Course Curriculum and Syllabus

For

M.Sc. in Mathematics

Effective from Session 2021-23

Department of Mathematics

School of Natural Sciences

Central University of Jharkhand, Ranchi 835222, Jharkhand

About the Department

The Department of Mathematics (as Centre for Applied Mathematics) was started in July 2009 under the School of Natural Sciences of Central University of Jharkhand. This department is first in Jharkhand to offer 5 years' integrated M.Sc. programs in Applied Mathematics from the year 2009 to 2016. It has started M. Sc. Program in Mathematics since 2017. It also offers PhD. program in Mathematics and allied subjects since the year 2013.

Mission of the Department

- To advance the logical, analytical thinking and development of scientific practice with applications among the students so that they can flourish themselves in areas of Pure and Applied Mathematics, Financial mathematics, Computer Science, Scientific Computing, Statistical Methods, Information Technology and Actuarial Science etc.
- To produce Mathematics scholars for management and operational research studies also for large corporations and leading manufacturing enterprises. The department also committed to produce most brilliant brains in academics.

Vision of the Department:

- The department aims to provide high-quality education in mathematics at all levels, from undergraduate to graduate studies. This includes fostering a deep understanding of mathematical concepts, promoting critical thinking skills, and preparing students for a wide range of careers or further academic pursuits.
- A strong emphasis is placed on advancing the frontiers of mathematical knowledge through research. This involves both fundamental research aimed at solving theoretical problems and applied research addressing real-world challenges. The department seeks to foster a vibrant research community, where faculty and students collaborate on cutting-edge projects and contribute to the global body of mathematical knowledge. The department strives to earn regional recognition for its expertise in the field of mathematics and the teaching of mathematics.

Program Name: M.Sc. in Mathematics

Eligibility Criteria for Admission:
Bachelor degree in Science with Mathematics /Statistics with a minimum 55% marks or equivalent grade in aggregate for General/EWS Category and 50% or equivalent grade in aggregate for SC/ST/OBC (non-creamy layer)/ PWD. The student should have studied Mathematics in all the three years.

About the Program

The Department has started offering a M.Sc. in Mathematics from the year 2017. Typically, this program is designed for students who have already completed a bachelor's degree in mathematics or a related field and wish to deepen their understanding of mathematical theory and its applications. The program offers rigorous coursework ensuring a strong foundational base and at least few advanced courses. The program curriculum would undergo periodic reviews, upgrades and changes, bearing in mind the rapid change in industry and R&D demands.

Students in a M.Sc. Mathematics program often have the opportunity to specialize in a particular area of mathematics based on their interests and career goals. They may also engage in research projects under the supervision of faculty members, leading to a thesis or dissertation. Graduates with a M.Sc. in Mathematics have a wide range of career options available to them. They may pursue academic careers as researchers or professors, work in industry as data scientists, analysts, or actuaries, or find employment in government agencies or research institutions. Additionally, the problem-solving and analytical skills developed during the program are highly valued in fields such as finance, engineering, computer science, and cryptography.

Name of the Department: Mathematics
Name of the School: Natural Sciences
Programme Name: M.Sc. in Mathematics

Course Structure Details

Programme Name	:	**M.Sc. in Mathematics**
Programme Objective (POs)	:	**Program Objectives (POs):** Program Objectives (PEOs) for a M.Sc. in Mathematics outline the expected accomplishments and career aspirations of graduates of the program. These objectives serve as benchmarks for evaluating the effectiveness of the program in preparing students for their professional roles and future endeavours. Some potential Program Educational Objectives for a M.Sc. in Mathematics: - **PO 1: Advanced Knowledge:** Post Graduates will demonstrate advanced knowledge and understanding of core mathematical concepts, theories, and techniques across various mathematical disciplines, including calculus, algebra, analysis, and applied mathematics. - **PO 2: Problem-Solving Skills:** Post Graduates will possess strong problem-solving skills and the ability to apply mathematical principles to solve complex real-world problems in diverse fields, including science, engineering, finance, and technology. - **PO 3: Research and Innovation:** Post Graduates will be equipped with the skills necessary to conduct independent research, including formulating research questions, designing experiments, analyzing data, and interpreting results. They will contribute to the advancement of knowledge in mathematics through scholarly publications and presentations. - **PO 4: Critical Thinking and Analysis:** Post Graduates will demonstrate critical thinking skills and the ability to analyze and evaluate mathematical arguments, proofs, and models. They will apply logical reasoning and mathematical rigor to assess the validity and implications of mathematical results. - **PO 5: Communication Skills:** Post Graduates will effectively communicate mathematical concepts, ideas, and results to both technical and non-technical audiences through written reports, oral presentations, and visualizations. They will collaborate with interdisciplinary teams and contribute to interdisciplinary research projects.
Programme outcome	:	- PO 1: Advanced Mathematical Knowledge: Post Graduates should demonstrate a deep understanding of fundamental mathematical concepts, theories, and techniques across various branches of mathematics. - PO 2: Problem-Solving Proficiency: Post Graduates will be proficient in analyzing complex problems, formulating

		mathematical models, and applying appropriate mathematical methods and algorithms to solve them effectively. - PO 3: Mathematical Reasoning and Rigor: Post Graduates should possess strong critical thinking skills and logical reasoning abilities, enabling them to construct sound arguments, evaluate mathematical statements, and justify mathematical assertions rigorously. - PO 4: Research Skills: Post Graduates should be able to conduct independent research, including formulating research questions, designing experiments or investigations, collecting and analyzing data, and drawing meaningful conclusions.
Programme Specific Outcome (SPOs)	:	**Program Specific Outcomes (PSOs)** for a M.Sc. in Mathematics specify the specific knowledge, skills, and attributes that graduates of the program should possess upon completion. These outcomes provide a more detailed framework for assessing the attainment of the program's educational objectives. Here are some potential Program Specific Outcomes for a M.Sc. in Mathematics: - **PSO 1:** Advanced Mathematical Knowledge: Post Graduates will demonstrate a deep understanding of advanced mathematical concepts, theories, and methodologies across various subfields of mathematics, including but not limited to calculus, algebra, analysis, geometry, and discrete mathematics. - **PSO 2:** Mathematical Modelling and Problem-Solving: Post Graduates will be proficient in formulating mathematical models to represent real-world problems, analyzing these models using appropriate mathematical techniques, and deriving solutions that address the underlying issues effectively. - **PSO 3:** Advanced Analytical Skills: Post Graduates will possess advanced analytical skills, including the ability to analyze complex mathematical structures, proofs, and algorithms. They will be able to critically evaluate mathematical arguments and identify logical flaws or inconsistencies. - **PSO 4:** Computational Proficiency: Post Graduates will be proficient in using computational tools and software packages for mathematical analysis, simulation, and visualization. They will be able to apply programming languages such as MATLAB, Python, or R to solve mathematical problems and implement algorithms. - **PSO 5:** Research Methodologies: Post Graduates will be familiar with research methodologies in mathematics, including literature review, hypothesis formulation, experimental design, data collection, statistical analysis, and interpretation of results. They will be able to conduct independent research and contribute to the advancement of

		knowledge in their area of specialization.

Course Code	Title of the Course	Course Type	Credit
Semester-I			
Course Code	**Title of the Course**	**Course Type**	**Credit**
MMA 111020	Differential Equations	Compulsory	4
MMA 111031	Mathematical Analysis	Compulsory	4
MMA 111050	Fundamentals of Computers and C Programming	Compulsory	4
MMA 111060	Numerical Analysis	Compulsory	4
MMA 111070	Linear Algebra	Compulsory	4
Semester-II			
Course Code	**Title of the Course**	**Course Type**	**Credit**
MMA 121050	Statistics – I	Compulsory	4
MMA 121060	Complex Analysis	Compulsory	4
MMA121070	Measure Theory and Integration	Compulsory	4
MMA 121080	Topology	Compulsory	4
MMA 121090	Abstract Algebra	Compulsory	4
Semester-III			
MMA 211010	Functional Analysis		
MMA 211030	Calculus of Variations and Integral Equations	Compulsory	4
MMA 211040	Partial Differential Equations	Compulsory	4
	Elective – I	Elective	4
	Elective – II	Elective	4
MMA 213060	Seminar	Compulsory	2
Semester-IV			
MMA 221040	Optimization Techniques	Compulsory	4
MMA 221050	Number Theory	Compulsory	4
	Elective – III	Elective	4
MMA 223030	Project	Compulsory	6

List of Electives for 3rd Semester

Sl. No.	Course Code	Course Title	L	T	P	CR
1	MMA 215040	Theory of Computations	3	1	0	4
2	MMA 215060	Field Theory	3	1	0	4
3	MMA 215070	Statistics-II	3	1	0	4
4	MMA 215080	Discrete Mathematics	3	1	0	4
5	MMA 215090	Fluid Dynamics	3	1	0	4
6	MMA 215100	Theory and Applications of Fuzzy sets	3	1	0	4
7	MMA 215110	Data Structures and Algorithm Analysis	3	0	1	4
8	MMA 215120	Cryptography	3	1	0	4
9	MMA 215130	Java Programming	3	0	1	4
10	MMA 215140	Graph Theory	3	1	0	4

12	MMA 215150	Mathematical Modelling	3	1	0	4
13	MMA215160	Integral Transforms	3	1	0	4
14	MMA215170	Numerical Optimization Techniques	3	1	0	4
15	MMA215180	Introduction to Fuzzy Set Theory, Arithmetic and Logic	MOOCS			4
16	MMA215190	Introduction to Methods of Applied Mathematics	MOOCS			4
17	MMA215200	Introduction to Probability Theory and Statistics	MOOCS			4
18	MMA215210	Foundations of R software	MOOCS			4
19	MMA215220	Rings and Modules	MOOCS			4
20	MMA215230	Essential Mathematics for Machine Learning	MOOCS			4

List of electives for 4th Semester

Sl. No.	Course Code	Course Title				CR
			L	T	P	
1	MMA 226050	Artificial Intelligence and Hybrid Systems	3	1	0	4
2	MMA 226060	Algebraic Number Theory	3	1	0	4
3	MMA 226070	Statistics III	3	1	0	4
4	MMA 226080	Difference Equations and Discrete Dynamic Systems	3	1	0	4
5	MMA 226090	Coding Theory	3	1	0	4
6	MMA 226100	Operator Theory	3	1	0	4
7	MMA 226110	Operating Systems	3	1	0	4
8	MMA 226120	Relational Database Management Systems	3	1	0	4
9	MMA 226130	Classical Mechanics	3	0	1	4
10	MMA226140	Tensor Algebra	3	0	1	4
11	MMA226150	Differential Manifold				
12	MMA 226160	A Primer to Mathematical Optimization	MOOCS			4
13	MMA 226170	Introduction to Database System	MOOCS			4
14	MMA 226180	Applied Linear Algebra in AI and ML	MOOCS			4
15	MMA 226190	Computational Mathematics with SageMath	MOOCS			4
16	MMA 226200	Dynamical System and Control	MOOCS			4
17	MMA 226210	Essentials of Data Science With R Software - 1: Probability and Statistical Inference	MOOCS			4
18	MMA 226220	Data Analytics with Python	MOOCS			4

DETAILED SYLLABUS

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 111020	**Differential Equations**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: Most "real life" systems that are described mathematically be they physical, biological, financial or economic, are described by means of differential equations. Our ability to predict the way in which these systems evolve or behave is determined by our ability to model these systems and find solutions of the equations explicitly or approximately. Every application and differential equation present its own challenges, but there are various classes of differential equations, and for some of these there are established approaches and methods for solving them.

Course Outcomes:

- Understand that physical systems can be described by differential equations
- Understand the practical importance of solving differential equations
- Understand the differences between initial value and boundary value problems (IVPs and BVPs)
- Appreciate the importance of establishing the existence and uniqueness of solutions
- Recognize an appropriate solution method for a given problem
- Classify differential equations
- Analytically solve a wide range of ordinary differential equations (ODEs)
- Obtain approximate solutions of ODEs using graphical and numerical techniques
- Use Fourier analysis in differential equation solution methods
- Solve classical linear partial differential equations (PDEs). Solve differential equations using computer software

Unit – 1	Existence and uniqueness of solution to first order ordinary differential equation, Picard’s iteration. Systems of first order differential equations, Trial solution method for a linear system with constant coefficients and Eigen value technique.
Unit – 2	Simultaneous differential equations. Total (or Pfaffian) differential equations. Orthogonal functions. Equations with regular singular points, power series solutions, Frobenius method. Bessel’s Equation, Legendre equation, Hermite equation, Laguerre equation, Hypergeometric equation.
Unit – 3	Sturm–Liouville problems and eigenfunction expansions: The Sturm–Liouville problem, Inner product spaces and orthonormal systems, basic properties of Sturm–Liouville eigenfunctions and eigenvalues, Nonhomogeneous equations, Nonhomogeneous boundary conditions, Green's functions.
Unit – 4	Elements of Fourier analysis: The Fourier series of a function, convergence of Fourier series, Fourier Integral, Fourier transform and their convergence.

Text Books
1. M. Braun: Differential Equations and Their Applications, 4^{th} edition, Springer, 1992. 2. S. Padhy and J. Sinha Roy: A Course in Ordinary and Partial Differential Equations, 4^{th} edition, Kalyani, 2014. 3. W. E. Boyce and R. C. DiPrima: Elementary Differential Equation, 12^{th} edition, Wiley, 2021. 4. C. H. Edwards and D. E. Penney: Elementary Differential Equations with Boundary Value Problems, 6^{th} edition, Pearson, 2014. 5. J.R. Hanna and J.H. Rowland: Fourier series, Transforms, and Boundary Value Problems, 2^{nd} Edition, Dover, 2008. 6. J.W. Brown and R.V. Churchill: Fourier Series and Boundary Value Problems, 8^{th} edition, McGraw Hill, 2011. 7. A. Vretblad: Fourier Analysis and its Applications, Springer, 2010. E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover, 1989
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 111031	**Mathematical Analysis**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: This course aims to provide students with the specialist knowledge necessary for basic concepts in Real Analysis. More precisely, students may learn basic concepts of convergence (pointwise and uniform) of a sequence of functions; students fist their idea towards the basic concepts of derivatives and Taylor series of functions of several variables. Furthermore, the course includes the Weierstrass approximation theorem, metric spaces (complete and compact), and Banach contraction principle to help students in the proof of the following Picard theorem, the inverse function theorem, and the implicit function theorem. The Baire category theorem provides a concept to prove in C(X), stone- Weirestrass theorem, and Arzela-Ascoli theorem.

Course Outcomes: After completion of this course students

- Recognize the contribution and impacts of mathematical analysis in different areas of mathematics and identify the steps required to carry out research on a topic within mathematical analysis.
- Will understand the limits of this course. Particularly the theories and concepts used in the mathematical analysis namely uniform convergence of sequences and series of functions, equicontinuity
- May identify whether a given several variables functions are differentiable or not, if so find its derivative.
- May use the Jacobian matrix and Hessian matrix of function to construct the Taylor

series • May use the Inverse function theorem to compute the derivative of the inverse function • May construct complete/ compact metric space from many different kinds of metric.	
Unit – 1	**Uniform Convergence:** Uniform Convergence of sequence of functions- pointwise versus uniform convergence for a function defined on an interval of $\mathbb{R}$, Integration of a limit of a sequence of functions. The Weierstrass' approximation theorem. Periodic functions.
Unit – 2	**Functions of Several Variables:** Derivative of a function from an open subset of Rn into Rm as a linear transformation. Chain rule. Partial derivatives. Taylor's theorem. Inverse function theorem. Implicit function theorem, Jacobians.
Unit – 3	**Metric Spaces:** Review of compact metric spaces, Banach's contraction principle, and its use in the proofs of Picard's theorem, inverse function theorem; implicit function theorems. Baire category theorem and some of its applications in the analysis of C(X) as a complete metric space when X is a compact metric space. Stone-Weierstrass theorem and Arzela-Ascoli theorem..
Text Books	
1. N.L. Carothers: Real Analysis, Cambridge University Press, 2000. 2. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw-Hill, 2004. 3. P. K. Jain and V. P. Gupta: Lebesgue Measure and Integration, New Age International 4. (P) Ltd., 2000. 5. G. De. Barra: Introduction to Measure Theory, New Age International (P) Ltd., 2000. H. L. Royden and P. Fitzpatrick: Real Analysis, 4th edition, PHI, 2010, Dover, 1989	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA111050	**Fundamentals of Computer and C Programming**	Compulsory	L	3	T	0	P	1	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The main aim of this course is to develop programming skills using the fundamentals of C language and learn problem-solving techniques. The course also includes the advantages of user-defined data type which provides flexibility for application development.

• **Course Outcome:** After completion of this course students will demonstrate basic knowledge in fundamentals of programming, algorithms and programming technologies, and fundamentals of Computer Science. Students also will demonstrate knowledge of fundamentals of hardware technology relevant to understanding Computer Science basics. Furthermore, they will be able to demonstrate the ability to design creative solutions to real-life problems faced by the industry	
Unit – 1	Introduction to computers, generations of computer, processors, memory hierarchy and I/O devices, System and application software, generation of languages, compiler, interpreter, assembler, Number systems, computer arithmetic. Flow Charting, Sequential, Branching & Iterative.
Unit – 2	Introduction to ‘C’ as Programming Language, An overview of a ‘C’ programme, ‘C’ character set, ‘C’ tokens, ‘C’ keywords, Data Types (Primary, derived & user-defined), Storage classes, symbolic constants, operators (arithmetic, logical & relational), Flow of control (if-else, switch-case; while, do-while & for-loops). Functions (UDF, String Functions, Mathematical functions).
Unit – 3	Recursion, pointers, array (2-D & 3-D), Strings, pre-processor directives, structures, linked list file handling. C-lab: Execution of a simple programme, Conditional & Un-conditional Branching, Loops, Functions (Interactive & Recursive), Arrays (2-D & 3-D), Structures, Linked Lists, File I/O.
Text Books	
1. B.W. Kernighan, D.M. Ritchie: The C Programming Language, 2nd edition, Pearson Education India, 2015. 2. Y.P. Kanetkar: Let us C, 15th edition, BPB Publications, 2016. 3. E. Balagurusamy: Programming in ANSI C, 8th edition, Tata McGraw Hill, 2019.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA111060	**Numerical Analysis**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								
Course Objective: This course covers the mathematical and computational foundations of the numerical approximation and solution of scientific problems; simple optimization; polynomial and spline interpolation; pattern recognition; integration and differentiation; solution of large-scale systems of linear and nonlinear equations; modeling and solution with sparse equations; Numerical Eigenvalue problem, explicit schemes to solve ordinary differential equations and partial differential equations.									
Course Outcome:									

- Demonstrate an understanding of common numerical methods and how they are used to obtain approximate solutions to mathematical problems.
- Apply numerical methods to obtain approximate solutions to mathematical problems.
- Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.
- Analyse and evaluate the accuracy of common numerical methods.
- Implement numerical methods in Matlab. Write efficient, well-documented Matlab code and present numerical results in an informative way.

Unit – 1	**Nature of numerical computations:** errors and their propagation, convergence and stability of numerical algorithms; efficiency and arithmetic, complexity. **Interpolation Theory:** Hermite Interpolation, the general Hermite interpolation, Spline interpolation problem. **Approximation of functions:** The Minimax and Least squares approximation problem. Orthogonal polynomials, The Least squares approximation problem using orthogonal polynomials. Minimax and Near-minimax approximations.
Unit – 2	**Numerical Integration:** Gaussian Quadrature. Asymptotic error formulas and their applications. Automatic numerical integration. Multiple Integrals, Singular integrals, Numerical Differentiations.
Unit – 3	**Numerical Solution of Ordinary differential equations:** Numerical solutions of IVP – Difference equations, stability, error and convergence analysis. Single step methods - Taylor series method, Euler method, Picard's method of successive approximation, Runge-Kutta method. Multi step methods – Predictor-Corrector (PC) method, Euler PC method, Milne and Adams Moulton PC method. System of first order ODE, higher order IVPs. Numerical solutions of BVP – Linear BVP, finite difference methods, shooting methods, stability, error and convergence analysis, nonlinear BVP, higher order BVP. **Numerical Solution of Partial Differential Equations.** – Initial/boundary value problems for parabolic and hyperbolic PDEs (one space and one time dimension). – Explicit finite-difference schemes. Implicit finite-difference schemes.
Unit – 4	**Numerical solution of systems of linear equations:** Quick review of direct methods for solving linear systems, error analysis. The residual correction method. Iteration methods, Error prediction and Acceleration. **The Matrix Eigenvalue problem:** Review of Eigenvalue location, error, and stability results, Power method. Orthogonal transformations using Householder matrices. The eigenvalues of a symmetric Tridiagonal matrix. QR method. The calculation of Eigenvectors and Inverse iteration.

Text Books

1. K. Atkinson: An Introduction to Numerical Analysis, 2nd edition, Wiley, 2008.
2. R.L. Burden and J.D. Faires: Numerical analysis, 8th edition, Brooks Cole, 2012.
3. P.J. Davis: Interpolation and Approximation, Dover, 2014.
4. J.M. Ortega: Numerical Analysis: A Second Course, SIAM, 1987.
5. S.S. Sastry: Introductory Methods of Numerical Analysis, 5th edition, Phi Learning, 2012.
6. S.D. Conte and C. de Boor: Elementary Numerical Analysis: An Algorithmic

Approach, SIAM, 2018.
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 111070	**Linear Algebra**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: This course teaches us, how Linear Algebra is universal in Mathematics and therefore a strong foundation has to be laid in studying the abstract algebraic concepts intertwining geometric ideas. The fundamental notions of vector spaces viz linear dependence, basis and dimension and linear transformations. Students must have computational techniques and algebraic skill for the study of linear transformation. This course also covers inner product space, eigenvalues, eigenvectors, diagonalization, bilinear forms, quadratic forms and their geometric properties.

Course Outcome:

After completion of course : The students will understand the ideas of vector spaces, subspaces, Linearly dependent and independent sets in a vector space, bases, and dimensions of different vector spaces and subspaces. The students will learn how to find the null space, range space, and matrix representation of a linear transformation w.r.t. given basis. They will be able to determine whether a linear transformation is one-to-one and onto. The students will learn to find the determinant of a matrix and how to use the properties of determinants to find the determinant in simple ways. The students will learn to use eigenvectors and eigenspaces to determine the diagonalizability of a linear transformation. The students will understand the notion of an inner product space in a general setting and how the notion of inner products can be used to define orthogonal vectors. They will be able to use the Gram-Schmidt process to generate an orthonormal set of vectors. The students will learn about normal, self-adjoint, and unitary operators and their properties.

Unit – 1	**A Quick review of matrices:** Algebra of matrices, determinants, rank and nullity of matrices, the system of linear equations, Symmetric, orthogonal and other special types of matrices, eigenvalues and eigenvectors of matrices, minimal and char. polynomial of a matrix, similar matrices, diagonalizable matrices.
Unit – 2	**Finite dimensional vector spaces over a field:** Linear span, linear dependence, and independence, basis, and dimension. Linear transformation and rank-nullity theorem. Matrix representation of a linear transformation. Matrix of Change of basis, algebra of linear operators, eigenvalues and eigenvectors, minimal and char. polynomial of a linear operator, Cayley-Hamilton theorem, transformation of linear operators to canonical forms: diagonal, triangular and Jordan forms.

Unit – 3	Inner product spaces, Orthogonality, Gram-Schmidt orthogonalization process, norms of vectors and matrices, linear functional, dual spaces, adjoint of an operator, normal, unitary, Hermitian and skew-Hermitian operators, Quadratic forms, reduction and classification of quadratic forms, Positive definite and negative definite matrices.
Text Books	

1. P. D. Lax: Linear Algebra and Its Applications, 2nd edition, Wiley, 2007.
2. R. A. Horn and C.R. Johnson: Matrix Analysis, 2nd Edition, Cambridge University Press, 2012.
3. K. Hoffman and R. Kunze: Linear Algebra, 2nd edition, Prentice Hall, 2015.
4. P. R. Halmos: Finite-dimensional Vector Spaces, 2nd Edition, Dover, 2017.
5. C.D. Meyer: Matrix Analysis and Applied Linear Algebra, SIAM, 2000.
6. S.L. Campbell and C.D. Meyer: Generalized Inverses of Linear Transformations, SIAM, 2008.
7. J. Laub: Matrix Analysis for Scientists and Engineers, SIAM, 2004.
8. H. Anton and C. Torres: Elementary Linear Algebra, 11th Edition, Wiley India Edition 2016.
9. 7. V. Krishnamurthy, V.P Mainra and J.L Arora: An Introduction to Linear Algebra, East-West Press, New Delhi 2011.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA121050	**Statistics – I**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The main objective of this course is to provide students with the foundations of probabilistic and statistical analysis mostly used in varied applications in engineering and science like disease modeling, climate prediction and computer networks etc.

Course Outcome:
At the end of this course students will be able to understand the concept of a statistical population and a sample from a population. They will describe data using location and variation measures. They will have a thorough understanding of association between variables using correlation and regression concepts.

Unit – 1	**Introduction to Probability:** Concept of Random Experiment, Sample Space, Event, Definitions of Probability, Conditional Probability, Independent events and Mutually exclusive events. Addition and Multiplication Theorems, Bayes' Theorem. **Random Variables and Probability Distributions:** Concept of a random variable, Discrete and Continuous Random Variables, Distribution Function, Probability Mass and Density Functions, Mathematical Expectation, Moment Generating Function, Characteristic Function, Probability Generating Function,

	Discrete and Continuous Probability Distributions such as Bernoulli, Binomial, Negative Binomial, Geometric, Hyper-Geometric, Poisson, Multinomial, Uniform, Exponential, Beta, Gamma and Normal.
Unit – 2	**Joint Probability Distributions:** Introduction, Joint Distribution for Two Dimensional Random Variables, Marginal Distributions, Conditional Distributions, Covariance, Conditional Expectation, Independence of Random Variables, Distribution of Sum of Two Independent Random Variables. **Sampling Distributions:** Sampling Distribution based on Normal Random Variables, t- Distribution, Chi-Square Distribution, F- Distribution, Order Statistics and their Distributions, Bivariate Normal Distribution, Multivariate Normal Distribution.
Unit – 3	**Correlation and Regression Analysis:** Introduction, Types of Correlation, Karl Pearson's Coefficient of Correlation, Spearman's Rank Correlation, Multiple and Partial Correlation, Linear Regression Model, Regression Coefficient and its Properties, Computation of Regression Equation, Multiple Regression Analysis. **Stochastic Process:** Introduction, Poisson Process, Birth and Death Process, Markov Chain, Transition Probabilities, Classification of States, Stationary Process.
Text Books	
1. S.M. Ross: Introduction to Probability and Statistics for Engineers and Scientists, Academic Press, 4th Edition, 2010. 2. W.W. Hines, D.C. Montgomery, D.M. Goldsman, and C.M. Borror: Probability and Statistics in Engineering, John Wiley and Sons, 4th Edition, 2007. 3. S.C. Gupta and V.K. Kapoor: Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2007. 4. A.M. Goon, M.K. Gupta, B. Dasgupta: Fundamental of Statistics, Vol. I, II, World Press, 2001. 5. V.K. Rohatgi and A.K. Ehsanes Saleh: An Introduction to Probability and Statistics, John Wiley and Sons, Inc. 2003. 6. G. Casella and R.L. Berger: Statistical Inference, Cengage Learning, 3rd Edition, 2008. 7. J. Medhi: Stochastic Processes, New Age Publication, 2nd Edition, 2002	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA121060	**Complex Analysis**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: To study the techniques of complex variables and functions together with their derivatives, Contour integration and transformations. • To study complex power series, classification of singularities, calculus of residues and its application in the evaluation of integrals, and other concepts and properties	
Course Outcome: Upon completing the course, students will be able to: • equipped with the understanding of the fundamental concepts of complex variable theory and skill of contour integration to evaluate complicated real integrals via residue calculus. • Apply problem-solving using complex analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts.	
Unit – 1	Basic algebraic properties of complex numbers, Exponential form, Roots of complex numbers. Functions of a complex variable, mappings, Cauchy-Riemann equations, sufficient conditions for differentiability, Analytic functions, Harmonic functions. Elementary functions: The exponential, logarithm functions, branches and derivatives of logarithms. Complex exponents, trigonometric, hyperbolic functions and their inverses.
Unit – 2	**Integrals:** Complex integrals, Upper bounds for moduli of contour integrals, Cauchy's theorem, Cauchy's integral formula, Liouvilles' theorem and fundamental theorem of algebra, maximum modulus principle.
Unit – 3	**Series:** Classification of singularities. Representations of holomorphic functions in terms of power series, Meromorphic functions, zeros and poles, Laurent expansions. Residues and Poles: poles and zeroes, Cauchy's residue theorem, Residue at infinity, Residue at poles. Evaluation of improper integrals and definite integrals using contour integration. Argument principle and Rouche's theorem.
Unit – 4	**Mapping by Elementary functions:** Linear transformations, linear fractional transformations, other mappings by elementary functions. Conformal mapping: Preservation of angles, transformations of harmonic functions and boundary conditions. Applications of conformal mappings.
Text Books	
1. R. V. Churchill and J. W. Brown: Complex Variables and Applications, 9th edition, McGraw Hill, 2013. 2. L. Ahlfors: *Complex Analysis*: An *Introduction* to the Theory of Analytic Functions of One *Complex* Variable, 3rd edition, Tata McGraw Hill, 2017. 3. E.T. Copson: Theory of Functions of a Complex Variable, Oxford University Press, 1970. 4. J.B. Conway: Functions of One Complex Variable, 2nd edition, Narosa, 1995. 5. D. Sarason: Complex Function Theory, 2nd edition, Hindustan Publishing Company, 2008. 6. M.J. Ablowitz: Complex Variables Introduction and Applications, 2nd edition, Cambridge University Press, 2003. 7. S. Ponnusamy and H. Silverman: Complex Variables with Applications, Birkh¨auser, 2006.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 121070	Measure Theory and Integration	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The course introduces the Lebesgue integral and develops the elements of measure theory. We give the notions of special set systems, algebras of sets. Borel sets, additive and sigma-additive set functions, outer measure and measure, extension and completion of measure, construction of Lebesgue and Lebesgue-Stieltjes measure, measurable functions and their properties, simple functions, construction of Lebesgue integral and its properties, absolute convergence of integral, integrable functions, Lebesgue theorem on dominated convergence, Lebesgue-Stieltjes integral, Convergence theorems, L^p-spaces, convergence and it's applications.

Course Outcome: After completed course, the students are expected to be able to:

- Describe basic properties of sigma-algebras and the Lebesgue integral
- Explain the construction of the Lebesgue measure on Euclidean space
- Describe the relationship between continuous functions and general integrable functions Work with Lebesgue-Stieltjes integral on the real line.
- Determine questions related to different kinds of convergence, like L^p-convergence, convergence in measure and convergence almost everywhere
- Describe the main ideas of the proofs for the Fubini-and Radon-Nikodym theorem.

Unit – 1	The Real Numbers: Sets, Sequences, and Functions. Lebesgue measure on R^n : Introduction, outer measure, measurable sets, Lebesgue measure, regularity properties, a nonmeasurable set, measurable functions, Egoroff's theorem, Lusin's theorem
Unit – 2	Lebesgue integration: Simple functions, Lebesgue integral of a bounded function over a set of finite measure, bounded convergence theorem, integral of nonnegative functions, Fatou's Lemma, monotone convergence theorem, the general Lebesgue integral Lebesgue convergence theorem, change of variable formula. Differentiation and integration: Functions of bounded variations, differentiation of an integral, absolutely continuity,
Unit – 3	L^p-spaces: The Minkowski's inequality and Holder's inequality, completeness of L^p-, denseness results in L^p-; Fourier series: Definition of Fourier series, formulation of convergence problems, L^2- theory of Fourier series, convergence of Fourier series.

Text Books
1. P. K. Jain and V. P. Gupta: Lebesgue Measure and Integration, 3rd Edition, New Age International (P) Ltd., 2019. 2. G. De. Barra: Introduction to Measure Theory, 2nd Edition, New Age International (P) Ltd., 2013. 3. H. L. Royden, P. Fitzpatrick: Real Analysis, 4thedition, PHI, 2010. 4. W. Rudin, Real and Complex Analysis, 3rd edition, McGraw Hill Education, 2023. G. B. Folland, Real Analysis, 2nd edition, Wiley,
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA121080	**Topology**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: Real analysis is a prerequisite course to understand the basic definitions of topological space. Topology is a very abstract mathematics discipline, so these topics need definitions, theorems, and proofs in a very proper formal way. A reader of this topic will learn the basics of point-set topology and will be introduced to follow-up topics such as knots, manifolds, dynamical systems, fixed points, and topological graphs. Furthermore, the reader will learn how results from topology are used in applications that range from the atomic scale in chemistry to the astronomic scale in cosmology.

Course Outcome: After successful completion of this course:
Students will understand the definitions, and concepts of open and closed sets, interior, closure and boundary of a set. Later students can create new topological spaces by using subspace, product, and quotient topologies. Furthermore, by using continuous functions and homeomorphisms to understand the structure of topological spaces. Students may know the concepts of axioms alongwith continuity in topological spaces and later they can relies the difference between geometry and topology. Students also can understand the concept of connected, compact topological spaces and separation of axioms. Finally they can apply theoretical concepts in topology to understand real-world applications.

Unit – 1	**Topological Spaces:** Introduction, open set topology, Basis, Subbasis, closed sets and closure, Order Topology, Product Topology, Subspace Topology, Quotient Topology, Metric Topology, Continous functions, Homeomorphisms, Open and Closed Maps
Unit – 2	**Connectedness and Compactness:** Connected and Path Connected Spaces, Components and Path Components, Local Connectedness, Compact Spaces, Local compact spaces, Heine Borel Theorem, Tychonoff Theorem
Unit – 3	**Countability and Seperation Axioms:** Countability Axioms, Separation Axioms, Urysohn Lemma, Urysohn Metrization Theorem, Tietze extension Theorem

Text Books
1. J. R. Munkres: Topology, Prentice Hall of India, 2001. 2. J. Dugundji: Topology, Universal Book Stall, New Delhi, 1990. 3. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw-Hill edition, 2004. 4. M. D. Crossley: Essential Topology, Springer International Edition, 2008.
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA121090	**Abstract Algebra**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: This course aims to provide a first approach to the subject of algebra, which is one of the basic pillars of modern mathematics. The focus of the this course will be the study of certain structures called groups, rings, fields, modules and some related structures. In particular to study in detail the Sylow theorems and polynomials rings. This course can help to gain skills in problem solving and critical thinking. Abstract algebra is a classical field that is associated with the study of polynomials in several variables.

Course Outcome: After completion of the course:
The student will be able to define the concepts of group, ring, field, modules, and will be able to readily give examples of each of these kinds of algebraic structures. Students also can define the concepts of coset and normal subgroup and prove elementary propositions involving these concepts. Furthermore, define the concept of subgroup and will be able to determine
(prove or disprove), in specific examples, whether a given subset of a group is a subgroup of the group. They also work with the concepts of homomorphism and Isomorphism. Finally, the student will be able to apply the basic concepts of field theory, including field extensions and finite fields.

Unit – 1	**Groups:** Quick review of basic ideas of Group Theory, Sylow's theorems and their applications, Finitely generated abelian groups
Unit – 2	**Rings and ideals:** Quick review in Commutative rings, Nilradical, Jacobson radical, Extension and Contraction, UFD, PID and ED, Rings of Fractions, Noetherian rings, Primary Decomposition
Unit – 3	**Modules:** Introduction, Submodules and Quotient modules, Direct sum and Product, Finitely generated modules, Exact sequences, Tensor product of modules, Noetherian and Artinian modules, Modules of Fractions
Text Books	

1. M. Atiyah: Introduction to Commutative Algebra, Westview Press, 1994. 2. D.S. Dummit and R.M. Foote: Abstract Algebra, 3rd edition, Wiley, 2003. 3. O. Zariski and P. Samuel: Commutative Algebra I. Vol. 1, Springer, 1975. 4.P. B. Bhattacharya, S. K. Jain, S. R. Nagpaul: Basic Abstract Algebra, 2nd edition, Cambridge, 1995
Reference Books:

SEMESTER III

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA211010	**Functional Analysis**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: This course aims to introduce students to the theory of Banach and Hilbert spaces, that is, infinite-dimensional vector spaces equipped with a norm respectively inner product that turns them into a complete metric space, and of the operators (i.e. linear maps) between these spaces. These objects arise naturally in applications including wavelets, signal processing and quantum mechanics, and underpin the theory of partial differential equations. The course will also introduce the most important examples of Hilbert and Banach spaces from the point of view of applications.

Course Outcome: By the end of this course students will be able to:

- Learn normed linear spaces and basic properties of Banach spaces. Be familiar with basic examples of complete and incomplete normed linear spaces.
- Define the concepts of bounded linear functionals and dual spaces, and discuss extensions of bounded linear functionals;
- Define the concepts of inner product spaces, develop and use the basic theory of Hilbert spaces and orthogonality, use the Gram-Schmidt process to produce orthonormal sequences.
- State and prove the Riesz representation theorem for Hilbert spaces and use this to define and establish properties of the adjoint operator, compute the adjoint of suitable operators;
- Learn Zorn's Lemma, Hahn-Banach theorem, Reflexive Spaces, Uniform-boundedness principle and its applications, Open Mapping Theorem, Closed Graph Theorem.
- Learn spectrum of a bounded linear operator. Prove and apply the spectral theorem for compact self-adjoint operators and discuss how this theorem generalises results for finite dimensional matrices.

Unit – 1	Quick review of metric spaces. Normed linear spaces: Finite dimensional normed spaces, Banach spaces, Heine-Borel theorem, Riesz lemma, Continuity of linear maps, Dual spaces and transposes

Unit – 2	Inner product spaces: Hilbert spaces, Orthonormal basis, Total Orthonormal Sets and Sequences Projection theorem and Riesz representation theorem. Representation of Functionals on Hilbert Spaces, Hilbert-Adjoint Operator, Self-Adjoint, Unitary and Normal Operators
Unit – 3	Zorn's Lemma, Hahn-Banach theorem, Reflexive Spaces, Uniform-boundedness principle and its applications, Open Mapping Theorem, Closed Graph Theorem. Spectrum of a bounded operator
Text Books	
1. E. Kreyszig: Introduction to Functional Analysis with Applications, Wiley, 2007. 2. J.B. Conway: A course in Functional Analysis, 2nd edition, Springer, Berlin, 2007. 3. A.N. Kolmogorov and S. Fomin: Elements of the theory of functions and functional analysis, Dover, 1999. 4. A. Taylor and D. Lay: Introduction to Functional Analysis, 2nd edition, Wiley, 1980.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 211030	**Calculus of Variations and Integral Equations**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: This course introduces the basic concepts of Relationship between Linear Differential equations and Volterra Integral Equations, The Method of Successive approximations, Eulers Integrals Beta and Gamma Functions and their Elementary Properties, Green's Function, Euler's equation-special cases, The problem of minimum, surface of revolution, Minimum energy problem-Brachistochrone problem. Variational problem, Application of Calculus of Variation-Hamilton's principle-Lagrange's equation- Hamilton's equations.

- **Course Outcome:** Conceptual Understanding of Relationship between Linear Differential equations and Volterra Integral Equations, and solutions by using resolvent kernels.
- Apply Laplace Transformation to get the solution of Integro-Differential Equations, Volterra Integral Equation of the First kind.
- Discuss Eulers Integrals, Abel's problem, Iterated Kernels.
- Evaluate Characteristic numbers and Eigen functions and its properties.
- Evaluate Green's Function for Ordinary Differential Equations.
- Conceptual Understanding of functionals, strong and weak variations, Euler's Equation.

• Explain Brachistochrone problem. Variational problem, Isoperimetric problem. • Analyse Hamilton's principle-Lagrange's equation- Hamilton's equations.	
Unit – 1	**Calculus of Variations:** Introduction, problem of brachistochrone, problem of geodesics, isoperimetric problem,Variation and its properties, functions and functionals, Comparison between the notion of extrema of a function and a functional.
Unit – 2	Variational problems with the fixed boundaries, Euler's equation, special cases containing only some of the variables, Invariance of the Euler-Lagrange Equation, Functionals Containing Higher-Order Derivatives, Euler- Poisson equation, Functionals Containing Several Dependent Variables, System of Euler's equation, Functionals containing several independent variables, Ostrogradsky equation. Variational problems in parametric form, applications to differential equations. The Isoperimetric Problem and some of their generalizations. Applications to Eigenvalue Problems. Holonomic and Nonholonomic Constraints.
Unit – 3	Variational problems with moving boundaries, pencil of extremals, Transversality condition. Extremals with corners, refraction of extremals, examples, One-sided variations, conditions for one sided variations, Field of extremals, central field of extremals, The Hamiltonian Formulation, Jacobi's condition. The Weierstrass function, a weak extremum, a strong extremum. The Legendre condition, Conjugate Points, Variational methods for boundary value problems in ordinary and partial differential equations.
Unit – 4	**Integral Equations:** Introduction and basic examples, Classification, Conversion of Volterra Equation to ODE, Conversion of IVP and BVP to Integral Equation, Successive approximation, Successive substitution methods for Fredholm Integral Equations, series solution, successive approximation, successive substitution method for Volterra Integral Equations, Volterra Integral Equation of first kind, Integral Equations with separable Kernel, Fredholm's first, second and third theorem, Integral Equations with symmetric kernel, Eigen functions expansion, Hilbert-Schmidt theorem, Fredholm and Volterra Integro-Differential equation, Singular Integral Equation.
Text Books	
1. B. Brunt: The Calculus of Variations, Springer-Verlag, New York, 2004. 2. F. Y. M. Wan: Introduction to the Calculus of Variations and its Applications, 2nd edition, Chapman & Hall, 1995. 3. M. Gelfand and S. V. Fomin: Calculus of Variations, Prentice Hall, 1963. 4. R. Weinstock: Calculus of Variations with Applications to Physics and Engineering, Dover, 1974. 5. R. Courant and D. Hilbert: Methods of Mathematical Physics, Vol I. John Wiley & Sons, 1989. 6. L.E. Elsgolc: Calculus of Variations, Pergamon Press Ltd., 1962. 7. D. Porter and D. S. G. Stirling: Integral Equations - A Practical Treatment from Spectral Theory and Applications, Cambridge University Press, 1990. 8. C. Cordumeanu: Integral Equations and Applications, Cambridge University Press, 1991. 9. S. G. Mikhlin: Integral Equations, Hindustan Publishing Co., 1960. 10. E. G. Tricomi: Integral Equations, Interscience, 1957.	

11. F. B. Hildebrand: Methods of Applied Mathematics, 2nd edition, Prentice Hall, 1965. 12.M. D. Raisinghania, Integral Equations And Boundary Value Problems, S. Chand, 2016.
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 211040	**Partial Differential Equations**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The course is aimed at exposing the students to how to solve linear and non-linear Partial Differential Equation with different methods and to derive heat and wave equations in 2D and 3D. Find the solutions of PDEs are determined by conditions at the boundary of the spatial domain and initial conditions at time zero. Technique of separation of variables to solve PDEs and analyze the behavior of solutions in terms of eigen function expansions.

Course Outcome: After the completion of the course, Students will be able to

- Understand the partial differential equation problem and analyze linear and non-linear systems.
- Classify second order PDE and solve boundary value problems by using separation of variable method. Solve linear partial differential equations of both first and second order.
- Determine integral surfaces passing through a curve, characteristic curves of second order PDE and compatible systems.
- Understand the formation and solution of some significant PDEs like wave equation, heat equation and diffusion equation.
- Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialisation.
- Extract information from partial derivative models in order to interpret reality.
- Identify real phenomena as models of partial derivative equations

Unit – 1	Introduction to partial differential equations. Solution of linear and nonlinear partial differential equations of order one. Introduction to Cauchy's problem. Homogeneous and non-homogeneous linear partial differential equations.
Unit – 2	Classification of partial differential equations, reduction to canonical or normal form. Monge's method, second order Cauchy Problem.
Unit – 3	The Cauchy problem and initial conditions, Solution of homogenous and non-homogenous problem, heat kernel. D'Alembert solution of the Cauchy problem, the characteristic triangle, Fourier series solution. **Cartesian Coordinate**: Heat Equation: the heat equation in two space variables. Wave equation: A Wave equation in two space dimensions, The

	Kirchhoff-Poisson solution, Hadamard's method of Descent. Laplace's equation: Dirichlet and Neumann Problems Harmonics functions, Dirichlet problems, Poisson's integral representation, The Neumann problem, Green's function, conformal techniques, existence theorems, solutions by Eigen function expansions. Elliptic equations: Existence of weak solutions, The maximum principle, Green's identities
Unit – 4	**Polar Coordinate:** Heat Equation: the heat equation in two space variables. Wave equation: A Wave equation in two space dimensions, The Kirchhoff-Poisson solution, Hadamard's method of Descent. Laplace's equation: Dirichlet and Neumann Problems Harmonics functions, Dirichlet problems, Poisson's integral representation, The Neumann problem, Green's function, conformal techniques, existence theorems, solutions by Eigen function expansions. Elliptic equations: Existence of weak solutions, The maximum principle, Green's identities
Unit – 5	**Cylindrical Coordinate:** Heat Equation: the heat equation in two space variables. Wave equation: A Wave equation in two space dimensions, The Kirchhoff-Poisson solution, Hadamard's method of Descent. Laplace's equation: Dirichlet and Neumann Problems Harmonics functions, Dirichlet problems, Poisson's integral representation, The Neumann problem, Green's function, conformal techniques, existence theorems, solutions by Eigen function expansions. Elliptic equations: Existence of weak solutions, The maximum principle, Green's identities

Text Books

1. P.V. O'Neil: Beginning Partial Differential Equations, 2nd edition, Wiley, 2008.
2. Y. Pinchover and J. Rubinstein: An Introduction to Partial Differential Equations, Cambridge University Press, 2005.
3. R. Haberman: Applied Partial Differential Equations with Fourier Series and Boundary Value Problems, 4th edition, Pearson, 2004.
4. M. D. Raisinghania: Advanced Differential Equation, 19th edition, S. Chand, 2018.
5. R. Agarwal and D. O'Regan: Ordinary and Partial Differential Equations. With Special Functions, Fourier Series, Boundary Value Problems, Springer 2009.
6. L.C. Evans: Partial Differential Equations, AMS, 1998.
7. E. A. Coddington and N. Levinson: Theory of Ordinary Differential Equations, Tata McGraw Hill, 1987.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 215040	**Theory of Computations**	**Elective**	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus	02								

Version :	
Course Objective: To provide the comprehensive insight into theory of computation by understanding grammar, languages and other elements of modern language design. To develop capabilities to design and develop formulations for computing models. To identify computing model applications in diverse areas. To introduce students to the mathematical foundations of computation including automata theory; the theory of formal languages and grammars; the notions of algorithm, decidability, complexity, and computability. Students will learn that certain problems do not admit efficient algorithms and identify such problems.	
Course Outcome: By the end of this course students will be able to: • Will apply knowledge of computing and mathematics appropriate to the discipline. • Learn about Automata theory and its application in Language Design. • Learn about Turing Machines and Pushdown Automata and understand Linear Bound Automata and its applications. • Discuss key notions of computation, such as algorithm, computability, decidability, reducibility, and complexity, through problem solving. • Solve computational problems regarding their computability and complexity and prove the basic results of the theory of computation	
Unit – 1	**Unit 1:** Chomsky Hierarchy: regular grammars, unrestricted grammars, context sensitive languages, relations between classes of languages. Finite Automata and Regular Expressions: Deterministic and non-deterministic finite automata, regular expressions, Two way finite automata, finite automata with output**:** Mealy and Moore machines; Properties of Regular Sets**:** Pumping lemma, closure properties, decision algorithm, MyHill-Nerode theorem and minimization of finite automata.
Unit – 2	Context-Free Grammars (CFG): CFGs, derivation trees, simplification, Chomsky normal forms, Greibach normal forms; Pushdown Automata (PDA): Definitions, relationship between PDA and context free languages, Properties of Context-Free Languages**,** Pumping lemma, closure properties, decision algorithm; Turing Machines: The turing machine model, computable languages and functions, techniques for turing machine construction, modification of turing machines, Church's hypothesis, Turing machines as enumerators;
Unit – 3	Decidability: Decidable Languages, The Halting problem, Reducibility. Undecidability: properties of recursive and recursively enumerable languages, universal Turing machines, rice's theorem, post correspondence problem, Greibach's theorem, Introduction to recursive function theory; Complexity Theory: Measuring complexity, The P, NP, NP-Hard and NP completeness
Text Books	
1. K.L.P. Mishra and N. Chandrasekharan: Theory of Computer Science: Automata Language and Computation, Prentice Hall of India, 3rd edition, 2007. 2. P. Linz: Introduction to Formal Language and Computation, Narosa, 2nd edition, 2006. 3. M. Sipser: Introduction to the Theory of Computation, Thomson Learning, 2001. 4. J. Martin: Introduction to Languages and the Theory of Computation, 3rd edition, McGraw Hill, 2002. 5. J. E. Hopcroft, R. Motwani and J.D. Ullman: Introduction to Automata Theory, Languages and Computation, 2nd Edition, Pearson Education, 2001.	

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215060	**Field Theory**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The prerequisite course is Abstract Algebra. This course aims to provide a approach to the subject of advanced algebra, which is one of the main pillars of modern mathematics. The focus of this course will be the study of certain structures called fields theory and some related structures. In particular to study in detail the Galois Theory and polynomials rings. This course can help to gain skills in problem-solving and critical thinking. Field Theory is a classical field that is associated with the study of polynomial rings and irreducibility criteria. Field extensions, Algebraic field extensions

Course Outcome: The student will be able to apply the basic concepts of field theory, including field extensions and finite fields. Students also can use diverse properties of field extensions in various areas. Establish the connection between the concept of field extensions and Galois Theory. They also describe the concept of automorphism, monomorphism and their linear independence in field Theory. Furthermore, students can compute the Galois group for several classical situations and solve polynomial equations by radicals along with the understanding of ruler and compass constructions.

Unit – 1	Fields, finite fields, Polynomial rings and irreducibility criteria. Field extensions, Algebraic field extensions.
Unit – 2	Normal and Separable Extensions, Galois extensions, Fundamental Theorem of Galois Theory.
Unit – 3	Constructibility by ruler and compass, Solvability by radicals, Insolvability of the general quintic by radicals.

Text Books:

1. P. B. Bhattacharya, S. K. Jain, S. R. Nagpaul: Basic Abstract Algebra, 2nd edition, Cambridge, 1995.
2. M. Artin: Algebra, 2nd Edition, Pearson Education India, 2015.
3. S. Lang: Algebra, 3rd edition, Springer, 2005.
4. J. Rotman: Galois Theory, 2nd edition, Springer, 2006.
5. P. Morandi: Field and Galois Theory, Springer, 2010.
6. I. S. Luthar and I. B. S. Passi: Algebra 4 - Field Theory, Narosa, 2004.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215070	**Statistics- II**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: To derive suitable point estimators of the parameters of the distribution of a random variable and give a measure of their precision. To learn computational skills to implement various statistical inferential approaches. To learn the development of null and alternative hypotheses. To learn types of errors, non-parametric tests. To perform Test of Hypothesis as well as obtain MP, UMP tests.

- **Course Outcome:** Knowledge about formulating and testing a hypothesis, using critical values to draw conclusions and determining probability of making errors in hypothesis tests.
- List the ideal properties of point estimators of an unknown parameter of a distribution and select the best estimators using different properties.
- Understand Basics of Interval Estimation.
- Determine estimators of unknown parameters using methods like MLE, Method of moments etc.
- Understand the stochastic processes, Markov chains, Transition probability matrix and various types of states
- Obtain asymptotic confidence interval of a parameter and its relation with testing of hypothesis problem

Unit – 1	**Inequalities and Limit Theorems:** Introduction, Markov's Inequality, Chebyshev's Inequality, One-sided Chebyshev Inequality, Jensen's Inequality, Random Sample, Modes of Convergence of a sequence of random variables: Convergence in Distribution,Convergence in Probability, Convergence Almost Sure; Weak Law of Large Numbers (WLLN), Strong Law of Large Numbers (SLLN) and Central Limit Theorems (CLT).
Unit – 2	**Theory of Estimation:** Introduction, Point Estimation and Interval Estimation, Methods of Estimation: Method of Maximum Likelihood, Method of Moments; Properties of Estimators: Unbiasedness, Consistency, Efficiency, Sufficiency; Minimum Variance Unbiased Estimator (MVUE), Cramer-Rao Inequality, Minimum Variance Bound (MVB) Estimator, Bayes Estimators.
Unit – 3	**Confidence Interval (CI) Estimation:** Introduction, CI on Mean and Variance of a Normal Distribution, CI on a Proportion, CI on the difference between Means for Paired Observations, CI on the ratio of Variances of Two Normal Distributions, CI on the difference between Two Proportions.
Unit – 4	**Tests of Hypotheses:** Introduction, Statistical Hypotheses, Type-I and Type-II Errors, One-Sided and Two-Sided Hypotheses, Tests of Hypotheses on the Mean of a Normal Distribution; Variance Known as well as Unknown Cases, Tests of Hypotheses on the Variance of a Normal Distribution, Tests of Hypotheses on a Proportion, Tests of Hypotheses on the Means of Two Normal Distributions; Variances Known as well as Unknown Cases, The Paired t-Test, Tests for Equality of two Variances, Tests of Hypotheses on two Proportions, Testing for Goodness of Fit, Contingency Table Tests, Neyman-Pearson Theory

	of Testing of Hypotheses, Uniformly Most Powerful Tests, Likelihood Ratio Tests, Unbiased Tests.

Text Books:

1. S.M. Ross: Introduction to Probability and Statistics for Engineers and Scientists, Academic Press, 4th Edition, 2010.
2. W.W. Hines, D.C. Montgomery, D.M. Goldsman, and C.M. Borror: Probability and Statistics in Engineering, John Wiley and Sons, 7th Edition, 2018.
3. S.C. Gupta and V.K. Kapoor: Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2007.
4. A.M. Goon, M.K. Gupta, B. Dasgupta: Fundamental of Statistics, Vol. I, II, World Press, 2001.
5. V.K. Rohatgi and A.K. Ehsanes Saleh: An Introduction to Probability and Statistics, John Wiley and Sons, Inc. 2015.
6. G. Casella and R.L. Berger: Statistical Inference, Cengage Learning, 3rd Edition, 2008.
7. S. Ross: A First Course in Probability, 8th Edition, Pearson Education, 2010.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215080	**Discrete Mathematics**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: Throughout the course, students will be expected to demonstrate their understanding of discrete mathematics by being able to do use of mathematically correct terminology and notation, construct correct direct and indirect proofs, and use division into cases in a proof and apply logical reasoning to solve a variety of problems. Also, in this course basic concepts of Graph theory such as Trees, Eulerian Graphs, Matching, Vertex colourings, Edge colourings, Planarity, are introduced.

Course Outcome: At the end of the course, the students will be able to :

1. Construct mathematical arguments using logical connectives and quantifiers.
2. Understand how lattices and Boolean algebra are used as tools and mathematical models in the study of networks.
3. Validate the correctness of an argument using statement and predicate calculus.
4. Learn how to work with some of the discrete structures which include sets, relations, functions, graphs and recurrence relation.
5. Understand the concepts Planarity including Euler identity.
6. Discuss and understand the importance of the concepts Matching's and Colourings'

Unit – 1	**Mathematical Logic**: Basic Logical Operations, Conditional And Bi-Conditional Statements, Tautologies, Contradiction, Predicate Calculus Truth Table.
Unit – 2	**Recursion and Recurrence Relations:** Polynomial expressions, telescopic form, recursion theorem, closed form expression, generating function, solution of recurrence relation using generating function, recursion. Pigeon Hole Principle, Inclusion Exclusion Principle, Techniques of Counting, Recurrence relations.
Unit – 3	**Graph Theory:** Introduction to Graph Theory, Basic terms of graph theory, handshaking theorem, Eulerian Graph, Hamiltonian Graph, Planar Graph, Colouring of Graphs, Colouring problem, Five colour Theorem.
Unit – 4	**Boolean Algebra:** Introduction to Binary relations, equivalence relations and partitions, Partial order relations, Hasse diagram. Lattices as partially ordered sets, properties, lattices as algebraic systems, sub lattices. Boolean algebra as lattices, Boolean identities, sub-algebra, Boolean forms and their equivalence, Applications of Boolean algebra to circuit theory.
Text Books: 1. *K. D. Joshi: Foundations* of Discrete Mathematics, New Age International Pb., 1996. 2. R. A. Brualdi, Introductory Combinatorics, 5th Edition, Pearson Education, 2009. 3. R. J. Wilson, Introduction to Graph Theory, 5th edition, Prentice Hall, 2010. 4. J. P. Tremblay and R. Manohar, Discrete Mathematical Structures with Application to Computer Science, Tata McGraw-Hill, 2008. 5. R. Johnsonbaugh, Discrete Mathematics, Eighth Edition, Pearson, 2015.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215090	**Fluid Dynamics**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective:

- To understand the properties of fluids and fluid statics
- To derive the equation of conservation of mass and its application
- To solve kinematic problems such as finding particle paths and stream lines
- To use important concepts of continuity equation, Bernoulli's equation and turbulence, and apply the same to problems
- To analyze laminar and turbulent flows
- To understand the various flow measuring devices

Course Outcome:

- Determine the fluid pressure and use various devices for measuring fluid pressure.
- Calculate hydrostatic force and use of law of conservation mass to fluid flow.

• Apply Bernoulli's equation to fluid flow problems and boundary layer theory to determine lift and drag forces on a submerged body. • Ability to present data or governing equations in non-dimensional form, design experiments, and perform model studies and to decide when appropriate to use ideal flow concepts and the Bernoulli equation. • Ability to solve for internal flow in pipes and channels through simple solutions of the Navier-Stokes equations, Moody chart and head-loss equations. • Ability to solve for external flow, evaluate lift and drag, know when there is possibility of flow separation, apply streamlining concepts for drag reduction by using experimental correlations. An understanding of how fluid mechanics applies to mechanical, biological and environmental systems.	
Unit – 1	Lagrangian and Eularian description, stream lines, path lines, streak lines, vortex lines, vorticity vector, equation of continuity, circulation, rotational and irrotational flows, boundary surface.
Unit – 2	General equations of motion, Bernoulli's theorem (Compressible, incompressible flows) Kelvin's theorem (constancy of circulation). Stream function, complex potential, sources, sinks and dublets, Circle theorem, Method of images. Theorem of Blasius.
Unit – 3	Viscuss flows- stress analysis in fluid motion, relations between stress and rate of strain. Stoke's stream function, Spherical Harmonics and motion of a Sphere. Helmholtz's vorticity equation (permanence of vorticity) Vortx filaments, vortex pair.
Unit – 4	Navier-Stoke's equations, Dissipation of energy, Diffusion of vorticity, Steady flow between two infinite parallel plates, through a circular pipe (Hagen Poiseuille flow).
Text Books: 1. R.W. Fox et.al. Introduction to Fluid Mechanics, 10th edition, Wiley, 2020. 2. B.R. Munson et.al. Fundamentals of Fluid Mechanics, 9th edition, Wiley, 2021. 3. A.K. Mohanty: Fluid Mechanics, 2nd edition, PHI, 2009. 4. M.D. Raisinghania: Fluid Dynamics, 9th edition, S. Chand, 2010. 5. F. Durst, Fluid Mechanics: An introduction to the Theory of Fluid Flows, Springer, 2008.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215100	**Theory and Applications of Fuzzy Sets**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus	02								

Version :	

Course Objective: To introduce the theory of fuzzy sets. To discuss theoretical differences between fuzzy sets and classical sets. To discuss fuzzy logic inference. To introduce fuzzy arithmetic concepts. To discuss fuzzy inference applications in the area of control.

Course Outcome: The Student will be able to:

- interpret fuzzy set theory and uncertainty concepts
- identify the similarities and differences between probability theory and fuzzy set theory and their application conditions
- apply fuzzy set theory in modeling and analyzing uncertainty in a decision problem
- apply fuzzy control by examining simple control problem examples.

Unit – 1	Basic concepts of fuzzy sets, fuzzy logic, operations on fuzzy sets, fuzzy relations, equivalence and similarity relations, ordering, morphisms, fuzzy relation equations.
Unit – 2	fuzzy measures, probability measures, possibility and necessity measures, measures of uncertainty, dissonance, confusion and nonspecificity.
Unit – 3	Principles of uncertainty and information. Applications of fuzzy sets in management, decision making, computer science and systems science.

Text Books:

1. T. J. Ross: Fuzzy Logic with Engineering Applications, 4th edition, Wiley, 2017.
2. G. J. Klir and B. Yuan: Fuzzy Sets and Fuzzy Logic Theory and Applications, Prentice Hall, 1995.
3. G. Chen and T. Pham: Introduction to Fuzzy Sets, Fuzzy Logic, and Fuzzy Control Systems, CRC, 2000.
4. H. J. Zimmermann: Fuzzy Set Theory - and Its Applications, 3rd edition, Springer, 1996.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215110	**Data Structures and Algorithm Analysis**	Compulsory	L	3	T	0	P	1	4

Pre-requisite	:
Course Assessment Methods :	As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)
Syllabus Version :	02

Course Objective: Acquire some basic mathematical tools and techniques of algorithm analysis. To familiarize with basic data structures and to develop the ability to choose the appropriate data structure for designing efficient algorithms. Learn some basic algorithms with their rigorous proofs of correctness and efficiency analysis of implementation using appropriate data structures.

Course Outcome: The Student will be able to: • To understand basic data structures, their implementation and some of their standard applications. • To develop the ability to design and analyze basic algorithms and prove their correctness using the appropriate data structure learned in the course	
Unit – 1	Data and Algorithms Introduction to Data, Information and structures of Data, Algorithms (Quick Review with algorithm design techniques). Introducing uses of data structures in algorithms (fundamental examples).
Unit – 2	Asymptotic analysis Introduction to Algorithms' analysis, cost of algorithms in terms of steps (time) and space (memory). Asymptotic Notations and analysing algorithms growth of functions (Graph representation). Recurrance and asymptotic notations, solving recurrences (Master theorem), Problems practices.
Unit – 3	Algorithms and analysis **Searching**: Linear, Binary, B-Tree, DFS, BFS, Binary Search Tree, AVL Search Tree, Hashing. **Sorting**: Finding max, min and sorting, Insertion Sort, Bubble Sort, Selection Sort, Heap sort, Quick sort, Merge sort, String sort. Strassen's matrix multiplication, Sum of subsets, Minimum spanning trees, Shortest Path algorithm.
Text Books: 1. R.B. Patel, Expert Data Structure with C, 4th edition, Khanna Publishers, New Delhi, 2018. 2. N. Wirth, Algorithms + Data Structures = Programs, 1st edition, Prentice Hall, 1976. 3. E. Horowitz, S. Sahni and S. Rajasekaran: Fundamentals of Computer Algorithms, 2nd edition, Universities Press, 2008. 2. T.H. Coremen, C.E. Leiserson, R.L. Rivest and C. Stein: Introduction to Algorithms, 20th edition, Prentice Hall India, 2010. 3. S. Lipschutz, Data Structures with C (Schaum's Outline Series), McGraw Hill Education P Ltd, New Delhi, 2017.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215120	**Cryptography**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: Understanding the fundamental cryptographic concepts such as encryption, decryption, cryptographic keys, algorithms, and cryptographic protocols. Familiarity with various cryptographic algorithms (e.g., symmetric-key algorithms like AES, DES, asymmetric-key algorithms like RSA, elliptic curve cryptography) and protocols is essential. Understanding how these algorithms and protocols work, their strengths, weaknesses, and appropriate use cases. is typically covered. Apart from these application of cryptographic techniques on secure communication, data integrity verification, authentication, digital signatures, and more to be discussed.

Course Outcome: By the end of this course students will be able to:

- Learn basic concepts of Cryptography, to calculate the tome complexity of an algorithm with big Oh notation.
- Learn methods to factorize of a number and fast exponent.
- Different type of cryptographic encryption schemes
- Application of Number theoretic results in cryptography
- Learn the concept of OTP, DES and its advanced version i.e AES algorithms.
- Learn different types of Public key cryptography like RSA, Rabin encryption, Diffie-Hellman key exchange, ElGamal cryptosystem.
- Programming of each encryption schemes with C++ and Sagemath

Unit – 1	Introduction to basic terminologies associated with Cryptography, Definition and classification of Cryptosystem, Classical crypto systems, Description of rail fence cipher, Simple Columnar cipher, Caesar cipher, Linear cipher, Affine linear cipher, Distinction between Substitution cipher and Permutation cipher. Classical cipher as particular case of Affine linear cipher, Insecurity of Affine linear cipher. Mathematical problems related to cryptography, Division Algorithm and extended Division Algorithm, Calculation of Units in Z/nZ, Fast Exponentiation, Factoring problem, Different factorisation Algorithms, Discrete Log Problem, Discussion of different algorithms for finding discrete log.
Unit – 2	Block cipher and different modes of implementation of Block cipher, Stream cipher, Feistel cipher, DES (Data Encryption Standard) and AES (Advanced Encryption Standard).
Unit – 3	Public Key cryptosystems, Need for Public Key cryptosystems, Description of RSA, Rabin cryptosystem, Diffie-Hellman key exchange, ElGamal cryptosystem, Cryptanalysis of Public Key cryptosystem, Digital signatures, Introduction to Elliptic curve cryptography, Perfect security and Shanon's Theorem.

Text Books:

1. J. A. Buchmann: Introduction to Cryptography, Springer, 2004.
2. N. Koblitz: A Course in Number Theory and Cryptography, Springer, 1994.
3. M. Welschenbach: Cryptography in C and C++, 2nd edition, Apress, 2002.
4. C. Paar and J. Pelzl Understanding Cryptography Springer, 2010.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215130	**Java Programming**	Compulsory	L	3	T	0	P	1	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The course provide profound knowledge in humanities and basic sciences along with core science/engineering concepts for practical understanding and project development. In Career Advancement: Enrich analytical and industry based technical skills for accomplishing research, higher education and entrepreneurship. This course also Infuse life-long learning, professional ethics, adaptation to innovation and effective communication skills with a sense of social awareness.

Course Outcome: After completion of this course student would be able to understand **Object-Oriented Programming & System** concepts to apply in basic Java constructs. Next they analyze the different forms of inheritance and usage of Exception Handling. Also students understand the different kinds of file I/O, Multithreading in complex Java programs, and usage of Container classes. Furthermore, students contrast different **Graphical User Interface** layouts and design **Graphical User Interface** applications. Finally the students construct a full-fledged Java **Graphical User Interface** application and Applet with database connectivity.

Unit – 1	History of java, Features of java, JVM Architecture, Data Types, Operators, Arrays, Command Line Arguments, OOPS in java, Abstract
Unit – 2	Classes, Interfaces, Packages, Access modifiers, Access Specifiers, Exception Handling, Applet, Multithreading, Streams (File I/O),
Unit – 3	Introduction to AWT, Introduction to Collection Framework (java.util.*), String Handling.
Unit – 4	Lab: JAVA lab. +Assignment:

Text Books:

1. H. Schildt: The Complete Reference, 8th Edition, Tata McGraw Hill, 2011.
2. K. Sierra, B. Bates; SCJP Sun Certified Programmer for java 6 study Guide, Tata McGraw Hill, 2008.

E. Balagurusamy: Programming with Java, 3rd/4th Edition Tata McGraw Hill 2007/2009

Reference Books:

Course Code	Course Title	Course Type	Contact Hours	Credit

MMA215140	**Graph Theory**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The objective of the course Graph Theory is to introduce students to the fundamental concepts, principles, and applications of graph theory, which is a branch of discrete mathematics. Graph theory provides a powerful framework for modelling and analyzing relationships and connections among objects in various real-world and theoretical contexts.

Course Outcome: By the end of this course students will:

- Have a comprehensive understanding of graphs and simple graphs, including definitions, properties, and representations. They will be able to distinguish between directed and undirected graphs, weighted and unweighted graphs, and multigraphs.
- Learn about the incidence and adjacency matrices of graphs and their applications in graph theory. They will understand how these matrices represent the connectivity and relationships among vertices in a graph and will study trees, cut edges, cut vertices, and spanning trees. They will understand the properties of trees and their applications in hierarchical structures, data organization, and network design.
- Comprehend the concepts of Euler tours and Hamiltonian cycles in graphs. They will understand the conditions under which a graph possesses Eulerian paths or circuits and Hamiltonian cycles. Students will study the Chinese Postman Problem and its variants and Hall's Marriage Theorem and its applications in matching problems.
- Comprehend the concept of connectivity in graphs, including m-connectivity and blocks and explore vertex coloring in graphs, including planar graphs, Euler's formula, chromatic number, Brook's theorem, and the 5-color theorem.

Unit – 1	Graphs and Sub graphs:- Graphs and simple graphs, Graph isomorphism, The incidence and adjacency matrices, sub graphs, connected and bipartite graphs, walk, trail, path and cycles. Application:- The Shortest path problem, Dijkstra algorithm, Warshall Algorithm. Trees:- Trees, Cut Edge and Bond, Cut vertex, spanning trees and Cayley's formula. The Connector Problem: Prim's Algorithm, Kruskal's Algorithm.
Unit – 2	Euler tour and Hamilton's Cycles, characterization of Eulerian graphs, a necessary and some sufficient characterizations of Hamiltonian graph. Closure and degree majorization and related results, Chinese Postman Problem. Matchings: Theorem of Berge, Matchings and coverings in Bipartite graphs, Application: Hall's marriage theorem, Some Assignment Problems.
Unit – 3	Connectivity: m-connectivity and blocks, Construction of Reliable Communication Networks.

	Vertex Coloring: Planar graph, Euler's formula, Chromatic Number, Brook's Theorem, 5-color theorem.
Unit – 4	**Lab Component:** Implementation in C: Dijkstra Algorithm, Warshall Algorithm, BFS, DFS, Prims Algorithm, Kruskal Algorithm, Connectivity Algorithm, Flurey Algorithm.

Text Books:

1. J.A. Bondy and U.S.R Murty: Graph Theory, Springer, 2008.
2. F. *Harary: Graph Theory, Westview Press, 1994.*
3. R.J. Wilson: Introduction to Graph Theory, 4^{th} edition, Pearson, 2002.
4. J. Clark and D. A. Holton: A First Look at Graph Theory, World Scientific, 1991.
5. D.B. West: Introduction to Graph Theory, 2^{nd}edition, PHI Learning, 2009.
6. N. Deo: Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India, 2004.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215150	**Mathematical Modelling**	Compulsory	L	3	T	1	P	0	4

Pre-requisite	:
Course Assessment Methods :	As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)
Syllabus Version :	02

Course Objective: The objective of the course Mathematical Modelling is to equip students with the fundamental principles, techniques, and tools necessary to formulate, analyse, and solve real-world problems using mathematical models. Through this course, students aim to develop a deep understanding of mathematical concepts and their application in various fields such as engineering, physics, economics, biology, and social sciences. Overall, the course aims to empower students with the ability to approach complex real-world problems analytically, systematically, and quantitatively, thereby preparing them for careers in academia, research, industry, and various other professional fields.

Course Outcome: By the end of this course:

- Students will be able to identify, define, and formulate real-world problems using appropriate mathematical abstractions and modelling techniques.
- Students will demonstrate proficiency in a variety of mathematical techniques including differential equations, optimization methods, probability theory, and statistical analysis for developing and solving mathematical models.
- Students will gain a comprehensive understanding of difference equations, including basic concepts concerning matrices, eigenvalues, and eigenvectors. They will be able

	to apply difference equations to model and analyze iterative processes, particularly in the context of population growth. • Students will apply ODE models to analyse economic and financial phenomena, including models of economic growth, investment dynamics, and asset pricing models. • Students will learn techniques for fitting data using polynomial functions and splines. They will understand the advantages and limitations of different curve-fitting approaches and apply them to real-world datasets. • Students will learn the methodology for conducting simulations, including model development, verification, validation, and experimentation. They will understand the steps involved in building a simulation model and ensuring its accuracy and reliability. • Students will apply the equation of continuity to model fluid flow phenomena, including incompressible and compressible flows. They will understand how to formulate and solve PDEs representing mass conservation principles in fluid dynamics, models to describe heat flow phenomena using PDEs such as the heat equation. They will analyse heat transfer processes in solids, liquids, and gases and understand concepts such as conduction, convection, and radiation. models to analyse traffic flow dynamics, including congestion, flow rates, and traffic density.
Unit – 1	Introduction to modelling, Mathematical modelling, Types of models, Characteristics of Mathematical models, Models on algebraic systems. Modelling with Difference Equations: overview of basic concepts concerning matrices, eigenvalues and eigenvectors; fixed points, stability and iterative processes; applications to population growth.
Unit – 2	Mathematical Models based on Ordinary differential equations, Models based on system of ordinary first order differential equations. Motion of satellites, Electrical Circuits, A curve and Persuit, Birth & Deaths model, Logistic model for growth, Models in Economics and Finance.
Unit – 3	Empirical Modelling with Data Fitting: error function, least squares method; fitting data with polynomials and splines. Types of Simulation, Simple Case Studies, Simulation methodology, Simulation Software, Criteria for valid and Creditable Simulation Models.
Unit – 4	Mathematical models through Partial Differential equations: Equation of Continuity in fluid flow, Heat flow and Traffic flow. Diffusion models in air pollution, Water pollution, simple models based on heat transfer, mass transfer and wave propagation.
Text Books: 1. J.N. Kapoor: *Mathematical Modelling*, Wiley Eastern Ltd, 1982. 2. R. Haberman: *Mathematical Models: Mechanical Vibrations, Population Dynamics, and Traffic Flow*, SIAM, 1998. 3. M. Braun: *Differential Equations and their Application: An Introduction to Applied Mathematics*, 3rd edition, Springer, 1991.	

4. A.M. Law: *Simulation Modelling and Analysis*, 4th edition, McGraw Hill, 2006.
5. R. M. Davies and R. M. O'Keefe: *Simulation Modelling with Pascal*, Prentice Hall 1989.
6. F. R. Giordano, W.P. Fox and S. B. Horton: *A First Course in Mathematical Modelling*, 5th edition, Cengage Learning, 2013

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215160	**Integral Transforms**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: Expose the basic properties of integral transforms and their applications in science and engineering problems. To describe the ideas of Fourier and Laplace Transforms and indicate their applications in the fields such as application of PDE, Digital Signal Processing, Image Processing, Theory of wave equations, Differential Equations and many others and To use Fourier series for solving boundary value problems appearing in scientific & engineering problems. Demonstrate their understanding of the Dirichlet conditions by using them to evaluate infinite series. Recognize even and odd functions and use the resulting simplifications for Fourier series and transforms.

Course Outcome:

- Have understanding regarding different kind of integral transforms.
- Understand Fourier transform and its properties and will be able to solve the examples based on it.
- Have deep understanding of Laplace Transformation and its real life application.
- Solve initial value problem and boundary value problem using Laplace Transform.
- Derive Fourier series representation of Periodic functions.
- Able to deal with problems in applied mathematics in science and engineering.
- Able to apply integral transforms to boundary and initial value problems in ODE's and PDE's.
- Able to present his/her calculations in a manner that is readily intelligible.
- Able to approach more advanced aspects of transform methods.

Unit – 1	**Laplace Transform:** Definition, Transform of some elementary functions, rules of manipulation of Laplace Transform, Transform of Derivatives, relation involving Integrals, the error function, Transform of Bessel functions, Periodic functions, convolution of two functions.
Unit – 2	Inverse Laplace Transform of simple function, Tauberian Theorems, Solution of Differential Equations- Initial value problems for linear equations with constant coefficients, two-point boundary value problem for a linear equation with constant coefficients, linear differential equation with variable coefficients, simultaneous differential equations with constant coefficients,

	Solution of diffusion and wave equation in one dimension and Laplace equation in two dimensions.
Unit – 3	**Fourier Series and Fourier Transforms:** Orthogonal set of functions, Fourier series, Fourier sine and cosine series, Half range expansions, Fourier integral Theorem, Fourier Transform, Fourier Cosine Transform, Fourier Sine Transform, Transforms of Derivatives, Fourier transforms of simple Functions, Fourier transforms of Rational Functions, Convolution Integral, Parseval's Theorem for Cosine and Sine Transforms, Inversion Theorem, , Solution of Partial Differential Equations by means of Fourier Transforms. First order and second order Laplace and Diffusion equations.
Unit – 4	**Laplace Transform:** Definition, Transform of some elementary functions, rules of manipulation of Laplace Transform, Transform of Derivatives, relation involving Integrals, the error function, Transform of Bessel functions, Periodic functions, convolution of two functions.

Text Books:

1. Ian N. Sneddon, The use of Integral Transforms, McGraw Hill; 2nd edition, 1972.
2. Ian N. Sneddon, Fourier Transforms, Dover Publications, 2010.
3. Loknath Debnath, Integral Transforms and their applications, Chapman and Hall/CRC; 2nd edition, 2006.
4. *R. K. Jain*, S. R. K. *Iyengar : Advanced Engineering Mathematics*, 5th *Edition*, Narosa, 2016.
5. Murray Spiegel: Schaum's Outlines of Laplace Transform, 1965.
2. Murray Spiegel: Schaum's Outlines of Fourier Analysis with Applications to Boundary Value Problems, 1974.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA215170	**Numerical Optimization Techniques**	Compulsory	L	3	T	1	P	0	4

Pre-requisite	:
Course Assessment Methods :	As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)
Syllabus Version :	02

Course Objective: The course aims to provide students an experience of mathematically formulating a large variety of optimization/decision problems emerging out of various fields like data science, machine learning, business and finance. The course focuses on learning techniques to optimize the problems in order to obtain the best possible solution.

Course Outcome: The Student will be able to:

- Mathematically formulate the optimization problems using the required number of independent variables.
- Define constraint functions on a problem.

• Check the feasibility and optimality of a solution. Apply conjugate gradient method to solve the problem	
Unit – 1	Introduction: Optimization, Types of Problems and Algorithms. Convex Sets and Convex Functions, Unconstrained Optimization: Basic properties of solutions and algorithms, Global convergence,
Unit – 2	Basic Descent Methods: Line Search Methods, and Newton Methods, Modified Newton methods, Gradients methods, Steepest Descent
Unit – 3	Globally convergent Newton Method. Nonlinear Least Squares Problem and Algorithms, Conjugate Direction Methods, Trust-Region Methods.
	Lab Component: Exposure to Matlab/Mathematica and computational experiments based on the algorithms discussed in the course.
Text Books: 1. E.K.P. Chong and S.H. Zak: *An Introduction to Optimization,* 2nd edition, Wiley, 2010. 2. R. Fletcher: *Practical Methods of Optimization,* 2nd edition, Wiley, 2000. 3. S. S. Rao: *Engineering Optimization: Theory and Practice,* 4th edition, Wiley, 2009. 4. D. Luenberger and Y. Ye: *Linear and Nonlinear Programming,* 3rd edition, Springer, 2008. 5. M.S. Bazaraa et al.: Nonlinear Programming - Theory and Algorithms, 3rd edition, Wiley, 2006.	
Reference Books:	

Semester-IV

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA221040	**Optimization Techniques**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								
Course Objective: Linear programming deals with the problem of optimizing a linear objective function subject to linear equality and inequality constraints on the decision variables. Linear programming has many practical applications (e.g. assignment problems, transportation, problems, production planning problems, etc). One aspect of linear programming that is often forgotten is the fact that it is also a useful proof technique. In the beginning chapter, we study some linear programming formulations for some classical problems. Later we see that linear programming problems can be expressed in a variety of equivalent ways.									
Course Outcome: After completion of this course students can formulate the optimization problems in LPP and then maximize (or, minimize) the profit (or, cost) of a general class of problems by using Graphical, the Simplex, Dual Simplex, Two-Phase, Big-M method. Also, students can able to minimize the transportation costs by using, the North-West corner rule,									

Least-Cost, and Vogel's approximation method. Furthermore, the queuing models are very helpful for determining how to operate a queuing system in the most effective way if too much service capacity to operate the system involves excessive cost. The queuing models enable to finding an appropriate balance between the cost of service and amount of waiting.	
Unit – 1	**Linear Programming:** Introduction, Linear Programming Problem (LPP) and its formulation, Graphical method for solving LPP, Basic Feasible Solution, Simplex Method, Big-M and Two-phase methods, Degeneracy, Alternative Optimal Solution, Unbounded Solution, Infeasible Solution, Dual Problem and Duality Theorems, Dual Simplex Method and its application in post-optimality analysis.
Unit – 2	**Transportation and Assignment Problems:** Introduction, Transportation algorithm, Mathematical formulation, Balanced and Unbalanced Transportation Problems, Vogel's approximation method for solving Transportation Problems, Hungarian method for solving Assignment Problems.
Unit – 3	**Queueing and Inventory Theory:** Introduction, Queueing System, Elements of a Queueing System, Operating Characteristics, Probability distributions in Queueing Systems, Elementary Queueing and Inventory Models, Steady-state solutions of Markovian Queueing Models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.
Text Books: 1. E.K.P. Chong and S.H. Zak: An Introduction to Optimization, 2nd edition, Wiley, 2001. 2. D.G. Luenberger, Y. Ye: Linear and Nonlinear Programming, 3rd edition, Springer, 2008. 3. A.Ravindran, K.M. Ragsdell, G.V. Reklaitis: Engineering Optimization, 2nd edition, Wiley, 2006. 4. H.A. Taha: Operations Research: An Introduction, 8th edition, Prentice Hall, 2007. 5. K. Swarup, P. K. Gupta and M. Mohan: Operations Research, Sultan Chand and Sons, 2004.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA221050	**Number Theory**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								
Course Objective: The course aims to give elementary ideas from number theory which will have applications in cryptology. Identify and apply various properties of and relating to the integers including the Well-Ordering Principle, primes, unique factorization, the division algorithm, and understand the concept of quadratic congruence. Prime power module and primitive roots may help to improve the existing algorithm for primality testing and prime factorization problem which is highly applicable in coding theory and cryptography to develop This course also covers Euler's, Lagrange, and Wilson theorems, Euler's criteria,									

Legendre symbol, Law of quadratic reciprocity; neither Euler nor Legendre were able to prove this but Gauss, Pell's equation.	
Course Outcome: After completing the course, students will be able to solve the elementary number theory problems and they can apply elementary number theory to cryptography. Students develop a deeper conceptual understanding of the theoretical basis of number theory and identify how number theory is related to and, used in cryptography. Students learn the Legendre symbol and use it to prove the Euler criterion, Furthermore, students also use Euler's criterion to prove some nice properties of the Legendre symbol. Students may also be able to understand solutions of Pell's equation and how Gauss was able to prove the Quadratic Reciprocity law.	
Unit – 1	Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø- function, primitive roots, Fermat's Little, Euler and Wilsons Theorem.
Unit – 2	Linear Congruence, Algebraic congruences of degree. Theorems on Prime Power, Modulus, Lagrange Theorem, Quadratic Congruences, Quadratic reciprocity law, Two Square Theorem, Primality Testing, and Factoring.
Unit – 3	Simple continued fractions, Pell's Equation, Diophantine Approximation. Arithmetical functions. Sum and number of Divisors, Dirichlet Product, Mobius inversion formula, Totally multiplicative functions.
Text Books: 1. G.H. Hardy and E.M. Wright: An Introduction to The Theory of Numbers, 6th edition, Oxford University Press, 2008. 2. D.M. Burton: Elementary Number Theory, 6th edition, McGraw-Hill, 2005. 3. I. Niven, H.S. Zuckerman and H.L. Montgomery: An Introduction to The Theory of Numbers, 5th edition, Wiley, 1991. 4. T. M. Apostol: Introduction to Analytic Number Theory, Springer- Verlag, 1976.	
Reference Books:	

Electives of Semester IV

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 226050	Artificial Intelligence and Hybrid Systems	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								
Course Objective: This course deals with an introduction to the basic principles, techniques, and applications of Artificial Intelligence and Hybrid System. Coverage includes knowledge of AI and hybrid system basics, applications and case studies of AI and ML in pharmacy, Theoretical models, use-cases, fundamental programming application of AI and ML in									

pharma datasets, statistical and probabilistic analysis. Foundation to the AI and Machine learning will be provided to the students.	
Course Outcome: Upon successful completion of the course, the students will be able to • Solve basic AI based problems. • Select appropriately from a range of techniques when implementing intelligent systems. • Apply principles of AI in solutions that require problem solving, inference, perception. • Implement algorithms on simple and complex decision making. • Apply AI techniques to real-world problems to develop intelligent systems.	
Unit – 1	**Artificial Intelligence:** Overview of AI, Knowledge representation, Mappings, Approaches and issues, Predicate logic, Propositional logic, Procedural and declarative knowledge. **Fuzzy Logic**: Fuzzy Sets, Fuzzy Relations, Fuzzy operations (on fuzzy sets), Fuzzy numbers and arithmetics, Fuzzy Logic and Possibility Theory. **Problem space and searching techniques** (Algorithms and Problem Practices): Heuristic search technique (s), State Space Search, Graph Search, Search Based on Recursion, Pattern-directed Search.
Unit – 2	**Machine Learning:** Introduction, training data, function approximation, Learning Input-Output Functions, Performance Evaluation. **Learning** (Algorithms and Problem Practices): Decision Tree based, Error correction learning, Supervised, Unsupervised, Hebbian learning, Clustering, K-Means Clustering, Credit assignment problem, Bayes Theorem and Classification.
Unit – 3	**Intelligent Systems**: Introduction, Cognitive Science, Expert Systems, Stages in the Development, Probability-based Expert Systems, Example of Chess game (Practice with 8-Queens problem).
Unit – 4	**Artificial Neural Networks:** Neural network, human brain, model of an artificial neuron, mathematical preliminaries, taxonomy of NN, classical artificial intelligence and neural network. **Artificial Neural Network**: Feed-forward network, Feed-backward network, Recurrent Network, Single Layer and Multi-layer Networks, Perceptron (example of Rosenblatt perceptron) **Single layer Perceptrons** (Algorithms and Problem Practices): Adaptive Filtering Problem, unconstrained optimization techniques, linear least square algorithm, perceptron convergence theorem. **Multilayer Perceptrons:** Back propagation algorithm, XOR problem, output representation and decision rule, back propagation and differentiation. **Geometry of Binary Threshold Neurons:** Pattern recognition and data classification, convex sets, convex hulls and linear separability, space of Boolean functions, binary neurons are pattern dichotomizers, non-linear separable problems, capacity of a simple threshold logic neurons, Re-visiting the XOR problem.
Unit – 5	Hybrid systems, Decision Making Systems, Neuro- fuzzy systems

Text Books: 1. Elaine Rich, Kevin Knight & Shivashankar B. Nair: Artificial Intelligence, 3rd Edition, Mc-Graw Hill, 2017. 2. Dan W. Patterson: Introduction to Artificial Intelligence and Expert Systems, First Edition, 2015. 3. G. J. Klir & B. Yuan, Fuzzy Sets & Fuzzy Logic - Theory and Applications, 2nd Edition, Pearson, 2015. 4. Nils J. Nilsson, Introduction To Machine Learning, 2014. 5. C. M. Bishop: Pattern Recognition and Machine Learning, Springer, Reprint of the Original 1st Edition, Springer, 2016. 6. S. Kumar: Neural Networks: A Classroom Approach, 2nd Edition, Tata McGraw-Hill, 2017. 7. Da Ruan: Intelligent Hybrid Systems: Fuzzy Logic, Neural Networks, And Genetic Algorithms, Springer 1997.
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA226060	**Algebraic Number Theory**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The objective of the course "Algebraic Number Theory" is to provide students with a deep understanding of the algebraic structure of number fields and the properties of algebraic numbers. Algebraic number theory serves as a bridge between algebra and number theory, exploring the arithmetic properties of algebraic objects such as algebraic integers and algebraic extensions of the rational numbers. Studying the properties of algebraic integers, which are roots of monic polynomials with integer coefficients. Students will learn about unique factorization, prime factorization, and arithmetic operations in rings of algebraic integers. Students will explore properties of rings of integers, including finiteness, integrality, and factorization properties. Investigating factorization properties in algebraic number fields, including unique factorization, prime factorization, and decomposition of prime ideals. Students will learn about Fermat's Last Theorem and its proof using techniques from algebraic number theory, including elliptic curves and modular forms.

Course Outcome: By the end of this course:

- Students will have a comprehensive understanding of algebraic numbers, which are roots of polynomial equations with integer coefficients, and algebraic integers, which are roots of monic polynomial equations with integer coefficients. They will learn about the algebraic properties of these numbers and their significance in number theory and algebraic geometry.

- Students will study algebraic number fields, which are extensions of the rational numbers obtained by adjoining algebraic numbers. They will understand the structure and properties of algebraic number fields, including degree, discriminant, and ring of integers.
- Students will explore the group of units in an algebraic number field, which consists of all invertible elements in the field under multiplication. They will learn about the structure and properties of the group of units, including its connection to the group of roots of unity and its role in algebraic number theory.
- Students will investigate divisibility in quadratic fields, which are algebraic number fields obtained by adjoining the square root of a rational number. They will learn about the arithmetic properties of quadratic fields, including factorization of primes, class number, and discriminant.
- Students will gain a comprehensive understanding of ideals, divisors, and factors in algebraic number fields. They will learn about the basic properties of ideals, including generation, containment, and factorization, and their applications in algebraic number theory. Students will learn about the Fermat Conjecture.

Unit – 1	Algebraic Numbers and Algebraic Integers, Algebraic Number Fields, Integral Basis and Discriminant, Ring of Integers in an Algebraic Number Field (with explicit calculations for Quadratic & Cyclotomic fields)
Unit – 2	Divisibility in Algebraic Number Fields, Euclidean Fields, Group of Units in an Algebraic Number Field, Divisibility in Quadratic Fields.
Unit – 3	Ideals, Divisors and Factors, Fundamental Theorem of Ideal Theory, Fractional Ideals, Inverse of an Ideal, Congruences, Norm of an Ideal , The problem of ramification, Class numbers, The Fermat conjecture.

Text Books:

1. Harry Pollard, Harold G. Diamond: The Theory of Algebraic Numbers, 3rd edition, Dover, 2010.
2. S. Alaca, K. S. Williams: Introductory Algebraic Number Theory, CUP, 2003.
3. E. Weiss: Algebraic Number Theory, Dover, 1998.
4. Stewart, D. Tall: Algebraic Number Theory and Fermat's Last Theorem, 3rd edition, A K Peters/CRC Press, 2001.
5. G. J. Janusz: Algebraic Number Fields, 2nd edition, 1996.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA226070	**Statistics III**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								

Course Assessment Methods :	As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)
Syllabus Version :	02

Course Objective: To impart knowledge on Statistical concepts like Data Collection, Measures of Central Tendency and Dispersion, Probability and Distributions, Statistical Methods, Inference, Sampling methods, Experimental Designs, Economical and Vital Statistics, SQC, reliability and Operations Research and To make the students to understand the needs of Statistics and Actuarial Science in Science, Technology and various industries like manufacturing, construction, insurance, IT, etc.

Course Outcome:

- Understand different sampling methods.
- Apply different sampling methods to real world.
- Apply clustering sampling to real problems.
- Interpret analysis of variance tables and other statistical summaries in the context of the aims of the experiment.
- Design and analyse factorial experiments for investigating multiple factors.
- Determine the sample size required to meet a required level of accuracy for an experiment.
- Identify and apply the basic principles of experimental design, including randomisation, replication and control.
- Manipulate and present experimental data using appropriate statistical tools.
  Use appropriate software to analyse experimental data.

Unit – 1	**Sampling Theory:** Introduction, Concept of Population and Sample, Primary and Secondary data, Methods of Collecting Primary data, Sampling frame, Sampling design.
Unit – 2	Determination of sample size, Census and Sample Surveys, Sampling and Non-sampling errors, Simple Random Sampling, Stratified Sampling, Systematic Sampling, Probability Proportional to Size (PPS) Sampling, Ratio and Regression Methods of Estimation.
Unit – 3	**Design and Analysis of Experiments:** Introduction, Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA), Fixed, Random and Mixed effects Models, ANOVA for one-way and two-way Classified Data,
Unit – 4	Basic principles of Design of Experiments, Completely Randomized Design (CRD), Randomized Block Design (RBD) and Latin Square Design (LSD), Factorial Experiments, Confounding in symmetrical factorial experiments (2^n series), Connectedness and Orthogonality of Block Designs, Balanced Incomplete Block Design (BIBD).

Text Books:

1. W. G. Cochran: Sampling Techniques, John Wiley and Sons, 3rd Edition, 1977.
2. P. V. Sukhatme, B. V. Sukhatme, S Sukhatme & C. Ashok : Sampling Theory of Surveys with Applications, Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi, 1984.
3. W. G. Cochran & D. R. Cox : Experimental Designs, John Wiley, 1992.
4. D. C. Montgomery: Design and Analysis of Experiments, John Wiley and Sons, 10th Edition, 2019.
5. S.C. Gupta and V.K. Kapoor: Fundamentals of Applied Statistics, Sultan Chand and Sons, 1994.

6. M.N. Das and N.C. Giri: Design and Analysis of Experiments, New Age Publication, 2nd Edition, 1986.
Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA206080	**Difference Equations and Discrete Dynamical Systems**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The objective of the course "Difference Equations and Discrete Dynamical Systems" is to provide students with a thorough understanding of the theory and applications of difference equations and discrete dynamical systems. Difference equations play a crucial role in modelling and analyzing discrete-time dynamical systems, which arise in various fields such as mathematics, engineering, physics, biology, and economics. By achieving these objectives, students will be well-equipped to analyze, model, and solve problems involving difference equations and discrete dynamical systems in various disciplines. They will possess the knowledge, skills, and analytical tools necessary to make meaningful contributions to research, industry, and academia in dynamical systems theory and its applications.

Course Outcome:

By the end of this course:

- Students will have a comprehensive understanding of difference equations and their role in modeling discrete-time dynamical systems. They will learn about the discrete nature of difference equations and their applications in various fields.
- Students will learn various solution techniques for first-order difference equations, including analytical methods such as iteration, recursion, and generating functions, as well as numerical methods such as finite differences and numerical integration.
- Students will explore the group of units in an algebraic number field, which consists of all invertible elements in the field under multiplication. They will learn about the structure and properties of the group of units, including its connection to the group of roots of unity and its role in algebraic number theory.
- Students will explore fixed points and periodic points in both discrete and continuous

dynamical systems. They will learn how to characterize these points and analyze their stability using linearization techniques and qualitative methods.

- Student will study chaos in discrete and continuous dynamical systems, including the concept of sensitive dependence on initial conditions and the existence of chaotic attractors. They will learn how to compute Lyapunov exponents and identify chaotic behavior in dynamical systems.

Unit – 1	**Difference Equations:** Introduction to Difference Equations, First order DEs, linear equations with constant coefficients, variable coefficients, stability in both hyperbolic and nonhyperbolic cases, bifurcations, symbolic dynamics and chaos, linear theory for two dimensional systems of difference equations, equilibria, stability, periodic solutions, period-doubling bifurcation, Lyapunov numbers, box dimension, stable and unstable manifolds, area preserving maps, systems with order higher than 2, numerical issues in difference equations.
Unit – 2	**Discrete Dynamical Systems:** Discrete and continuous dynamical systems, One and two dimensional maps as discrete dynamical systems, Fixed points, periodic points and stability, Chaos, Lyapunov exponents and chaotic attractors, Differential equations as continuous dynamical systems, Periodic orbits and limit sets, Bifurcations.

Text Books:

1. S. Goldberg: Introduction to difference Equations, Dover, 1986.
2. K.T. Alligood, T.D. Sauer and J.A. Yorke: An Introduction to Dynamical Systems, Springer, 1997.
3. E. Ott: Chaos in Dynamical Systems, Cambridge University Press, 2nd edition 2002.
4. S.H. Strogatz: Nonlinear Dynamics and Chaos - With Applications to Physics, Biology, Chemistry and Engineering, Westview Press, 2000.
5. S. Elaydi: An Introduction to Difference Equations, Springer, 1995.
6. W.G. Kelley and A.C. Peterson: Difference Equations - An Introduction with Applications, 2nd edition, AP, 2001.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA206090	**Coding Theory**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The objective of the course "Coding Theory" is to provide students with a comprehensive understanding of the principles, techniques, and applications of coding theory

in the design and analysis of error-correcting codes. Coding theory plays a crucial role in various fields, including telecommunications, data storage, cryptography, and information theory. Techniques for error detection and correction in digital communication systems, data storage devices, and transmission channels will be discussed. Explaining the theory behind linear codes and their representation using matrices. Students will learn about generator matrices, parity-check matrices, and how to encode and decode linear block codes using matrix operations. Also it the discussion on BCH bound, Encoding decoding of cyclic codes, Hamming and Golay codes as cyclic codes, BCH codes, Reed-Soloman codes, Quadratic residue codes, Graphical codes, Convolutional codes.	
Course Outcome: By the end of this course students will: • Have a comprehensive understanding of communication channels and their characteristics, including noise, distortion, and error propagation. They will learn about the challenges and limitations of transmitting information over communication channels and the need for error control techniques. • Learn about the coding problem in communication theory, which involves designing efficient and reliable encoding and decoding schemes to mitigate errors introduced by noisy communication channels. Also it includes block codes, which are error-correcting codes that operate on fixed-size blocks of data. • Have a comprehensive understanding of Hamming codes, which are a class of linear error-correcting codes. They will study Golay codes, Reed- Muller code which are optimal binary linear codes with high error-correcting capabilities. They will study different kinds of bounds involved in coding theory. • Comprehend the applications of algebra in coding theory and study some special codes like BCH bound, Encoding decoding of cyclic codes, Hamming and Golay codes as cyclic codes, BCH codes, Reed-Soloman codes, Quadratic residue codes, Graphical codes, Convolutional codes.	
Unit – 1	The Communication Channel, The coding problem, Block codes, Hamming metric, Nearest neighbour decoding, Linear codes, Generator and parity check matrices, dual codes, Standard array decoding, Syndrome decoding, Permutation equivalent codes.
Unit – 2	Hamming codes, Golay codes, Reed–Muller codes, Codes derived from hadamard matrices. Bounds on codes: $A_q(n,d)$ and $B_q(n,d)$, sphere packing bound, covering radius and perfect codes. Singleton bound and MDS codes, Gilbert lower bound and Varshamov lower bound, Plotkin bound.
Unit – 3	Finite fields, cyclotomic cosets and minimal polynomials. Cyclic codes: factoring $x^n - 1$, basic theory of cyclic codes, Generator polynomial and check polynomial, minimum distance of cyclic codes. BCH bound, Encoding decoding of cyclic codes, Hamming and Golay codes as

	cyclic codes, BCH codes, Reed-Soloman codes, Quadratic residue codes, Graphical codes, Convolutional codes.

Text Books:

1. W.C. Huffman and V. Pless: Fundamentals of Error-correcting Codes, Cambridge University Press, 2003.
2. S. Ling and C. Xing: Coding Theory - A First Course, Cambridge University Press, 2004.
3. E. R. Berlekamp: *Algebraic Coding Theory*, Aegean Park Press, 1984.
4. J. H. Van Lint: Introduction to Coding Theory, 3rd edition, Springer, 1999.
5. R. Roth: Introduction to Coding Theory, Cambridge University Press, 2006.
6. S. Roman: Introduction to Coding and Information Theory, Springer-Verlag, 1997

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 226100	**Operator Theory**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective:
Students would typically learn the theoretical foundations of linear operators which are nothing but linear mappings from one vector space to a vector space. They would study properties of operators, techniques for analyzing spectra, and methods for solving equations involving operators. Spectral theory deals with the decomposition of operators into simpler components, such as eigenvalues and eigenvectors, and the study of the spectrum of an operator, which includes its point spectrum, continuous spectrum, and residual spectrum. They would also know about nonlinear operators variational inequalitites, complimentarty problems. Some applications in the field of quantum mechanics, differential equations, partial differential equations, signal processing, and control theory will also be covered

Course Outcome: The Student will be able to:

- Learn the theoretical foundations of linear operators, properties of operators, techniques for analyzing spectra, and methods for solving equations involving operators.
- Learn how to decompose operators into simpler components, such as eigenvalues and eigenvectors, and the study of the spectrum of an operator, which includes its point spectrum, continuous spectrum, and residual spectrum.
- Learn about nonlinear operators' variational inequalitites, complimentarty problems.
- Learn some applications in the field of quantum mechanics, differential equations, partial differential equations, signal processing, and control theory etc

Unit – 1	Linear Operators, self-adjoint operators and compact operators.
Unit – 2	Eigenvalues, Eigenvectors, Spectrum, spectral theorem, Sturm-Liouville systems, and the Fredoholm alternative.
Unit – 3	Nonlinear operators, variational inequalitites, complimentarty problems.
Text Books: 1. B. Choudhary and S. Nanda: Functional Analysis with Applications, Wiley, 1989. 2. E. Kreyszig: Introductory Functional Analysis with Applications, Wiley, 1978. 3. N. Dunford and J. T. Schwartz: Linear Operators, Part I-III, Wiley, 2009. 4. G. Bachman and L. Narici: Functional analysis, AP, 1966.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 226110	**Operating Systems**	Compulsory	L	3	T	0	P	1	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: This course Operating Systems is an essential part of any Computer-Science education. The objective of this course is to understand the mechanisms of the Operating Systems like Process Management, Process Synchronization, Memory Management, File System Implementation, Storage Structures used in OS and Protection Principles. How effectively the OS is utilizing the CPU resources with the help of these mechanisms.

Course Outcome: After completing this course, the student will be able to

- Control access to a computer and the files that may be shared
- Demonstrate the knowledge of the components of computer and their respective roles in computing.
- Recognize and resolve user problems with standard operating environments
- Gain practical knowledge of how programming languages, operating systems, and architectures interact and how to use each effectively.

Unit – 1	Introduction to Operating Systems, Evolution, Types of OS. Processes: Concept of processes, process scheduling, operations on processes, co-operating processes, interprocess communication. Overview of Threads, benefits of threads, CPU scheduling Criteria, Scheduling Algorithms (FCFS, SRTN, RR), Algorithm evaluation. Process Synchronization, critical section problem, critical region, classical problems of synchronization, semaphores. Deadlocks: Deadlock characterization, Methods to handle deadlocks, deadlock (prevention, avoidance, detection, recovery).
Unit – 2	Memory Management, logical vs. physical address space, swapping, contiguous memory allocation, paging, segmentation, segmentation with

	paging. Virtual Memory, demand paging, performance, page replacement, page replacement algorithms (FCFS, LRU), allocation of frames, thrashing, Concept of Cache Memory.
Unit – 3	File System concepts, access methods, directory structure, file system structure, allocation methods (contiguous, linked and indexed) and free-space management. Disk Management: disk structure, disk scheduling (FCFS, SSTF, SCAN, C-SCAN). Protection and Security.

1. Text Books: A. S. Tanenbaum: Operating System Design and Implementation, 3rd Edition, Pearson Education India, 20015.
2. A. Silberschatz, G. Gagne and P.B. Galvin: Operating System Concepts, 8th Edition, Wiley, 2017.
3. D. M. Dhamdhere: Operating Systems - A Concept Based Approach, 3rd Edition, McGraw Hill Education, 2017.
4. W. Stallings: Operating Systems: Internals and Design Principles, 6th Edition, Pearson Education, 2008.
5. S. Das: Unix: Concept and Application, 4th Edition Tata McGraw-Hill, 2017.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 226120	Relational Database Management Systems	Compulsory	L	3	T	0	P	1	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: The objective of the course is to present an introduction to database management systems, with an emphasis on how to organize, maintain and retrieve - efficiently, and effectively - information from a DBMS.

Course Outcome: Upon successful completion of this course, students should be able to:

- Describe the fundamental elements of relational database management systems
- Understand the basic concepts and the applications of database systems.
- Explain the basic concepts of relational data model, entity-relationship model, relational database design, relational algebra and SQL.
- Design ER-models to represent simple database application scenarios
- Convert the ER-model to relational tables, populate relational database and formulate SQL queries on data
  Familiar with basic database storage structures and access techniques: file and page organizations, indexing methods including B tree, and hashing

Unit – 1	Data and Database Management System, the Database Life Cycle, the Relational Model. ER Model: Entities, Relationship, Attributes, Degree of

	Relationship connectivity, attributes of a relationship. Concepts of Generalization, Specialization & Aggregation. Concepts of FD. Normalisation : 1NF, 2NF, 3NF & BCNF, lossless join, dependency preservation. Denormalization.
Unit – 2	Relational Algebra & Calculus. Transforming the Conceptual Data Model to SQL Storage using RAID architecture. B-tree and B^+-tree Index Files. Measures of Query Cost & overview of query evaluation.
Unit – 3	Transaction concept, Concurrency Control, Database Recovery.
	Laboratory: Types of SQL commands: DDL, DML, DQL & DCL. Tables: create, alter, drop. View: creating view, Data query and manipulation with view. Testing for NULL and when not to use NULL. Aggregate Functions: Count(), SUM(), AVG(), MAX(), MIN(). Select Statement, Subquaries, INSERT, UPDATE and DELETE operation. Joins: Natural join, Self join, outer join and Cartesian product. Data security: GRANT and REVOKE.

Text Books:

1. T. J. Teorey et al.: Database Modelling and Design: Logical Design, 4th Edition, Morgan Kaufmann, 2005.
2. A. Silberschatz, H. F. Korth and S. Sudarshan: – Database System Concepts, 6th Edition, McGraw Hill, 2013.
3. A. Leon, M. Leon: SQL: A Complete Reference, McGraw Hill, 2007.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA 226130	**Classical Mechanics**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: A course designed to introduce students to classical mechanics. An introduction to modern classical mechanics as applied to the particles and solid bodies. If you do not learn classical mechanics, then you will not understand the major developments of science. To revise Newtonian mechanics and introduce Lagrangian formulation of mechanics. To emphasis the understanding of Classical Mechanics using Lagrangian and Hamiltonian Approach. To realize the reduction of a two-body problem to a one-body problem in a central force system. To appreciate the theory of relativity for particles having relativistic speeds.

- **Course Outcome:** Identify the motion of a mechanical system using Lagrange-Hamilton formalism.
- Apply the formalism of Lagrangian and Hamiltonian in generating equations of motion for complicated mechanical systems of classical mechanics.
- Determine the differential equation of orbit, stability of orbit under central force, scattering cross section, scattering angle, impact factor.
- Compare Lagrangian and Hamiltonian formalism, Galiliean and Lorentz

transformation and various reference frames. • Apply theory of relativity to determine time dilation, length contraction and simultaneity • Determine the various Four vectors: position, velocity, acceleration, momentum, Force.	
Unit – 1	Integrals of Motion: Ignorable Coordinates Routhian function. Generalized coordinates, Lagrange's equations.
Unit – 2	Hamilton's canonical equations, Hamilton's principle and principle of least action, Hamilton Jacobi equation, Possain and Lagrange's Brackets, Canonical transformation.
Unit – 3	Two-dimensional motion of rigid bodies, Euler's dynamical equations for the motion of a rigid body about a fixed point, theory of small oscillations.
Text Books: 1. T. Greenwood: Classical Dynamics, Dover, 1997. 2. H. Goldstein, C.R. Poole and J. Safko: Classical Mechanics, 3rd Edition, Pearson India, 2011. 3. E.T. Whittaker: A Treatise on the Analytical Dynamics of Particles and Rigid Bodies: With an Introduction to the Problem of Three Bodies, 4th edition, CUP, 1989. 4. L.D. Landau and E.M. Lifshitz: Mechanics, 3rd edition, Butterworth-Heinemann, 1982. 5. H.C. Corben and P. Stehle: Classical Mechanics, 2nd edition, Dover Publications, 1994. 6. J.B. Marion and S.T. Thornton: Classical Dynamics of Particles and Systems, 5th edition, Cengage Learning, 2003. 7. V.I. Arnold and A. Weinstein: Mathematical Methods of Classical Mechanics, 2nd edition, Springer, 1997.	
Reference Books:	

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA226140	**Tensor Algebra**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								
Course Objective: The role of the course is to introduce the principles of tensor analysis. It is assumed that students entering this course have previously taken the entry level course on Continuum Mechanics and the fundamental concept of special theory of relativity and its applications. To learn about tensor quantities and algebra of tensor addition and multiplication. To understand differentiation of tensors fields.									
Course Outcome:									

Unit – 1	Transformation of coordinates, Tensors, Algebra of Tensor, Symmetric and skew-Symmetric tensors, Contraction of Tensor and Quotient law.
Unit – 2	Riemannian metric, Christoffel Symbol, Covariant derivatives, Intrinsic derivatives and geodesics.
Unit – 3	Riemann Christoffel Curvature Tensor and it's symmetry properties, Binachi identities and Einstein tensor.
Unit – 4	Quick Review of the special theory of relativity and general relativity, Einstein's Field equations, Schwarzchild's external solution and isotropic form, Energy-Momentum tensor of a perfect fluid, Schwarzchild's internal solution.
Unit – 5	Boundary conditions, Energy-Momentum tensor of an electromagnetic field, Einstein-Maxwell equations, Reissner-Nordstrom solution.

Text Books:

1. C. E. Weatherburn: An Introduction to Riemannian Geometry and the Tensor Calculus, CUP, 2008.
2. H. Stephani et al.: General Relativity: An Introduction to the Theory of Gravitational Field, 2nd edition, CUP, 1990.
3. A. S. Eddington: The Mathematical Theory of Relativity, 2nd edition, CUP, 2010.
4. J. V. Narlikar: Lectures on General Relativity and Cosmology, Macmillan Press, 2013
5. R. Adler: Introduction to General Relativity, 2nd edition, McGraw-Hill, 1975.
6. B. Schutz: A First Course in General Relativity, 2nd edition, CUP, 2010.
7. J.K. Goyal and K.P. Gupta: Theory of Relativity, Krishna Prakashan, 2019.

Reference Books:

Course Code	Course Title	Course Type	Contact Hours						Credit
MMA226150	**Differential Manifold**	Compulsory	L	3	T	1	P	0	4
Pre-requisite	:								
Course Assessment Methods :		As per CUJ norms (60 marks from end semester and 40 marks from sessional examinations)							
Syllabus Version :	02								

Course Objective: introduce "Differential Manifold" to the students. The course typically revolves around introducing students to the fundamental concepts, theories, and techniques related to the study of differential manifolds, smooth manifolds, topological manifolds, and geometric properties of manifolds. This includes understanding concepts like dimensionality, connectivity, compactness, and orientability. Techniques for studying differentiable structures smooth partitions of unity, immersions, embeddings, and submersions on manifolds would be explored. Introduction to the tangent bundle and cotangent bundle of a manifold. A deeper dive into Lie groups and Lie algebras, which are special types of manifolds with group structures. This includes understanding Lie group actions, Lie brackets, and the relationship between Lie groups and Lie algebras.

Course Outcome:

- Students should demonstrate a thorough understanding of the definition and properties of different types of manifolds, including smooth, topological, and differentiable

<table>
<tr><td colspan="2">manifolds.

Students should be able to compute tangent spaces, tangent bundles, and understand vector fields on manifolds. They should also demonstrate proficiency in differentiating functions on manifolds.
Students should be able to work with differential forms, understand their geometric significance, and perform integration of forms over manifolds.
Students should demonstrate familiarity with Lie groups, Lie algebras, and their properties, including Lie group actions and Lie brackets
</td></tr>
<tr><td>Unit – 1</td><td>Quick review to Curves and Surfaces (at most 5 classes), Derivative of a function from an open subset of R^n into R^m as a linear transformation. Chain rule. Partial derivatives. Taylor's theorem. Inverse function theorem. Implicit function theorem, Jacobians.</td></tr>
<tr><td>Unit – 2</td><td>Manifolds, Smooth maps and diffeomorphisms, Tangent Spaces to a manifold, Derivatives of smooths maps, Immersions and submersions, submanifolds, Vector fields, Flows and exponential map, Frobenius theorem, Lie groups and Lie algebras, Homogeneous spaces,</td></tr>
<tr><td>Unit – 3</td><td>Multilinear algebra, Exterior algebra, Tensor fields, Exterior derivative, Lie derivatives. Orientable manifolds, Integration on manifolds, Stokes' theorem, Tangent Bundles and Vector Bundles.</td></tr>
<tr><td colspan="2">Text Books:

S. Kumaresan: A Course in Differential Geometry and Lie Groups, Hindustan Book Agency, 2002.
J. R. Munkres: Analysis on Manifolds, Westview Press, 1997.
S. Lang: Introduction to Differentiable Manifold, 2nd edition, Springer, 2002.
L. Auslander and R. E. Mackenzie: Introduction to Differentiable Manifolds, Dover, 2009.
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