MASTER OF SCIENCE

IN

MATHEMATICS

CURRICULUM AND SYLLABUS

(For students admitted from the academic year 2023-2024 onwards)

UNDER CHOICE BASED CREDIT SYSTEM

Department of Mathematics, School of Physical Sciences
DIT University, Dehradun
Uttarakahnd, India-248009

Approved by the Academic Council at its 22nd meeting held on 06.03.2023

Programme Name: M. Sc. Mathematics

Objectives

The M.Sc. Mathematics programme provides students with rigorous and thorough knowledge of a broad range of pure and applied areas of mathematics. It is designed to train students with different professional goals, ranging from employment in academics or industry to basic training in foundations needed to pursue a Ph. D. in mathematics or mathematics-related fields.

Eligibility

- Minimum 50% aggregates marks in B.Sc.(H) Mathematics OR
- Minimum 50% aggregates marks in B.Sc.(PCM) Mathematics with at least 55% marks in Mathematics

Duration

2 Years (4 semesters)

Programme Educational Objectives (PEOs)

The Graduates will be able to:

PEO_01. choose a successful career in diversified sectors such as teaching, research, banking, planning, and higher education.

PEO_02. obtain and apply the practical and technical skills to identify, analyze and solve the problems related to the industries.

PEO_03. develop and possess a professional attitude and skills to be socially responsible individuals and work as a team in the workplace and in society considering the professional's ethics, environmental factors, and contribute to the economic growth of the country.

PEO_04. utilize their expertise gained to pursue higher studies and outshine in careers like teaching, research, or technologists.

PEO_05. exhibit their acquired multidisciplinary skills for lifelong learning in their professional and personal upliftment.

Programme Outcomes (POs)

On successful completion, graduates will be able to:

PO1: inculcate critical thinking to carry out scientific investigation objectively without being biased by preconceived notions.

PO2: equip the student with skills to analyze problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions thereof.

PO3: prepare students for pursuing research or careers in industry in mathematical sciences and allied fields

PO4: imbibe effective scientific and/or technical communication in both oral and writing.

PO5: continue to acquire relevant knowledge and skills appropriate to professional activities and demonstrate the highest standards of ethical issues in mathematical sciences.

PO6: create awareness to become an enlightened citizen with a commitment to deliver one's responsibilities within the scope of bestowed rights and privileges.

PO7: carry out development work as well as take up challenges in the emerging areas of Industry.

PO8: demonstrate competence in using mathematical and computational skills to model, formulate and solve real-life applications.

PO9: acquire deep knowledge of different mathematical and computational disciplines so that they can qualify NET/ GATE examination.

PO10: nurture problem-solving skills, thinking, and creativity through assignments, project work.

PO11: articulating ideas and strategies for addressing a research problem

PO12: demonstrate the ability to conduct research independently and pursue higher studies toward Ph. D. degree in mathematics and computing.

Programme Specific Outcomes (PSEs)

On successful completion, graduates will be able to:

PSO1 communicate concepts of Mathematics and its applications.

PSO2 acquire analytical and logical thinking through various mathematical tools and techniques.

PSO3 investigate real-life problems and learn to solve them through formulating mathematical models.

PSO4 attain in-depth knowledge to pursue higher studies and the ability to conduct research.

Work as a mathematical professional.

PSO5 achieve targets of successfully clearing various examinations/interviews for placements in teaching, banks, industries and various other organizations/services.

CURRICULUM AND SYLLABUS

M. Sc. (Mathematics) **Total credits: 88**

Year 1 **Semester 1**

Category	Course Code	Course Name	L	T	P	Credit
CC	MA606	Real Analysis	3	1	0	4
CC	MA607	Linear Algebra	3	1	0	4
CC	MA608	Ordinary Differential Equations	3	1	0	4
CC	MA609	Mathematical Statistics	3	1	0	4
CC	MA616	Complex Analysis	3	1	0	4
SEC	MA617	Scientific Computing with MATLAB	-	-	4	2
Total			**15**	**5**	**4**	**22**

Year 1 **Semester 2**

Category	Course Code	Course Name	L	T	P	Credit
CC	MA618	Algebra	3	1	0	4
CC	MA619	Numerical Analysis	3	0	2	4
CC	MA626	Topology	3	1	0	4
CC	MA627	Partial Differential Equations	3	1	0	4
DSE	MA646	Orthogonal Polynomials & Special Functions	3	1	0	4
	MA647	Fuzzy Sets and Applications				
	MA648	Statistical Inference				
	MA649	Integral Equation and Calculus of Variations				
SEC	MA628	Introduction to Python Programming	-	-	4	2
Total			**15**	**5**	**4**	**22**

Year 2 **Semester 3**

Category	Course Code	Course Name	L	T	P	Credit
CC	MA706	Fluid Dynamics	3	1	0	4
CC	MA707	Functional Analysis	3	1	0	4
CC	MA708	Operations Research	3	1	0	4
CC	MA709	Differentiable Manifold	3	1	0	4
DSE	MA746	Mathematical Modeling and Simulations	3	1	0	4
	MA747	Introduction to Mathematical Finance				
	MA769	Statistics through SPSS	3	0	2	4
SEC	MA716	Documentation in Latex	0	0	4	2
		Total	**14**	**4**	**8**	**22**

Year 2 **Semester 4**

Category	Course Code	Course Name	L	T	P	Credit
CC	MA717	Measure and Integration Theory	3	1	-	4
CC	MA727	Dynamical Systems	3	1	-	4
CC	MA719	Number Theory & Cryptography	3	1	-	4
DSE	MA759	Classical Mechanics	3	1	0	4
	MA756	Stochastic Processes				
	SWAY757	MOOC/SWAYAM Course				
	MA758	Numerical Solution of PDEs	3	0	2	4
Project	MA726	Project (Research and seminar)	-	-	-	6
		Total	**12**	**4**		**22**

As per UGC (Credit Framework for Online Learning Courses through **SWAYAM**) Regulation 2016, DIT University strongly encourages the use of SWAYAM (Study Web of Active Learning by Young and Aspiring Minds) platform. Based on the availability of relevant courses on SWAYAM, students shall choose an online course on the recommendation of faculty advisor and the credits will be transferred.

Summary of the Credits

Year	Semester	Max Credits
1	1	22
	2	22
2	3	22
	4	22
Total		**84**

Category wise classification of the Credit

Category		**Credits**	**No. of Subjects**
CC	Departmental Core Course	64	16
AEC	Ability Enhancement Course	6	3
DSE	Discipline Specific Elective	11	3
PRJT/THESIS	Project	6	1
Total		**88**	**23**

Course Title	**Real Analysis**
Course Code	MA606
Credits	4
Course Category	CC
Year / Semester	I / I
Prerequisite Courses	
L T P	3 1 0
Course Objectives	To develop the understanding of metric space and its different aspects, continuity and uniform continuity of a function, compactness, Cauchy sequence and complete metric space, convergence of sequence and series of functions, and Riemann integral and its properties, continuity and differentiability of function of two variables.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the countable and uncountable sets and will learn Bolzano-Weierstrass theorem. **CO2:** understand the Riemannian integrals and Riemann- Stieltjes integral and its properties. **CO3:** check whether an infinite series of functions is convergence or not. **CO4:** understand inverse and implicit function theorems and its applications. **CO5:** apply the basic properties of metric space, compactness, and Weierstrass approximation theorem.

Syllabus	**No. of Lectures**
Unit 1 Real number systems Finite set, countable and uncountable sets, real number system as a complete ordered field, Archimedean property, supremum, infimum, Bolzano-Weierstrass theorem, Heine Borel theorem.	8
Unit 2 Differentiation and integration Limit, continuity, uniform continuity, differentiability, mean value theorems, Riemann sums and Riemann integral, Riemann- Stieltjes integral and its properties.	8
Unit 3 Sequences and series Sequences and series of functions, convergence, uniform convergence.	8
Unit 4 Function of several variables Functions of several variables, partial derivatives, inverse and implicit function theorems, maxima and minima.	8
Unit 5 Metric spaces and properties Basic concepts, continuous functions, completeness, contraction mapping theorem, connectedness, compactness, Weierstrass approximation theorem.	10
Total No. of Lectures	**42**

Text Books	1. Rudin W., Principles of Mathematical Analysis, Mc-Graw Hill, 1976. 2. E. Kreyszig, Introductory Fnctional Analysis with Applications, John Wiley and Sons, 2010.
References Books	1. Royden H. L., Real Analysis, Macmillan Publishing Company, 1998. 2. Tao T., Analysis II, Hindustan Book Agency, Springer, 2015. 3. Apostol T. M., Mathematical Analysis, Addison-Wesley, 1974. 4. Simmons G. F., Topology and Modern Analysis, Kreiger, 2003.

Course Title	**Linear Algebra**
Course Code	MA607
Credits	4
Course Category	CC
Year / Semester	I / I
Prerequisite Courses	Matrix Theory
L T P	3 1 0
Course Objectives	The aim of this course is to introduce students with the fundamental concepts of vector spaces, concepts of linear transformations, decomposition theorem, canonical forms, and adjoint operators. to develop critical reasoning by studying the logical proofs and axiomatic methods as applied to prove various theorems. The objective of this course is to develop the skill to students to understand how abstract definitions are motivated by concrete examples, how result follows from the axiomatic definitions and are specialized back to the concrete examples, and how applications are woven in throughout.
Course Outcomes	After studying this course the student will be able to 1. apply the concepts and methods described in syllabus, will be able to solve problems using methods in Linear algebra, and will know the application of Linear Algebra to follow complex logical arguments and develop modest logical argument. 2. understand and compute transition matrices, dual basis, dual vector spaces and dual linear transformations. 3. deal with the inner product spaces, orthonormal basis, Bessel's inequality and Riesz Representation theorem with applications. 4. understand implications of the existence of various operators on inner product spaces viz. self-adjoint operator, normal operator and their properties. 5. apply diagonalization of matrices in various problems together with canonical and quadratic forms.

Syllabus	**No. of Lectures**
UNIT I: System of Linear Equations and Vector Space Solving Linear Systems Using Gaussian Elimination, Gauss-Jordan Row Reduction and Reduced Row Echelon Form, Equivalent Systems, Rank, and Row Space, Introduction to Vector Spaces, Subspaces, Span, Linear dependence and independence, basis, dimension and related properties.	8
UNIT-II: Linear Transformations Introduction to Linear Transformations, Algebra of Linear transformations, Vector space of Linear transformations $L(U,V)$, Dimension of space of linear transformations, Change of basis and transition matrices, Linear functional, Dual basis, Computing of a dual basis, Dual vector spaces, Annihilator, Second dual space, Dual transformations.	8
UNIT III: Inner Product Spaces Inner-product spaces, Normed space, Cauchy-Schwartz inequality, Pythagorean Theorem, Projections, Orthogonal Projections, Orthogonal complements, Orthonormality, Matrix Representation of Inner-products, Gram-Schmidt Orthonormalization Process, Bessel's Inequality, Riesz Representation theorem and orthogonal Transformation, Inner product space isomorphism.	10

UNIT IV: Operators on Vector Spaces Operators on Inner-product spaces, Isometry on Inner-product spaces and related theorems, Adjoint operator, Self-adjoint operators, Normal operator and their properties, Matrix of adjoint operator, Algebra of $Hom(V,V)$, Minimal Polynomial, Invertible Linear transformation, Characteristic Roots, Characteristic Polynomial and related results.	8
UNIT V: Canonical Forms and Quadratic Forms Diagonalization of Matrices, Invariant Subspaces, Cayley-Hamilton Theorem, Canonical form, Jordan Form. Forms on vector spaces, Bilinear Functionals, Symmetric Bilinear Forms, Skew Symmetric Bilinear Forms, Rank of Bilinear Forms, Quadratic Forms, Classification of Real Quadratic forms.	8
Total No. of Lectures	**42**

Text Books	1. Strang G., Introduction to Linear Algebra, Wellesley-Cambridge Press, 1993. 2. Hoffman K. and . Kunze R, Linear Algebra, 2nd Ed., Prentice Hall of India, 2005. 3. Herstein, I. N., Topics in Algebra, John Wiley & Sons, 2nd edition,
References Books	1. Kumaresan S., Linear Algebra: A Geometric Approach, Prentice-Hall of India, 2004. 2. Axler S., Linear Algebra Done Right, 2nd Ed., Springer UTM, 1997. 3. Lang S., Linear Algebra, Springer Undergraduate Texts in Mathematics, 1989.

Course Title	**Ordinary Differential Equations**
Course Code	MA608
Credits	4
Course Category	CC
Year / Semester	I / I
Prerequisite Courses	Basic concepts of Calculus and geometry.
L T P	3 1 0
Course Objectives	The aim of the course is to introduce students with the depth knowledge of differential equation with different forms of solution, like eigen value and eigen vector method, method of undetermined coefficients, method of variation of parameters.
Course Outcomes	After studying this course the student will be able to **CO1**: express the existence and uniqueness theorem of differential equations. **CO2:** apply the method of undetermined coefficient to solve non-homogeneous differential equation with constant coefficient. **CO3:** determine particular solutions to differential equations with given boundary conditions or initial conditions. **CO4:** to apply eigenvalue-eigenvector method to find solutions system of differential equations. **CO5:** describe Legendre polynomials and Bessel functions and their properties.

Syllabus	**No. of Lectures**
Unit-1: Ordinary differential equations, equations with variable separable, exact equations, Lipschitz condition, non-local existence of solutions, uniqueness of solutions, existence and uniqueness theorem for first and higher order equations.	10
Unit-2: Linear differential equations with constant coefficients, initial value problems for second order differential equations, existence and uniqueness theorem, linear dependence and independence of solutions, Wronskian and linear independence.	8
Unit-3: Linear differential equations with variable coefficients, methods of solutions, initial value problems for the homogeneous equations, existence and uniqueness theorem for solution of homogenous differential equations and n linearly independent solutions.	6
Unit-4: Regular and singular points, power series and series solutions of Bessel and Legendra differential equations, Frobenius method.	10
Unit-5: Two-point boundary value problem, self-adjoint problem and properties, Strum-Liouville problem, solution by Green functions, eigen functions and expansion formulae, comparison and separation theorems of BVP.	8
Total No. of Lectures	**42**

Text Books	1. Coddington E. A., *An Introduction to Ordinary Differential Equations*, PHI Learning 1999. 2. Simmons G. F., *Differential Equations with Applications and Historical Notes*, 2nd Ed, McGraw- Hill, 1991. 3. Agarwal R. P. and O'Regan D., *An Introduction to Ordinary Differential Equations*, Springer- Verlag, 2008.
References Books	1. Agarwal R. P. and Gupta R. C., *Essentials of Ordinary Differential Equations*, McGraw-Hill, 1993. 2. Braun M., *Differential Equations and Their Applications*, 3rd Ed., Springer-Verlag, 1983. 3. Deo S. G., Raghavendra V., Kar R. and Lakshmikantham V., *Textbook of Ordinary Differential Equations*, McGraw Hill Education, 3rd Ed., 2015.

Course Title	**Mathematical Statistics**
Course Code	MA609
Credits	4
Course Category	CC
Year / Semester	I / I
Prerequisite Courses	Basic concepts of set theory.
L T P	3 1 0
Course Objectives	The aim of the course is to introduce the concepts and methods of probability and distribution theory and the tools which are used to develop the theory of statistical estimation and hypothesis testing.
Course Outcomes	After studying this course the student will be able to **CO1**: calculate conditional probability, covariance and correlation and determine independence of random variables. **CO2:** find the distribution of a function of random variables using the methods of distribution functions, transformations, and moment generating functions. **CO3:** calculate probabilities and quartiles for sampling distributions related to the probability distributions. **CO4:** perform hypothesis tests for the mean; compute p-values, and probabilities of Type I and Type II errors. **CO5:** construct point and interval estimators; evaluate their goodness (bias, variance, mean squared error).

Syllabus	**No. of Lectures**
Unit-I: Probability Definition and various approaches of probability, Addition theorem, Boole inequality, Conditional probability and multiplication theorem, Independent events, Mutual and pairwise independence of events, Bayes theorem and its applications.	8
Unit-II: Random variable and probability functions Definition and properties of random variables, Discrete and continuous random variables, Probability mass and density functions, Distribution function. Concepts of bivariate random variable: joint, marginal and conditional distributions. Mathematical expectation: Definition and its properties. Variance, Covariance, Moment generating function- Definitions and their properties.	12
Unit-III: Distributions Uniform, Bernoulli, Binomial, Poisson and Geometric distributions with their properties. Uniform, Exponential and Normal distributions with their properties.	8
Unit-IV: Testing of hypothesis Parameter and statistic, Sampling distribution and standard error of estimate, Null and alternative hypotheses, Simple and composite hypotheses, Critical region, Level of significance, One tailed and two tailed tests, Two types of errors.	8
Unit V: Tests of significance Large sample tests for single mean, Single proportion, Difference between two means and two proportions.	6
Total No. of Lectures	**42**

Text Books	1. Hogg V. and Craig T., Introduction to Mathematical Statistics, 7th addition, Pearson Education Limited-2014. 2. Mood A.M., Graybill F.A. , and D.C. Boes, Introduction to the Theory of Statistics, Mc Graw Hill Book Company.
References Books	1. Speigel M., Probability and Statistics, Schaum Outline Series. 2. Gupta S.C. and Kapoor V.K., Fundamentals of Mathematical Statistics, S. Chand Pub., New Delhi.

Course Title	**Complex Analysis**
Course Code	MA616
Credits	4
Course Category	CC
Year / Semester	I / I
Prerequisite Courses	Basic concepts of Calculus.
L T P	3 1 0
Course Objectives	The aim of the course is to introduce the students with complex functions, Cauchy integral theorem and formula, conformal mapping, and convex functions and their properties.
Course Outcomes	After studying this course the student will be able to **CO1:** To describe and apply the complex integration and its theorems. **CO2:** find series expansion about isolated singularities and determine residues. **CO3:** use conformal mapping between many kinds of domain. **CO4:**. Understand Analytic Continuations and Meromorphic Functions.

Syllabus	**No. of Lectures**
Unit I: Complex Integration Curves in the complex plane, Properties of complex line integrals, Fundamental theorem of line integrals (or contour integration), Simplest version of Cauchy's theorem, Cauchy-Goursat theorem, Symmetric, starlike, convex and simply connected domains, Cauchy's theorem for a disk, Cauchy's integral theorem, Index of a closed curve, Advanced versions of Cauchy integral formula and applications, Cauchy's estimate, Morera's theorem, maximum and minimum modulus principles. Riemann's removability theorem	10
Unit II: Singularities and Residues Zeros of analytical functions, singularities, classification of singularities, characterization of removable singularities and poles, Taylor's series, Laurent's series, Convergence of sequences and series of functions, Weierstrass' M-test, residues, calculus of residues, evaluation of definite integral, calculus of residues; evaluation of definite integrals; argument principle; Rouche's Theorem.	10
Unit III: Conformal Mappings and Transformations Rational functions, behaviour of functions in the neighbourhood of an essential singularity, contour integration problems, Mobius transformation, cross-ratio, and conformal mappings. Fixed points, Characterizations of Möbius maps in terms of their fixed points, Triples to triples under Möbius maps, Complex form of equations of straight lines, half planes, circles, etc., analytic (holomorphic) function as mappings.	12
Unit IV: Analytic Continuations and Meromorphic Functions Direct analytic continuations, uniqueness of analytic continuation along a curve, Monodromy theorem and its consequence, analytic continuation via Reflection**,** Meromorphic functions and argument principle, Schwarz lemma, convex functions and their properties, Hadamard 3-circles theorem.	10
Total No. of Lectures	**42**

Text Books	1. Ablowitz M.J. and Fokas A.S., Complex Variables: Introduction and Applications, Cambridge University Press, 2003. 2. Zill D.G. and Shanahan P.D., A First Course in Complex Analysis with Applications, 2nd ed., Boston: Jones and Bartlett Learning, 2010.
References Books	1. Mathews J.H. and Howell R.W., Complex Analysis for Mathematics and Engineering, 6th ed., London: Jones and Bartlett Learning, 2011. 2. Brown J.W. and Churchill R.V., Complex Variables and Applications, 7th ed., New York: McGraw-Hill, 2003. 3. S. Ponnusamy: Foundations of Complex Analysis, 2nd Ed, Narosa Publishing House, 2005

Course Title	**Scientific Computing with Matlab**
Course Code	MA617
Credits	2
Course Category	SEC
Year / Semester	I / I
Prerequisite Courses	No specific prerequisites are needed.
L T P	0 0 4
Course Objectives	The main objective of the course is to provide a basic understanding of MATLAB, including popular toolboxes. The course consists of interactive lectures and sample MATLAB problems given as assignments and discussed in class. Concepts covered include basic use, graphical representations and tips for designing and implementing MATLAB code.
Course Outcomes	After studying this course the student will be able to **CO1**: use the MATLAB GUI effectively. **CO2:** write simple programs in MATLAB to solve scientific and mathematical problems. **CO3:** create and control simple plot and user-interface graphics objects in MATLAB. **CO4:** use MATLAB effectively to analyze and visualize data. **CO5:** use in-built functions to complete the different types of task.

Syllabus	**No. of Lectures**
Unit-I: Introduction to MATLAB Vector and matrix generation, subscripting and the colon notation, matrix and array operations and their manipulations, introduction to some inbuilt functions related to array operations. M-files: scripts and functions, editing, saving m-files, and interaction between them.	4
Unit-II: Two & Three-dimensional Graphics Basic plots, change in axes and annotation in a figure, multiple plots in a figure, saving and printing figures, mesh plots, surface plots and their variants.	6
Unit-III: Relational and Logical Operators Flow control using various statements and loops including If-End statement, If-Else-End statement, nested If-Else-End statement, For-End and While-End loops with Break commands.	4
Unit-IV: Introduction to Built-in Functions Related to matrix inversion, eigenvalues, eigenvectors, condition number; for data representation: bar charts, histograms, pie chart, stem plots etc; for solving various type of differential equations; for specialized plotting e.g., contour plots, sphere, and animations.	6
Total No. of Lectures	**20**

Text Books	1. Gilat Amos, MATLAB: An introduction with applications, 5th Edition, Wiley India, 2014. 2. Chadha Naresh Mohan, Programming in Matlab: With Applied Numerical Methods for Engineers and Scientists, ASIN: B08RH5N113, 2020.
References Books	1. Chapra Steven, Applied Numerical Methods with Matlab for Engineers and Scientists, 4th Ed., McGraw Hill, 2017. 2. Pratap Rudra, Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers, Oxford University Press, 2010.

Course Title	**Algebra**
Course Code	MA618
Credits	4
Course Category	CC
Year / Semester	I / II
Prerequisite Courses	
L T P	3 1 0
Course Objectives	To develop the understanding of basic structures of algebra like groups, rings, fields and vector spaces, Sylow's theorems, Galois theorem and field theory.
Course Outcomes	After studying this course the student will be able to **CO1**: assess properties implied by the definitions of groups and rings. **CO2:** analyze and demonstrate examples of subgroups, normal subgroups and quotient groups. **CO3:** use the concepts of isomorphism and homomorphism for groups and rings. **CO4:** describe Sylow's theorems and their applications. **CO5:** understand properties of finite fields and Galois theory.

Syllabus	**No. of Lectures**
Unit-I: Group theory Groups, subgroups, normal subgroups, Euler's Ø- function, quotient groups and homomorphism theorems, automorphisms, cyclic groups and permutation groups, Cayley's theorem.	8
Unit-II: Sylow's theorems Class equations, Sylow's theorems and their applications.	8
Unit-III: Ring theory Rings, ideals, prime and maximal ideals, quotient rings, fundamental theorem of arithmetic, unique factorization domain, principal ideal domain, Euclidean domain, polynomial rings and irreducibility criteria.	10
Unit-IV: Field theory Finite and algebraic extensions, existence and cardinality of algebraic closure, finite fields.	8
Unit-V: Galois theory Chinese remainder theorem, Galois theory of polynomial in characteristic zero and simple examples.	8
Total No. of Lectures	**42**

Text Books	1. Gallian J. A., Contemporary Abstract Algebra, Narosa, 4th Ed., 1999. 2. Herstein,I. N. Topics in Algebra, John-Wiley, 1995.
References Books	1. Artin M., Algebra, Prentice Hall Inc., 1994. 2. Sharma R. K., Algebra-I: A Basic Course in Abstract Algebra, Pearson Education India, 2011. 3. Fraleigh J. B., A First Course in Abstract Algebra, Pearson, 7th Ed., 2003.

Course Title	**Numerical Analysis**
Course Code	MA619
Credits	4
Course Category	CC
Year / Semester	I / II
Prerequisite Courses	Some exposure to linear algebra and calculus.
L T P	3 0 2
Course Objectives	To develop the understanding of errors in computations, several methods for interpolation, methods to solve an algebraic and transcendental equations, direct and iterative methods to solve a system of linear equations, different methods to solve ODE and methods to find numerical derivative and integration of a function.
Course Outcomes	After studying this course the student will be able to **CO1**: analyze the error incumbent in any such numerical approximation. **CO2:** compare the viability of different approaches to the numerical solution of problems arising in roots of solution of non-linear equations. **CO3:** describe the interpolation and approximation, numerical differentiation and integration, solution of linear systems. **CO4:** solve linear and nonlinear systems of equations numerically. **CO5:** solve initial and boundary value problems numerically.

Syllabus	**No. of Lectures**
Unit-I: Solution of equations Computer arithmetic, errors, numerical solution of algebraic and transcendental equations, bisection, secant method, Newton- Raphson method, rate of convergence.	8
Unit-II: Direct methods for solving linear system of equation Norms of vectors and matrices, solution of systems of linear equations: direct methods (Gauss elimination, LU decomposition), iterative methods (Jacobi and Gauss-Seidel), ill conditioning and convergence analysis.	8
Unit-III: Interpolation Error of polynomial interpolation, Lagrange, Hermite and spline interpolations, Newton interpolations, Chebyshev approximation, power method to find the eigenvalues.	8
Unit-IV: Numerical differentiation and numerical integration Numerical differentiation based on interpolation, Trapezoidal and Simpson rules.	8
Unit-V: Numerical solution of differential equations Numerical solutions of ODE's using Picard, Euler, modified Euler and Runge-Kutta methods, single step and multi-step methods, order, consistency, stability and convergence analysis, stiff equations, two point boundary value problems: shooting and finite difference methods.	10
Total No. of Lectures	**42**

Text Books	1. Kincaid D. and Cheney W., Numerical Analysis and Mathematics of Scientific Computing, Brooks/Cole, 1999. 2. Jain M. K., Iyengar S. R. K. and Jain R. K., Numerical Methods for Scientific and Engineering Computation, New age International Publishers, 2012.
References Books	1. Butcher J. C., The Numerical Analysis of Ordinary Differential Equations, John Wiley, 1987. 2. Schwarz H. R., Numerical Analysis: A Comprehensive Introduction, Wiley, 1st Ed., 1989. 3. Sharma R. K., Complex Numbers and the Theory of Equations, Anthem Press India, 2012.

** **Laboratory Work:**
Laboratory experiments will be set in consonance with the materials covered in theory.

Course Title	**Topology**
Course Code	MA626
Credits	4
Course Category	CC
Year / Semester	I / II
Prerequisite Courses	Exposure to set theory and metric spaces.
L T P	3 1 0
Course Objectives	To introduce the basic definitions and standard examples of topological spaces, define and illustrate a variety of topological properties such as like compactness, connectedness and separation axioms.
Course Outcomes	After studying this course the student will be able to **CO1**: define and illustrate the concept of topological spaces and continuous functions. **CO2:** define and illustrate the concept of product topology and quotient topology. **CO3:** prove a selection of theorems concerning topological spaces, continuous functions, product topologies, and quotient topologies. **CO4:** define connectedness and compactness, and prove a selection of related theorems. **CO5:** describe different examples distinguishing general, geometric, and algebraic topology.

Syllabus	**No. of Lectures**
Unit-I: Basic concepts of topology Topological spaces, basis for a topology, order topology, subspace topology.	8
Unit-II: Topological spaces and continuous functions Closed sets, countability axioms, limit points, continuous functions, product topology, metric topology, quotient topology.	8
Unit-III: Connectedness Connected spaces, connected sets in R, components and path components.	8
Unit-IV: Compactness Compact spaces, compactness in metric spaces, local compactness, convergence of nets in topological spaces.	8
Unit-V: Countability and separation axioms Countability and separation axioms, normal spaces, Urysohn'slemma, Urysohn metrization theorem.	10
Total No. of Lectures	**42**

Text Books	1. Munkres J. R., *Topology*, Prentice Hall, NJ, 2000. 2. Simmons G. F., *Introduction to Topology and Modern Analysis*, International Student Edition, 1963.
References Books	1. Joshi K. D., *Introduction to General Topology*, New Age International, New Delhi, 2000. 2. Deshpande J. V., *Introduction to Topology*, Tata McGraw-Hill, 1988. 3. Dugundji J., *Topology*, Allyn and Bacon Inc., 1966.

Course Title	**Partial Differentials Equations**
Course Code	MA627
Credits	4
Course Category	CC
Year / Semester	I / II
Prerequisite Courses	Exposure to multivariable calculus and ordinary differential equations.
L T P	3 1 0
Course Objectives	The main aim of this course is to understand various analytical methods to find exact solution partial differential equations and their implementation to solve real life problems.
Course Outcomes	After studying this course the student will be able to **CO1**: solve the first-order linear and non-linear PDE's by using Lagrange's and Charpit's methods respectively. **CO2:** determine the solutions of linear PDE's of second and higher order with constant coefficients. **CO3:** classify second order PDE and solve standard PDE using separation of variable method. **CO4:** competent in solving linear PDEs using classical solution methods. **CO5:** solve PDEs in cylindrical and spherical coordinates.

Syllabus	**No. of Lectures**
Unit-I: First order PDE Basic definitions, Origin of PDEs, Classification, Geometrical interpretation. The Cauchy problem, the method of characteristics for Semi linear, quasi linear and Non-linear equations, complete integrals.	8
Unit-II: Second order PDE Definitions of Linear and Non-Linear equations, Linear Superposition principle, Classification of second-order linear partial differential equations into hyperbolic, parabolic and elliptic PDEs, Reduction to canonical forms ,solution of linear Homogeneous and non-homogeneous with constant coefficients, Variable coefficients, Monge's method.	10
Unit-III: Wave equation Solution by the method of separation of variables and integral transforms, Cauchy problem, Wave equation in cylindrical and spherical polar co-ordinates.	8
Unit-IV: Laplace and Diffusion Equations Solution by the method of separation of variables and transforms. Dirichlet's, Neumann's and Churchills problems, Dirichlet's problem for a rectangle, half plane and circle, Solution of Laplace equation in cylindrical and spherical polar coordinates.	8
Unit-V: Transform Method Fundamental solution by the method of variables and integral transforms, Duhamel's principle, Solution of the equation in cylindrical and spherical polar coordinates.	8
Total No. of Lectures	**42**

Text Books	1. SNEDDON N., Elements of PDE's, McGraw Hill Book company Inc., 2006. 2. DEBNATH L, Nonlinear PDE's for Scientists and Engineers, Birkhauser , Boston, 2007.
References Books	1. Treves F., Basic linear partial differential equations, Academic Press, 1975. 2. Smith M.G., Introduction to the theory of partial differential equations, Van Nostrand, 1967. 3. Rao Shankar, Partial Differential Equations, PHI, 2006.

Course Title	**Orthogonal Polynomials & Special Functions**
Course Code	MA646
Credits	4
Course Category	DSE
Year / Semester	I / II
Prerequisite Courses	
L T P	3 1 0
Course Objectives	The aim of the course is to (i) investigate and derive the properties of special functions, (ii) know the inter-relations between such functions and their representations in various forms, (iii) learn certain specific systems of orthogonal polynomials and their properties, and (iv) to obtain the generating functions of the polynomials.
Course Outcomes	After studying this course the student will be able to **CO1**: solve, expand and interpret solutions of many types of important differential equations by making use of special functions and orthogonal polynomials. **CO2**: derive the formulas and results of certain classical special functions and orthogonal polynomials by different methods. **CO3**: derive the generating relations involving special functions. **CO4**: achieve the knowledge to analyses the problems using the methods of special functions and orthogonal polynomials. **CO5**: describe the role of special functions and orthogonal polynomials in other areas of mathematics.

Syllabus	**No. of Lectures**
UNIT I: Gamma, Hypergeometric, and Bessel Functions Introduction; Gamma Function; Hypergeometric Functions: Definition and special cases, convergence, analyticity, integral representation, differentiation, transformations and summation theorems; Bessel Functions: Definition, connection with hypergeometric function, differential and pure recurrence relations, generating function, integral representation; Neumann polynomials, Neumann series and related results; Examples on above topics.	10
UNIT II: Legendre and Neumann Polynomials Legendre polynomials: (i) Generating function (ii) Special values (iii) Pure and differential recurrence relations (iv) Differential equation (v) Series definition (vi) Rodrigues' formula (vii) Integral representation; Neumann polynomials, Neumann series and related results; Examples on above topics.	8
Unit-III Hermite and Laguerre Polynomials Hermite polynomials: Results (i) to (vii) and expansion of x^n in terms of Hermite polynomials; Laguerre polynomials: Results (i) to (vii); Examples on above topics.	8
UNIT III: Orthogonal Polynomials Simple sets of polynomials; Orthogonal polynomials: Equivalent condition for orthogonality; Zeros of orthogonal polynomials; Expansion of polynomials; Three-term recurrence relation; Christoffel-Darboux formula; Normalization and Bessel's inequality; Orthogonality of Legendre, Hermite and Laguerre polynomials; Ordinary and singular points of differential equations, Regular and irregular singular points of hypergeometric, Bessel, Legendre, Hermite and Laguerre differential equations; Examples on above topics.	8

Unit-V: Generating Functions Generating functions of some standard forms including Boas and Buck type. Sister Celine's techniques for finding pure recurrence relation. Characterization: Appell, Sheffes and s-type characterization of polynomial sets.	8
Total No. of Lectures	**42**

Text Books	1. Rainville E. D., Special Functions, Chelsea Publishing Co., Bronx, New York, Reprint, 1971. 2. Marcellan F. and Assche W. Van , Orthogonal Polynomials and Special Functions: Computation and Applications, Lecture Notes in Mathematics, Springer, 2006.
References Books	1. Szego G., Orthogonal Polynomials, Memoirs of AMS, 1939. 2. Ismail M.E.H., Classical and Quantum Orthogonal Polynomials in One Variable, Cambridge University Press, 2005. 3. Chihara T.S,, An Introduction to Orthogonal Polynomials, Dover Publications, 2011. 4. McBride E. B., Obtaining Generating Functions, Springer Verlag, Berlin Heidelberg, 1971.

Course Title	**Fuzzy Sets and Applications**	
Course Code	MA647	
Credits	4	
Course Category	DSE	
Year / Semester	I / II	
Prerequisite Courses	Preliminary knowledge of Set Theory	
L T P	3 1 0	
Course Objectives	The objective of this course is to teach the students the need of fuzzy sets, arithmetic operations on fuzzy sets, fuzzy relations, possibility theory, fuzzy logic, and its applications.	
Course Outcomes	After studying this course the student will be able to **CO1**: construct the appropriate fuzzy numbers corresponding to uncertain and imprecise collected data. **CO2:** handle the problems having uncertain and imprecise data. **CO3:** find the optimal solution of mathematical programming problems having uncertain and imprecise data. **CO4:** know the concepts of fuzzy graph, fuzzy relation, fuzzy morphism and fuzzy numbers. **CO5:** deal with the fuzzy logic problems in real world problems.	
Syllabus		**No. of Lectures**
Unit-I: Fuzzy Sets Overview of classical sets, Membership function, A-cuts, Properties of a-cuts, Extension principle. Compliment, Intersections, Unions, Combinations of operations, Aggregation operations.		8
Unit-II: Fuzzy Arithmetic Fuzzy numbers, Linguistic variables, Arithmetic operations on intervals and numbers, Fuzzy equations.		8
Unit-III: Fuzzy Relations Crisp and fuzzy relations, Projections and cylindrical extensions, Binary fuzzy relations, Binary relations on single set, Equivalence, Compatibility and ordering Relations, Morphisms, Fuzzy relation equations.		10
Unit IV: Possibility Theory & Fuzzy Logic Fuzzy measures, Evidence and possibility theory, Possibility versus probability theory. Classical logic, Multivalued logics, Fuzzy propositions, Fuzzy qualifiers, Linguistic hedges.		8
Unit-V: Applications of Fuzzy Logic Washing machines, Control systems engineering, Power engineering and Optimization.		8
	Total No. of Lectures	**42**
Text Books	1. Klir G. J. and Folger T.A., Fuzzy Sets, Uncertainty and Information, 1st Edition edition, Prentice Hall Inc.,1988. 2. Klir G.J. and Yuan B., Fuzzy Sets and Fuzzy logic: Theory and Applications, PHI, 1997.	
References Books	1. Zimmermann H.J., Fuzzy Set Theory and its Applications, 4th Edition, Allied Publishers, 2001. 2. J. Yen and R. Langari, Fuzzy Logic: Intelligence, Control, and Information, Pearson Education, 2003.	

Course Title	**Statistical Inference**
Course Code	MA648
Credits	4
Course Category	DSE
Year / Semester	I / II
Prerequisite Courses	Exposure to basic concepts of statistics and probability.
L T P	3 1 0
Course Objectives	The course aims to shape the attitudes of learners regarding the field of statistics. Specifically, the course aim to motivate students in an intrinsic interest in statistical thinking and instill the belief that statistics is important for scientific research.
Course Outcomes	After studying this course the student will be able to **CO1**: describe the error and its significance in different types of sampling. **CO2:** construct point and interval estimators; evaluate their goodness (bias, variance, mean squared error). **CO3:** understand the concept of the sampling distribution of a statistic, and in particular describe the behavior of the sample mean. **CO4:** demonstrate understanding the estimation of mean and variance and respective one-sample and two-sample hypothesis tests. **CO5:** explain the large sample properties of sample mean.

Syllabus	**No. of Lectures**
Unit-I: Distributions The concept of sampling distribution, standard error and its significance, sampling distribution of Chi Square, t and F with derivations, properties of these distributions and their inter relations.	8
Unit-II: Estimation Problem of estimation; point estimation, interval estimation, criteria for a good estimator, unbiasedness, consistency, efficiency and sufficiency with examples.	8
Unit-III: Moments Method of moments and maximum likelihood and application of these method for obtaining estimates of parameters of binomial, Poisson and normal distributions, properties of M.L. E's (without proof), merits and demerits of these methods.	8
Unit-III: Testing of Hypothesis Statistical hypothesis, Null and alternative hypothesis, simple and composite hypothesis, two types of error, critical region, power of test, level of significance. Best Critical Region, NP Lemma, its applications to find most powerful in case of binomial. Poisson and normal distributions.	8
Unit IV: Test of significance Small sample tests based on t, F and Chi-square distribution and test based on normal distribution, confidence interval for single mean, difference of means and variance (only for normal case) confidence interval for single mean, difference of means and variance (only for normal case). Test of significance for large samples for attributes and variable, proportions and means, single sample, two samples (both paired and independent).	10
Total No. of Lectures	**42**

Text Books	1. Kale, B.K.: A First Course on Parametric Inference, Narosa Publishing House, 1999. 2. Rohatgi, V.K.: An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi, 1988. 3. Lehmann, E.L.: Theory of Point Estimation, Student Edition, 1986.
References Books	1. Lehmann, E.L.: Testing Statistical Hypotheses, Student Editions, 1986. 2. Rao, C.R.: Linear Statistical Inference and its Applications, Wiley Eastern, 1973. 3. Zacks, S.: Theory of Statistical Inference, Wiley, New York, 1971.

Course Title	**Integral Equation and Calculus of Variations**
Course Code	MA649
Credits	4
Course Category	DSE
Year / Semester	I / II
Prerequisite Courses	
L T P	3 1 0
Course Objectives	The main goal of this course is to introduce to students the fundamental concepts and some standard results of the integral equations, the methods of solving Integral Equations, the problems of the calculus of variations and its many methods and techniques without using deep knowledge of functional analysis.
Course Outcomes	After studying this course the student will be able to **CO1**. to recognize difference between Volterra and Fredholm Integral Equations, First kind and Second kind, homogeneous and inhomogeneous etc. **CO2**. to apply different methods to solve Integral Equations and fully understand the properties of geometrical problems. **CO3**. to understand the fundamental concepts of the space of admissible variations. **CO4**. to understand weak and a strong relative minimum of an integral. **CO5**. to exposed to the variational problems with moving boundaries.

Syllabus	**No. of Lectures**
Unit-I: **Preliminary Concepts** Definition and classification of linear integral equations. Conversion of initial and boundary value problems into integral equations. Conversion of integral equations into differential equations. Integro-differential equations.	8
Unit-II: Fredholm Integral Equations Solution of integral equations with separable kernels, Eigenvalues and Eigen functions. Solution by the successive approximations, and resolvent kernel. Solution of integral equations with symmetric kernels, Hilbert-Schmidt theorem, Green's function approach.	8
Unit-III: Fredholm Classical Theory Fredholm method of solution and Fredholm theorems.	8
Unit-IV: Volterra Integral Equations Successive approximations, Neumann series and resolvent kernel. Equations with convolution type kernels. Singular integral equations, Hilbert-transform, Cauchy type integral equations.	8
Unit-V: Calculus of Variations Basic concepts of the calculus of variations such as functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum, Euler's equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler's equations. Variational problem in parametric form. Functionals dependent on one or two functions, Derivation of basic formula, Variational problems with moving boundaries, Broken extremals: Weierstrass –Erdmann conditions.	10
Total No. of Lectures	**42**

Text Books	1. Jerry, A. J., Introduction to Integral Equations with Applications, Wiley Publishers (2nd Edition), 1999. 2. Kanwal R. P., Linear Integral Equations, Birkhäuser Bosten, (2nd Edition), 1997. 3. Weinstock R., Calculus of Variations with Applications to Physics and Engineering, Dover Publications, 1974.
References Books	1. Chambers, L. G., Integral Equations: A Short Course, International Text Book Company Ltd., 1976. 2. Gelfand, I. M., Fomin, S. V., Calculus of Variations, Dover Books, 2000.

Course Title	**Introduction to Python Programming**
Course Code	MA628
Credits	2
Course Category	SEC
Year / Semester	I / II
Prerequisite Courses	
L T P	0 0 4
Course Objectives	The objective of the course is to provide skills for writing PYTHON programs, to create simple programming scripts and functions, and to solve basic and advanced numerical and symbolic mathematics problems, and to visualize and present data.
Course Outcomes	After studying this course the student will be able to **CO1**: translate mathematical methods to PYTHON code. **CO2:** use in-built functions to complete the different types of task.. **CO3:** use python software to solve mathematical problems. **CO4:** create and control simple plot and user-interface graphics objects in Python. **CO5:** use Python effectively to analyze and visualize data.

Syllabus	**No. of Lectures**
Unit-I: Basics of Python Programming Brief Introduction, Installation of PYTHON, Use of PYTHON, Key features, Introduction to PYTHON Software and different editors, Data files and Data types: Character and string, Arrays and vectors, Column vectors, Row vectors.	4
Unit-II: Functions Assigning value to variables, input functions, Eval functions, formatting number and strings, python inbuilt functions.	4
Unit-III: Operators, Expressions & Control Flow Arithmetic operators; unary operators, binary operators, Bitwise operator, Compound assignment operator. Decision statements, Loop control, Functions, Strings, Lists, List processing: searching & sorting.	4
Unit-IV: **Python Packages** Introduction to Scientific Python and Numpy, Program for Arithmetic operations on functions and equations, Factorizing and Expanding Expressions, Substituting Values, Solving Equations, program for Matrix operations, and Trigonometric functions, programs to solve mathematical problems by user defined functions, Programs for Symbolic Math.	6
Unit-V: Plotting with Python Introduction to matplotlib, Plotting and Graphics.	4
Total No. of Lectures	**22**

Text Books	1. Saha Amit, Doing Math with Python. William Pollock (2015).
References Books	1. Hall Tim and Stacey J. P. Python 3 for Absolute Beginners. (2009).

Course Title	**Fluid Dynamics**
Course Code	MA706
Credits	4
Course Category	CC
Year / Semester	II / III
Prerequisite Courses	Nil
L T P	3 1 0
Course Objectives	The objective is to provide the student with knowledge of the fundamentals of fluid dynamics and an appreciation of their application to real world problems.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the basic principles of fluid mechanics, such as Lagrangian and Eulerian approach, conservation of mass etc. **CO2:** use Euler and Bernoulli's equations and the conservation of mass to determine velocity and acceleration for incompressible and inviscid fluid. **CO3:** understand the concept of rotational and irrotational flow, stream functions, velocity potential, sink, source, vortex etc. **CO4:** analyze simple fluid flow problems (flow between parallel plates, flow through pipe etc.) with Navier - Stoke's equation of motion. **CO5:** understand the phenomenon of flow separation and boundary layer theory.

Syllabus	**No. of Lectures**
Unit-I: Introduction to fluid flows Real and ideal fluids, velocity, acceleration, streamlines, pathlines, steady and unsteady flows, velocity potential, vorticity vector, local and particle rates of change, equation of continuity, conditions at a rigid boundary.	8
Unit-II: Conservation laws Pressure at a point in a fluid, boundary conditions of two inviscid immiscible fluids, Euler’s equations of motion, Bernoulli’s equation, some potential theorems, flows involving axial symmetry.	8
Unit-III: Analysis and classification of fluid motion Two dimensional flows, use of cylindrical polar co-ordinates, stream function, complex potential for two-dimensional flows, irrotational, incompressible flow, complex potential for standard two-dimensional flows, two dimensional image systems, Milne-thomson circle theorem, theorem of Blasius, mathematical formulation and solution procedures.	8
Unit-IV: Dynamic similarity Dimensional analysis, Buckingham's pi theorem, dynamic similarity, vorticity diffusion, steady flow between parallel plates, steady flow in a circular pipe, steady flow between two co-axial cylinders.	8
Unit-V: Flow instability Navier-Stokes equations of motion and some exact solutions, Flows at small Reynolds numbers, boundary layer theory, Method of normal modes, Benard problem, double-diffusive instability, Taylor problem, Kelvin-Helmholtz instability, instability of continuously stratified parallel flows.	10
Total No. of Lectures	**42**

Text Books	1. Chorlton F., Textbook of Fluid Dynamics, CBS Publishers, 1998. 2. Kundu P. K. and Cohen I. M., Fluid Mechanics, Academic Press London, 2002.
References Books	1. Batechelor G. K., An Introduction to Fluid Dynamics, Cambridge Press, 2nd Ed., 2000. 2. White F. M., Fluid Mechanics, McGraw Hill, New York, 8th Ed., 2015. 3. Drazin P. G. and Reid W. H., Hydrodynamic Stability, Cambridge Press, 2nd Ed., 2004.

Course Title	**Functional Analysis**
Course Code	MA707
Credits	4
Course Category	CC
Year / Semester	II / III
Prerequisite Courses	Exposure to real analysis, topology and linear algebra.
L T P	3 1 0
Course Objectives	To introduce the definitions and illustrations of several normed spaces, linear operators and derive their properties, and elaborate on basic theorems like open and closed mapping theorem, Hahn-Banach theorem and uniform boundedness theorem.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the normed linear spaces, Banach space and Dual spaces. **CO2**: understand inner product spaces, orthogonality and Hillbert spaces. **CO3**: distinguish between finite and infinite dimensional spaces. **CO4**: apply linear operators in the formulation of differential and integral equations

Syllabus	**No. of Lectures**
Unit-I: Algebraic systems Linear spaces and dimension of spaces, linear transformations and linear operators, algebras, normed linear spaces, definition of Banach spaces with examples.	10
Unit-II: Banach spaces Continuous linear transformations, The Hahn-Banach theorem, natural imbedding of a space into its second conjugate space, open mapping theorem, closed graph theorem, conjugate of an operator, Banach Steinhaus's uniform boundedness theorem.	12
Unit-III: Hilbert spaces Inner product spaces, definition and properties, Schwarz inequality and theorems, orthogonal complements, orthonormal sets, Bessel's inequality, complete orthonormal sets, conjugate space H***.**	12
Unit-IV: Operators on Hilbert spaces Adjoint of an operator, self-adjoint operators, normal and unitary operators, projections.	8
Total No. of Lectures	**42**

Text Books	1. Simmons G. F., Introduction to Topology and Modern Analysis, Tata McGraw-Hill International Ed.2004, Fourteenth reprint 2010. 2. Nair M. T., Functional Analysis: A First Course, PHI-Learning (Formerly: Prentice-Hall of India), New Delhi, 2002.
References Books	1. Kreyszig E., Introductory Function Analysis with Applications, John Wiley and Sons, 2010. 2. Rudin W., Functional Analysis, TMH Edition, 2006. 3. Limaye B. V., Functional Analysis, New Age International, 2nd Ed., 1996.

Course Title	**Operation Research**
Course Code	MA708
Credits	4
Course Category	CC
Year / Semester	II / III
Prerequisite Courses	NIL
L T P	3 1 0
Course Objectives	The course aims to introduce students to the use of quantitative methods and techniques for effective decisions–making; model formulation and applications that are used in solving business decision problems.
Course Outcomes	After studying this course the student will be able to **CO1**: Formulate some real-life problems into Linear programming problems and use the simplex method to find an optimal vector for the standard linear programming problem. **CO2**: Concept of duality and prove the optimality condition for feasible vectors for Linear programming problems and Dual Linear programming problems. **CO3**: find an optimal solution to a transportation problem and assignment problem. **CO4**: understand integer and mixed integer programming and its role in the real world. **CO5**: understand and describe games & strategies and inventory models.

Syllabus	**No. of Lectures**
Unit-I: Basics of LPP Review of LPP: Types of OR models, formulation of LPP, Graphical method, infeasible and unbounded LPPs, simplex method, Big-M method, Two-Phase method, Revised Simplex method.	10
Unit-II: Duality theory Duality and duality theorems, Dual simplex method, sensitivity analysis.	8
Unit-III: Transportation problems Transportation problems and assignment problems.	7
Unit-IV: Integer programming Cutting plane and branch and bound techniques for all integer and mixed integer programming problems.	5
Unit-V: Game Theory and Inventory Models Graphical method and linear programming method for rectangular games, saddle point, and the notion of dominance. Inventory models: Concept of EOQ, Inventory problems with no shortages, Inventory problems with shortages, Inventory Control Techniques.	13
Total No. of Lectures	**43**

Text Books	1. Swarup Kanti, Gupta P. K. and Man Mohan, An Introduction to management Science: Operations Research, Sultan Chand & Sons, Educational Publishers, New Delhi, 16th Ed., 2012. 2. Ravindran A., D. T. Phillips and J. J. Solberg, Operations Research: Principles and Practice, John Wiley and Sons, NY, 2nd Ed., 2012.
References Books	1. Bronson R. and Naadimuthu G., *Schaum's Outline of Operations Research*, McGraw-Hill Education, 1981. 2. Hillier F. S. and Liberman G. J., Introduction to Operation Research, McGraw-Hill, 7th Ed., 2001.

Course Title	**Operation Research**
Course Code	MA708
Credits	4
Course Category	CC
Year / Semester	II / III
Prerequisite Courses	NIL
L T P	3 1 0
Course Objectives	The course aims to introduce students to use quantitative methods and techniques for effective decisions–making; model formulation and applications that are used in solving business decision problems.
Course Outcomes	After studying this course the student will be able to **CO1**: formulate some real life problems into Linear programming problem. **CO2**: use the simplex method to find an optimal vector for the standard linear programming problem and the corresponding dual problem. **CO3**: prove the optimality condition for feasible vectors for Linear programming problem and Dual Linear programming problem. **CO4**: find optimal solution of transportation problem and assignment problem **CO5**: describe the steady-state solutions of Markovian queuing models.

Syllabus	**No. of Lectures**
Unit-I: Basics of LPP Different types of OR models, convex sets, graphical method, infeasible and unbounded LPP's, simplex method, big-M method, two phase method, revised simplex method.	8
Unit-II: Duality theory Dual simplex method, sensitivity analysis, parametric linear programming.	8
Unit-III: Transportation problems Transportation problems and assignment problems.	8
Unit-IV: Integer programming Cutting plane and branch and bound techniques for all integer and mixed integer programming problems.	8
Unit-V: Game theory Graphical method and linear programming method for rectangular games, saddle point, notion of dominance, queuing theory, steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited space, M/G/1, inventory models.	10
Total No. of Lectures	**42**

Text Books	1. Taha H. A., Operations Research: An Introduction, MacMillan Pub Co., NY, 9th Ed., 2013. 2. Ravindran A., D. T. Phillips and J. J. Solberg, Operations Research: Principles and Practice, John Wiley and Sons, NY, 2nd Ed., 2012.
References Books	1. Bronson R. and Naadimuthu G., Schaum's Outline of Operations Research, McGraw-Hill Education, 1981. 2. Hillier F. S. and Liberman G. J., Introduction to Operation Research, McGraw-Hill, 7th Ed., 2001.

Course Title	**Differentiable Manifold**
Course Code	MA709
Credits	4
Course Category	CC
Year / Semester	II / III
Prerequisite Courses	Calculus/real analysis of functions of one and several variables up to and including the implicit and inverse function theorem and linear algebra.
L T P	3 1 0
Course Objectives	The primary objective of this course is to provide basic knowledge of manifolds, sub manifolds and geometry of manifolds.
Course Outcomes	After studying this course the student will be able to **CO1**: understand about differentiation of functions of several variables, tangent vector, and vector field. **CO2:** understand the differential forms and Connections. **CO3:** describe the covectors, covariant and contravariant tensors **CO4:** understand the torsion and curvature of a connection, structure equation of Cartan, Bianchi's identities. **CO5:** understand the affine connection, parallelism, Geodesic covariant differentiation of tensors.

Syllabus	**No. of Lectures**
UNIT I: Calculus of ℝn Differentiable functions from ℝn → ℝm, Chain rule, Directional derivatives, Differential of a map, Chain rule for differentials, Inverse mapping theorem, Implicit function theorem.	8
UNIT II: Manifold and its differentiable structure Topological manifolds, Differentiable atlas, Smooth maps, Diffeomorphism, Equivalent atlases, Differentiable structure on a manifold, Space of smooth maps, Tangent vectors and tangent space, Differential of a smooth map.	12
UNIT III: Submanifolds, Vector fields and Covectors Immersion, Embedding and Submanifolds, Vector fields, Lie algebra of vector fields, Integral curve of a vector field, Covectors and Cotangent spaces, Pull back of a linear differential form, One parameter group of transformation, Exponential map, Covariant and Contravariant tensors, Laws of transformation for the components of tensors.	12
UNIT IV: Differential forms and Connection Differential forms, Exterior product, Grassman algebra of forms, Exterior derivative, Affine Connection, Parallelism, Geodesic Covariant differentiation of tensors, Torsion and Curvature of a Connection, Structure equation of Cartan, Bianchi's identities.	10
Total No. of Lectures	**42**

Text Books	1. Boothby W. M., An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press, Revised Ed, 2003.
References Books	1. Matsushima Yozo., Differentiable Manifolds, Blue Collar Scholar/Kindle; 2nd Edition, 2019. 2. Kumaresan S., A Course in Differential Geometry and Lie groups, Hindustan Book Agency, 2002.

Course Title	**Mathematical Modelling and Simulations**
Course Code	MA746
Credits	4
Course Category	DSE
Year / Semester	II / III
Prerequisite Courses	Differential equation and optimization theory.
L T P	3 1 0
Course Objectives	The goal of the course is to introduce students to the elements of the mathematical modeling process, the basic rules of logic, including the role of axioms or assumptions, logical arguments, and rigorous proofs and formulation of conjectures by abstracting general principles from examples.
Course Outcomes	After studying this course the student will be able to **CO1**: translate everyday situations into mathematical statements (models) which can be solved/analyzed, validated, and interpreted in context. **CO2:** identify assumptions which are consistent with the context of the problem and which in turn shape and define the mathematical characterization of the problem. **CO3:** revise and improve mathematical models so that they will better correspond to empirical information and/or will support more realistic assumptions. **CO4:** assess the validity and accuracy of the approach relative to the problem requirement. **CO5:** apply tools to mathematically analyze and solve contemporary problems.

Syllabus	**No. of Lectures**
Unit I: Introduction Models, reality, Properties of models, model classification and characterization, steps in building mathematical models, sources of errors, and dimensional analysis. Modeling using Proportionality, Modeling using Geometric similarity; graphs of functions as models.	8
Unit II: Modeling Modeling using Proportionality, Modeling using Geometric similarity; graphs of a functions as models. Fitting models to data graphically, Analytic methods of model fitting, Applying the least square criterion, High order polynomial models, Cubic Spline models.	8
Unit III: Discrete Probabilistic & Optimization Modeling Probabilistic modeling with discrete system; Modeling components & System Reliability; Linear Regression. Linear Programming – Geometric solutions, Algebraic Solutions, Simplex Method and Sensitivity Analysis.	8
Unit IV: Modeling with a Differential Equations Population Growth, Graphical solutions of autonomous differential equations, numerical approximation methods-- Euler's Method and R.K. Method. Predator Prey Model, Epidemic models, Euler's method for systems of Differential equations.	8

Unit V : Simulation Modeling Discrete-Evnt Simulation, generating random numbers; simulating probabilistic behavior; Simulation of Inventory model and Queuing Models using C program. Other Types of simulation—Continuous Simulation, Monte-Carlo simulation. Advantages, disadvantages and pitfalls of simulation		10
Total No. of Lectures		**42**
Text Books	1. Frank R. Giordano, Mawrice D Weir & William P. Fox, A first course in Mathematical Modeling, 3rd Edition, Thomson Brooks/Cole, Vikas Publishing House (P) Ltd., 2003. 2. Murray J.D., Mathematical Biology – I, 3rd Edition, Springer International Edition, 2004. 3. Kapoor J.N., Mathematical Models in Biology and Medicine, East West Press, New Delhi, 1985.	
References Books	1. Robert E. Shannon, Systems Simulation: The Art and Science, Prentice Hall, U.S.A, 1975. 2. Law Averill M. & Kelton W. David, Simulation Modeling and Analysis, 3rd Edition, Tata McGraw Hill, 1999.	

Course Title	**Introduction to Mathematical Finance**
Course Code	MA747
Credits	4
Course Category	DSE
Year / Semester	II / III
Prerequisite Courses	Exposure to multivariable calculus, linear algebra, and probability.
L T P	3 1 0
Course Objectives	The goal of the course is to provide the students with knowledge of a range of mathematical and computational techniques that are required for a wide range of quantitative positions in the financial sector and to develop student appreciation of the major issues involved in rigorous advances in the area of financial mathematics.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the mathematical foundations of quantitative finance. **CO2**: understand the standard and advanced quantitative methodologies and techniques of importance to a range of careers in investment banks and other financial institutions. **CO3**: appreciation of emerging theory and techniques in the area of financial mathematics. **CO4**: create and evaluate potential models for the price of shares. **CO5**: construct, evaluate and analyze models for investments and securities.

Syllabus	**No. of Lectures**
Unit-I: Fundamentals of the financial markets Fundamentals of the financial markets, meaning of notions like asset portfolio derivatives (example: futures, options forwards etc.).	8
Unit-II: Asset pricing model Binomial asset pricing model under no arbitrage condition single-period model, multi-period model. Risk-neutral probabilities, martingales in the discrete framework, risk-neutral valuation of European and American options under no arbitrage condition in the Binomial framework.	8
Unit-III: Black-Scholes formula Random walk and Brownian motion, Geometric Brownian motion, Black-Scholes formula, properties of Black-Scholes option cost, estimation of sigma, pricing American put option and European call option.	8
Unit-IV: Portfolio management Risk, risk and expected return on a portfolio, capital asset pricing model: capital market line, beta factor and security market line.	8
Unit-V: Arbitrage: Arbitrage theorem, multi-period binomial model, hedging: delta hedging, Greek parameters, hedging business risk, value at risk, speculating with derivatives.	10
Total No. of Lectures	**42**

Text Books	1. Ross S. M., An Introduction to Mathematical Finance, Cambridge University Press, 1999. 2. Capinski M and Zastawniak T., Mathematics for Finance: An Introduction to Financial Engineering, Springer-Verlag, London, 2003.
References Books	1. Luenberger D. G., Investment Science, Oxford University Press, NY, 1998. 2. Hull J. C., Options, Futures and Other Derivatives, Prentice Hall Inc., Upper Saddle River, 4th Ed., 2000. 3. Lamberton D and Lapeyre B, Introduction to Stochastic Calculus Applied to Finance, Chapman and Hall, London, 1996.

Course Title	**Statistics through SPSS**
Course Code	MA769
Credits	4
Course Category	DSE
Year / Semester	II / III
Prerequisite Courses	Exposure to statistics.
L T P	3 0 2
Course Objectives	To familiar and to develop learning mindsets to analyze statistical data through SPSS software and to learn the basic syntax, coding and vocabulary to aid in data analysis.
Course Outcomes	After studying this course the student will be able to **CO1**: learn basic workings of SPSS and perform a wide range of data management tasks in SPSS with the understanding of different types of data and scales of their measurement. **CO2:** plot various kinds of chart and graph for analysis of data. **CO3:** obtain descriptive statistics and basic inferential statistics for comparisons using SPSS. **CO4:** apply basic statistical parametric and non-parametric tests for the given data. **CO5:** carry out correlation, regression and factor analysis through the use of SPSS.

Syllabus	**No. of Lectures**
Unit-I: Data Data: Qualitative and quantitative data, Cross-sectional and time series data, Univariate and multivariate data. Scales of measurement of data. SPSS data file: Opening a data file in SPSS, SPSS Data Editor, Creating a data file, Editing and manipulating data, Missing values, Editing SPSS output, Copying SPSS output, Printing from SPSS, Importing data.	8
Unit-II: Descriptive statistics with SPSS Measures of central tendency, Dispersion, Skewness, Kurtosis.	8
Unit-III: Charts and graphs with SPSS Frequencies, Bar charts, Pie charts, Line graphs, Histograms, Box plots.	8
Unit – IV: Statistical tests using SPSS Normality tests, t-tests, F-test, One way and Two way ANOVA, Non-parametric tests-Chi Square, Spearman rank, Maan Whitney U and Wilcoxon signed rank test.	8
Unit – V: Correlation and regression using SPSS Linear correlation and regression, Multiple regression. Factor analysis using SPSS.	10
Total No. of Lectures	**42**

Text Books	1. Gupta S.L. and Gupta H., SPSS for Researchers, International Book House Pvt. Ltd, 2011. 2. Field A., Discovering Statistics using SPSS, SAGE Publications, 4th Ed. 2013.
References Books	1. Gupta V., SPSS for Beginners, VJ Books Inc., 1999. 2. Rajathi A. and Chandran P., SPSS for you, MJP Publishers, 2010.

Course Title	**Documentation in Latex**
Course Code	MA716
Credits	2
Course Category	SEC
Year / Semester	II / III
Prerequisite Courses	
L T P	0 0 4
Course Objectives	Installation and basic handling of the software, teach the basics of Latex, introduce advanced techniques for writing mathematics, introduce advanced techniques for editing and formatting documents and preparing large documents such as use of Latex in daily academic and official work.
Course Outcomes	After studying this course the student will be able to **CO1**: Execute typesetting of journal articles, technical reports, thesis, books, and slide presentations. **CO2:** Control over large documents containing sectioning, cross-references, tables and figures. **CO3:** Typesetting of complex mathematical formulae. **CO4:** Advanced typesetting of mathematics with AMS-LaTeX. **CO5:** Automatic generation of table of contents, bibliographies and indexes.

Syllabus	**No. of Lectures**
Unit-I: **Installation** Installation of Latex and editors. Introduction of Latex and different editors.	4
Unit-II: Typesetting Basic and advanced document typesetting. Mathematical equation typing and editing. Typesetting of Journal articles, Technical reports, Thesis, Books.	4
Unit-III: Tables & Figures Inclusion of figures and tables.	4
Unit-IV: Bibliography Preparation of bibliography.	4
Unit-V: Beamer Slide preparation using Beamer.	4
Total No. of Lectures	**20**

Text Books	1. Lamport Laslie, Latex: A Document Preparation System, (2nd Edition), 1994 .
References Books	1. Gratzer George, Practical Latex, Springer, 2014.

Course Title	**Measure Theory and Integration**	
Course Code	MA717	
Credits	4	
Course Category	CC	
Year / Semester	II / IV	
Prerequisite Courses	Real analysis	
L T P	3 1 0	
Course Objectives	To develop an understanding of the basic concepts of the theory of measure and integration, the main proof techniques in the field, and apply the theory abstractly and concretely, and use measure theory in Riemann integration and work with Lebesgue measure and to exploit its special properties.	
Course Outcomes	After studying this course the student will be able to **CO1**: understand how Lebesgue measure on R is defined, **CO2**: understand basic properties are measurable functions, **CO3**: understand how measures may be used to construct integrals, **CO4**: know the basic convergence theorems for the Lebesgue integral, **CO5**: understand the relation between differentiation and Lebesgue integration.	
Syllabus		**No. of Lectures**
Unit I: Lebesgue Measure Lebesgue Outer Measure, The s-Algebra of Lebesgue Measurable Sets, Outer and Inner Approximation of Lebesgue Measurable Sets, Countable Additivity, Continuity and the Borel-Cantelli Lemma, Non-measurable Sets.		8
Unit-II: Lebesgue Function The Cantor Set and the Canton-Lebesgue Function, Sums, Products and Compositions of Lebesgue Measurable Functions, Sequential Pointwise Limits and Simple Approximation, Littlewoods's three principles, Egoroff's Theorem and Lusin's Theorem.		8
Unit III: The Lebesgue Integration The Lebesgue Integral of a Bounded Measurable Function over a Set of Finite Measure, The Lebesgue Integral of a Measurable Nonnegative Function; The General Lebesgue Integral; Countable Additivity and Continuity of Integration, Uniform Integrability, Uniform Integrability and Tightness, Convergence in measure, Characterizations of Riemann and Lebesgue Integrability.		8
Unit IV: Differentiation and Lebesgue Integration Continuity of Monotone Functions, Differentiation of Monotone Functions, Functions of Bounded Variation, Absolutely Continuous Functions, Integrating Derivatives.		8
Unit IV: The Lp Spaces Normed Linear Spaces, The Inequalities of Young, Hölder and Minkowski, The $\mathbf{L^p}$ spaces, Approximation and Separability, The Riesz Representation for the Dual of $\mathbf{L^p}$, Weak Sequential Convergence in $\mathbf{L^p}$, Weak Sequential Compactness, The Minimization of Convex Functionals.		10
Total No. of Lectures		**42**

Text Books	1. Royden I. H.L. and Fitzpatrick P.M., Real Analysis, 4th Ed. New Jersey: Pearson Education Inc., 2013.
References Books	1. Halmos P. R., Measure Theory, Springer, 2014. 2. Munroe M.E., Introduction to measure and integration, Addison Wesley, 1959. 3. Barra G. de, Measure theory and integration, New Age, 1981. 4. Jain P.K. and Gupta V.P., Lebesgue measure and integration, New Age, 1986.

Course Title	**Dynamical Systems**
Course Code	MA727
Credits	4
Course Category	DSE
Year / Semester	II / IV
Prerequisite Courses	Fluid Dynamics
L T P	3 1 0
Course Objectives	The goal of the course to introduce the students with the concepts of well-posedness of differential equations, to familiarize with Bifurcations in 1Dand 2D flows, chaos, and exposure to stability analysis.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the Lipschitz condition, well-posedness of differential equation and contraction mapping theorem. **CO2:** describe the stability and bifurcation. **CO3:** understand nonlinear autonomous system in 2D flows. **CO4:** apply variable gradient method. **CO5:** understand the chaos and attractors.

Syllabus	**No. of Lectures**
Unit-I: Mathematical preliminaries Open and closed sets, compact set, dense set, continuity of functions, Lipschitz condition, smooth functions, vector space, normed linear space, inner product space, well-posedness of ordinary differential equations, Lipschitz continuity and contraction mapping theorem.	9
Unit-II: One-dimensional flows Fixed points and stability, linear stability analysis, saddle- node bifurcation, transcritical bifurcation, pitchfork bifurcation, flows on the circle.	9
Unit-III: Two-dimensional flows Linear systems, nonlinear autonomous systems, phase portraits, fixed points and linearization, conservative systems, index theory, limit cycles, Poincare Bendixson theorem, Bendixson's criteria, Lienard systems.	10
Unit-IV: Lyapunov stability Variable gradient method, LaSalle's invariance property, transcritical and pitchfork bifurcations, Hopf bifurcation, Poincare maps.	10
Unit-V: Chaos Introduction to chaos and attractors.	4
Total No. of Lectures	**42**

Text Books	1. Strogatz S. H., Nonlinear Dynamics and Chaos, Perseus books publishing, 1994. 2. Ricardo H. J., A Modern Introduction to Differential Equations, Academic Press, 2nd Ed., 2009. 3. Khalil H. K., Nonlinear Systems, PHI, 1996.
References Books	1. Wiggins S., Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer, 1996. 2. Meiss J. D., Differential Dynamical Systems, SIAM, 2007. 3. Grimshaw R., Nonlinear Ordinary Differential Equations, Blackwell Scientific Publications, 1990.

Course Title	**Number Theory and Cryptography**
Course Code	MA719
Credits	4
Course Category	CC
Year / Semester	II / IV
Prerequisite Courses	Linear algebra and Discrete Mathematics
L T P	3 1 0
Course Objectives	The goal of the course is to give a simple account of classical number theory, prepare students to graduate-level courses in number theory and algebra, and to demonstrate applications of number theory and exposure to cryptography.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the properties of divisibility and prime numbers, compute the greatest common divisor and least common multiples and handle linear Diophantine equations. **CO2**: understand the operations with congruences, linear and non-linear congruence equations **CO3**: understand and use the theorems: Chinese Remainder Theorem, Lagrange theorem, Fermat's theorem. **CO4**: understand continue fractions and will be able to approximate reals by rationales. **CO5**: understand the basics of RSA security and be able to break the simplest instances.

Syllabus	**No. of Lectures**
Unit 1: Prime numbers and divisibility, Number system, Divisibility and properties, Prime numbers factorization, Fundamental theorem of arithmetic, Euclid's lemma, Division algorithm, Fermat numbers and applications, Linear Diophantine equation, prime counting function, Goldbach conjecture.	12
Unit 2: Mobius function □(n) and properties, Divisor sum formula for □(n), Euler totient function □(n), Divisor sum formula for □ (n), Relation connecting □ and □□□Product formula for □ (n), Multiplicative functions.	11
Unit 3: Congruence relation, Basic properties, Congruence and equivalence relation, Simple applications, Residue classes, Linear congruences, Congruence relation conditions for many solutions, Euler- Fermat theorem, Little Fermat theorem, Chinese reminder theorem.	11
Unit 4: Public key encryption, RSA encryption and decryption, the equation $x^2 + y^2 = z^2$, Fermat's Last theorem.	8
Total No. of Lectures	**42**

Text Books	1. David Sankara and Burton M., Elementary Number Theory, 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.
References Books	1. Jones A. & Jones M., Elementary Number Theory, Springer publications, 1998. 2. Stein William, Elementary Number Theory, Springer 2009.

Course Title	**Classical Mechanics**
Course Code	MA759
Credits	4
Course Category	CC
Year / Semester	II / IV
Prerequisite Courses	Exposure to Newton's laws and basic physics concepts.
L T P	3 1 0
Course Objectives	To develop the understanding of moments of inertia and its applications in the dynamics of a rigid body rotating about a fixed point, concept of geometrical equations and Lagrange's equations of motion of a rigid body, principles of Hamiltonian, and introduction to Lagrange and Poisson brackets and its applications.
Course Outcomes	After studying this course the student will be able to **CO1**: study the path described by the particle moving under the influence of central force. **CO2**: apply the concept of system of particle in finding moment inertia, directions of principle axes. **CO3**: apply Euler's dynamical equations for studying rigid body motions. **CO4**: represent the equation of motion for mechanical systems using the Lagrangian and Hamiltonian formulations of classical mechanics. **CO5**: obtain canonical equations using different combinations of generating functions and subsequently developing Hamilton Jacobi method to solve equations of motion.

Syllabus	**No. of Lectures**
Unit – I: Moment of Inertia Moments and products of inertia, Angular momentum of a rigid body, Principal axes and principal moment of inertia of a rigid body, Kinetic energy of a rigid body rotating about a fixed point, Momental ellipsoid and equimomental systems, Coplanar mass distributions, General motion of a rigid body. (Relevant topics from the book of Chorlton).	8
Unit – II: Free & constrained systems Constraints and their classification, Holonomic and non-holonomic systems, Degree of freedom and generalized coordinates, Virtual displacement and virtual work, Statement of principle of virtual work (PVW), Possible velocity and possible acceleration, Ideal constraints, General equation of dynamics for ideal constraints,	8
Unit-II: Lagrange equations Lagrange equation of the first kind. D' Alembert principle, Independent coordinates and generalized forces, Lagrange equations of the second kind, Generalized velocities and accelerations. Uniqueness of solution, Variation of total energy for conservative fields. Lagrange variable and Lagrangian function $L(t, Q_i, \dot{q}_i)$, Lagrange equations for potential forces, Generalized momenta pi.	8
Unit – III : Hamiltonian equation Hamiltonian variable and Hamiltonian function, Donkin theorem, Ignorable coordinates, Hamilton canonical equations, Routh variables and Routh function R, Routh equations, Poisson Brackets and their simple properties, Poisson identity, Jacobi – Poisson theorem. Hamilton action and Hamilton principle, Poincare – Carton integral invariant, Whittaker equations, Jacobi equations, Lagrangian action and the principle of least action.	8

Unit-V: Canonical Transformation Necessary and sufficient condition for a canonical transformation, Univalent Canonical transformation, Free canonical transformation, Hamilton-Jacobi equation, Jacobi theorem, Method of separation of variables in HJ equation, Lagrange brackets, Necessary and sufficient conditions of canonical character of a transformation in terms of Lagrange brackets, Jacobian matrix of a canonical transformation, Conditions of canonicity of a transformation in terms of Poison brackets, Invariance of Poisson Brackets under canonical transformation.		10
	Total No. of Lectures	**42**
Text Books	1. Gantmacher F., *Lectures in Analytic Mechanics*, MIR Publishers, Moscow, 1975. 2. Panat P.V., *Classical Mechanics*, Narosa Publishing House, New Delhi, 2005. 3. Rana N.C. and Joag P.S., *Classical Mechanics*, Tata McGraw- Hill, New Delhi, 1991.	
References Books	1. Louis N. Hand and Janet D. Finch, *Analytical Mechanics*, CUP, 1998. 2. Sankra Rao K., *Classical Mechanics*, Prentice Hall of India, 2005. 3. Chorlton F., *Textbook of Dynamics*, CBS Publishers, New Delhi.	

Course Title	**Stochastic Processes**
Course Code	MA756
Credits	4
Course Category	DSE
Year / Semester	II / IV
Prerequisite Courses	Probability and Linear algebra.
L T P	3 1 0
Course Objectives	The aim of this course is to provide a good understanding of the key concepts of stochastic processes.
Course Outcomes	After studying this course the student will be able to **CO1**: understand the definition, classification of Stochastic processes and Markov chains. **CO2:** define the concept of a homogeneous Poisson process, and derive the form of the distribution of the inter-arrival times. **CO3:** decide whether a birth-death process has a stationary distribution. **CO4:** calculate the expected number of renewals in a renewal process. **CO5:** define the concepts of a reliability function and k-out-of-n standby system.

Syllabus	**No. of Lectures**
Unit- I Stochastic Processes: definition, classification and examples. Markov Chains: definition and examples, Transition matrix, Order of a Markov chain, Markov chain as graphs.	8
Unit – II Higher transition probabilities, Classification of states and chains. Determination of higher transition probabilities. Poisson Process: Introduction, Postulates, Properties and related distributions.	10
Unit – III Pure birth process. Birth and death process: Immigration-emigration process, Definitions and simple examples of renewal process in discrete and continuous time, Regenerative stochastic processes, Markov renewal, and semi-Markov processes.	12
Unit – IV Reliability, systems with components in series, Systems with parallel components, k-out-of-n systems, Non-series parallel systems, Systems with mixed mode failures. Standby redundancy: Simple standby system, k-out-of-n standby system.	12
Total No. of Lectures	**42**

Text Books	1. Ross, S. M., "Stochastic Processes" Wiley India Pvt. Ltd., 2nd Ed., 2008. 2. Hoel, P.G. and Stone, C.J., "Introduction to Stochastic Processes", Waveland Press, 1986.
References Books	1. Medhi J., Stochastic Processes, New Age International Publishers, 2009. 2. Balagurusami E., Reliability Engineering, Tata McGraw Hill, New Delhi, 1984.

Course Title	**Numerical Solutions of PDEs**
Course Code	MA758
Credits	4
Course Category	DSE
Year / Semester	II / IV
Prerequisite Courses	
L T P	3 0 2
Course Objectives	Introduce the finite difference schemes (FDS), order of accuracy of a scheme, concept of stability convergence, dissipation and dispersion, and exposed to FDS for hyperbolic, parabolic and elliptic PDE's.
Course Outcomes	After studying this course the student will be able to **CO1**: apply FDS to solve partial differential equations. **CO2:** describe the boundary conditions for different schemes. **CO3:** understand the convergence estimate for parabolic equation, well-posed, and stable stable initial BVP. **CO4:** solve parabolic and elliptic PDEs with ADI schemes and FDS respectively. **CO5:** apply finite difference schemes to solve Poisson's equation.

Syllabus	**No. of Lectures**
Unit-I: Linear stability and convergence Introduction to hyperbolic PDE's, finite difference schemes, convergence and consistency, CFL number and Fourier and Von Neumann stability analysis for FDS.	8
Unit-II: Dissipation and dispersion Order of accuracy of LxW and Crank-Nicolson finite difference schemes boundary condition, Thomas algorithm, dissipation and dispersion.	8
Unit-III: Parabolic PDE's Parabolic systems and boundary conditions, finite difference schemes for parabolic and convection diffusion equations, ADI scheme on square, boundary conditions and stability for ADI schemes.	8
Unit-IV: Well-posed systems and estimations The theory of well-posed IVPs scalar and systems, convergence estimates for smooth and non-smooth initial conditions, convergence estimate for parabolic differential equations, Lax-Richmyer equivalence theorem, well-posed and stable initial BVP, matrix method for stability.	10
Unit-V: Elliptic PDE's Elliptic equations and regularity estimates, maximum principle and boundary condition, finite difference schemes for Poisson's equation.	8
Total No. of Lectures	**42**

Text Books	1. Thomas J. W., Numerical Partial Differential Equations: Finite Difference Methods, Springer, 1998. 2. Strikwerda J. C., Finite Difference Schemes and Partial Differential Equations, SIAM, Philadelphia, 2nd Ed., 2004.
References Books	1. Leveque R. J., Finite Difference Methods for Ordinary and Partial Differential Equations, Steady State and Time Dependent Problems, SIAM Philadelphia, 2007. 2. Smith G. D., Numerical Solution of Partial Differential Equations: Finite Difference Methods, Oxford University press, 1977.

Course Title	MOOC/SWYAM Course
Course Code	SWAY757
Credits	4
Course Category	DSE
Year / Semester	II / IV

Course Title	Project Thesis
Course Code	MA726
Credits	6
Course Category	CC
Year / Semester	II / IV