1	-	-	1	3	2	
			2.75	**2.5**	**2.75**	**3**	**3**	**-**	**1.25**	**-**	**1**	**-**	**-**	**1**	**3**	**2.75**	**2.5**

MTH351	**Project**	**CO1**	3	2	2	2	-	-	-	-	2	1	-	-	3	-	2
		CO2	3	2	3	3	2	-	-	-	2	1	2	2	3	1	2
		CO3	2	2	2	2	1	-	-	-	1	1	-	-	2	2	2
		CO4	3	2	3	3	2	-	-	-	2	2	2	2	3	1	2
			2.75	**2**	**2.5**	**2.5**	**1.67**	**-**	**-**	**-**	**1.75**	**1.25**	**2**	**2**	**2.75**	**1.33**	**2**
MTH306	**Continuum Mechanics**	**CO1**	3	2	2	2	2	-	-	-	-	-	-	-	3	-	2
		CO2	3	2	3	3	2	-	-	-	-	-	-	-	3	-	2
		CO3	3	2	2	3	3	-	-	-	-	-	-	-	3	-	3
		CO4	3	3	2	3	2	-	-	-	-	-	-	-	3	-	2
		CO5	3	3	3	3	3	-	-	-	-	-	-	-	3	-	3
		CO6	3	2	2	2	2	-	-	-	-	-	-	-	3	-	2
			3	**2.25**	**2.25**	**2.75**	**2.25**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**-**	**2.25**
MTH307	**Discrete Mathematics and Graph Theory**	**CO1**	2	2	2	2	1	1	1	1	1	2	1	1	3	2	2
		CO2	2	3	2	2	1	1	1	1	1	2	1	1	3	2	2
		CO3	1	2	3	3	2	1	1	1	1	1	1	1	3	3	2
		CO4	2	2	2	3	2	1	1	1	1	2	1	1	3	2	2
			1.75	**2.25**	**2.25**	**2.5**	**1.5**	**1**	**1**	**1**	**1**	**1.75**	**1**	**1**	**3**	**2.25**	**2**
MTH308	**Applied Statistics**	**CO1**	2	3	1	1	-	-	-	-	-	-	-	-	2	-	1
		CO2	3	3	2	2	-	-	-	-	-	-	-	-	3	-	2
		CO3	3	3	3	3	2	-	-	-	-	-	-	-	3	-	3
		CO4	3	3	3	3	3	-	-	-	-	-	-	-	3	-	3
			2.75	**3**	**2.25**	**2.25**	**2.5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2.75**	**-**	**2.25**

MTH401	**Mathematical Modelling**	**CO1**	3	3	2	2	1	-	-	-	-	-	-	-	3	-	2
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	-	3
		CO3	3	3	3	3	3	-	-	-	-	-	-	-	3	-	3
		CO4	3	2	3	2	3	-	-	-	-	-	-	-	3	-	3
			3	**2.75**	**2.75**	**2.5**	**2.25**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**-**	**2.75**
MTH402	**Fluid Dynamics**	**CO1**	3	3	2	3	2	1	1	-	1	1	-	2	3	2	2
		CO2	3	2	3	3	3	1	2	-	-	1	1	2	3	2	2
		CO3	2	2	3	3	3	1	2	-	1	1	1	1	3	3	3
		CO4	3	2	3	3	3	2	2	1	-	1	1	2	3	3	3
			2.75	**2.25**	**2.75**	**3**	**2.75**	**1.25**	**1.75**	**1**	**1**	**1**	**1**	**1.75**	**3**	**2.5**	**2.5**
MTH403	**Advanced Abstract Algebra**	**CO1**	2	2	2	3	2	1	1	1	1	2	1	1	3	2	2
		CO2	2	2	2	3	2	1	1	1	1	2	1	1	3	2	2
		CO3	1	2	2	3	2	1	1	1	1	1	1	1	2	3	2
		CO4	2	2	2	3	2	1	1	1	1	2	1	1	3	2	2
			1.75	**2**	**2**	**3**	**2**	**1**	**1**	**1**	**1**	**1.75**	**1**	**1**	**2.75**	**2.25**	**2**
MTH404	**Fuzzy Sets and Its Aapplications**	**CO1**	3	-	3	-	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	-	3	2	2	-	-	-	-	-	-	-	3	-	-
		CO3	3	-	3	2	2	-	-	-	-	-	-	3	3	-	3
		CO4	3	-	3	-	-	-	-	-	-	-	-	3	3	-	3
			3	**-**	**3**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**-**	**3**
MTH405	**Operations Research**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**

MTH406	**Topology and Metric Space**	**CO1**	2	3	2	2	1	1	1	1	1	1	1	1	3	2	2
		CO2	2	3	2	2	1	1	1	1	1	1	1	1	3	2	2
		CO3	2	3	3	3	2	1	1	1	1	1	1	1	3	3	2
		CO4	2	2	3	3	2	1	1	1	1	1	1	1	3	3	2
			2	**2.75**	**2.5**	**3**	**1.5**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**2.5**	**2**
MTH407	**Classical Mechanics**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH450	**Research Methodology**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH408	**Computational Matrix Theory**	**CO1**	3	2	2	2	2	-	-	-	-	-	-	-	2	-	-
		CO2	3	3	2	3	3	-	-	-	-	-	-	-	3	-	3
		CO3	3	2	2	3	3	-	-	-	-	-	-	-	3	2	2
		CO4	3	2	2	3	3	-	-	-	-	-	-	-	3	-	3
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH451	**Stochastic Methods in Industry**	**CO1**	3	2	-	-	3	-	-	-	-	-	-	2	3	2	2
		CO2	3	3	-	1	3	2	-	-	-	-	-	2	3	3	2
		CO3	3	3	2	2	3	3	-	-	-	-	-	2	3	3	3
		CO4	3	3	3	3	3	3	-	-	-	-	-	2	3	3	3
			3	**2.75**	**2.5**	**3**	**3**	**2.67**	**-**	**-**	**-**	**-**	**-**	**2**	**3**	**2.75**	**2.5**

MTH452	**Physical Oceanography**	**CO1**	3	3	-	3	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
		CO3	3	3	3	3	-	-	-	-	-	-	-	3	-	3	
		CO4	3	-	3	3	-	-	-	-	-	-	-	-		3	-
			3	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**3**	**3**
MTH453	**Mathematical Modelling in Bio-Sciences**	**CO1**	3	2	2	3	2	-	-	-	-	-	-	-	2	-	-
		CO2	3	2	2	3	3	-	-	-	-	-	-	-	3	-	3
		CO3	3	2	2	3	2	-	-	-	-	-	-	-	2	2	2
		CO4	3	3	3	3	2	1	-	-	-	2	-	-	3	-	3
			3	**3**	**3**	**3**	**2**	**1**	**-**	**-**	**-**	**2**	**-**	**-**	**2.75**	**2**	**2.67**
MTH454	**Measure Theory**	**CO1**	2	3	2	2	1	1	1	1	1	1	1	1	3	2	2
		CO2	2	3	2	2	1	1	1	1	1	1	1	1	3	2	2
		CO3	3	3	3	3	2	1	1	1	1	1	1	1	3	3	2
		CO4	3	3	3	3	2	1	1	1	1	1	1	1	3	3	2
			2.5	**3**	**2.5**	**3**	**1.5**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**2.5**	**2**
MTH455	**Optimization**	**CO1**	3	-	3	-	-	-	-	-	-	-	-	3	3	-	-
		CO2	3	-	3	-	2	-	-	-	-	-	-	-	3	-	3
		CO3	3	-	3	-	2	-	-	-	-	-	-	3	3	-	3
		CO4	3	-	3	-	-	-	-	-	-	-	-	3	3	-	3
			3	**-**	**3**	**-**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**-**	**3**
MTH456	**Ocean Dynamics and Modelling**	**CO1**	3	3	2	2	-	2	-	-	-	-	-	-	3	-	2
		CO2	3	3	3	3	-	2	-	-	-	-	-	-	3	-	2
		CO3	3	3	2	2	-	2	-	-	-	-	-	-	3	-	2
		CO4	2	2	1	1	-	-	-	-	-	-	-	-	2	-	1
			2.75	**2.75**	**2**	**2**	**-**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**2.75**	**-**	**1.75**

MTH457	**Advanced Differential Equation**	**CO1**	3	2	2	3	1	-	-	-	-	-	-	-	2	-	-
		CO2	3	2	2	3	1	-	-	-	-	-	-	-	2	2	-
		CO3	3	2	2	3	1	-	-	-	-	-	-	-	2	3	2
		CO4	3	2	2	3	1	-	-	-	-	-	-	-	2	-	3
		CO5	3	2	2	3	1	-	-	-	-	-	-	-	2	2	3
			3	**2**	**2**	**3**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2**	**2.5**	**2.5**
MTH458	**Functional Analysis**	**CO1**	2	2	1	2	1	1	1	1	1	1	1	1	3	2	2
		CO2	2	2	2	3	1	1	1	1	1	1	1	1	3	2	2
		CO3	2	2	3	3	2	1	1	1	1	1	1	1	3	3	2
		CO4	2	2	3	3	2	1	1	1	1	1	1	1	3	2	2
		CO5	2	2	2	3	2	1	1	1	1	1	1	1	3	3	2
			2	**2**	**2.25**	**2.75**	**1.5**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**2.25**	**2**
MTH459	**Mathematical Finance**	**CO1**	3	3	2	2	-	-	-	-	-	-	-	-	3	-	2
		CO2	3	3	3	2	-	-	-	-	-	-	-	-	3	-	2
		CO3	3	3	3	3	2	-	-	-	-	-	-	-	3	-	3
		CO4	3	3	3	3	2	-	-	-	-	-	-	-	3	-	3
		CO5	3	3	3	3	3	-	-	-	-	-	-	-	3	-	3
			3	**3**	**2.75**	**2.5**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**-**	**2.5**
MTH460	**Computational Fluid Dynamics**	**CO1**	3	3	2	3	2	1	1	-	-	1	1	2	3	2	2
		CO2	3	3	3	3	3	1	2	-	-	1	1	2	3	3	3
		CO3	2	2	3	3	3	1	2	-	-	1	1	1	3	3	3
		CO4	3	3	3	3	3	2	2	-	-	1	1	2	3	3	3
		CO5	3	3	3	3	3	2	2	-	-	1	1	2	3	3	3
		CO6	3	3	2	3	2	1	1	-	-	1	1	2	3	2	2
			2.75	**2.75**	**2.75**	**3**	**2.75**	**1.25**	**1.75**	**-**	**-**	**1**	**1**	**1.75**	**3**	**2.75**	**2.75**

MTH499	**Project/ Dissertation**	**CO1**	3	3	2	2	-	-	-	-	-	-	-	-	3	-	2
		CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	-	3
		CO3	3	3	3	3	2	-	-	-	-	-	-	-	3	-	3
		CO4	3	3	2	2	-	-	-	-	-	3	3	-	3	-	2
		CO5	3	3	2	2	-	-	-	-	-	-	-	-	3	-	2
			3	**3**	**2.5**	**2.5**	**2**	**-**	**-**	**-**	**-**	**3**	**3**	**-**	**3**	**-**	**2.5**