Department of Mathematics & Computing, IIT (ISM) Dhanbad

Course Structure for 2 year M.Sc (Mathematics & Computing) (W.E.F: Academic Year 2019 – 2020)

First Semester						
S No	**Course No**	**Course Name**	**L**	**T**	**P**	**C**
1	MCC501	Analysis	3	0	0	9
2	MCC502	Differential Equations	3	0	0	9
3	MCC503	Numerical Methods	3	0	0	9
4	MCC504	Data Structures	3	0	0	9
5	MCC505	Probability & Statistics	3	0	0	9
6	MCC506	Numerical Methods - Practical 1	0	0	3	3
7	MCC507	Data Structures – Practical 2	0	0	2	2
		Total	**15**	**0**	**5**	**50**

Second Semester						
S No	**Course No**	**Course Name**	**L**	**T**	**P**	**C**
1	MCC508	Advanced Algebra	3	0	0	9
2	MCC509	Statistical Inference	3	0	0	9
3	MCC510	Operating Systems	3	0	0	9
4	MCC511	Data Base Management Systems	3	0	0	9
5	XXXXXX	Open Elective 1	3	0	0	9
6	MCC512	Operating Systems – Practical 3	0	0	3	3
7	MCC513	Data Base Management Systems – Practical 4	0	0	2	2
		Total	**15**	**0**	**5**	**50**

Third Semester						
S No	**Course No**	**Course Name**	**L**	**T**	**P**	**C**
1	MCC514	Functional Analysis	3	0	0	9
2	MCC515	Topology	3	0	0	9
3	MCC516	Computational Fluid Dynamics	3	0	0	9
4	MCC517	Design and Analysis of Algorithms	3	0	0	9
5	XXXXXX	Open Elective 2	3	0	0	9
6	MCC518	Computational Fluid Dynamics– Practical 5	0	0	3	3
7	MCC519	Design and Analysis of Algorithms - Practical 6	0	0	2	2
		Total	**15**	**0**	**5**	**50**

Fourth Semester						
S No	**Course No**	**Course Name**	**L**	**T**	**P**	**C**
1	MCD5##	Departmental Elective-1 (Pure & Applied Group)	3	0	0	9
2	MCD5##	Departmental Elective-2 (Computer/Statistics/OR)	3	0	0	9
3	MCC598	Thesis Unit	0	0	0	18
		Total	**6**	**0**	**0**	**36**
Note: 1. ## indicates the numeric digits of Elective Papers.						

Open Elective*

S No	Course No	Course Name	L	T	P	C
1	MCO501	Discrete Mathematics	3	0	0	9
2	MCO502	Optimization Techniques	3	0	0	9

* Any one out of this list or from Departmental Electives or from other Departments may be opted subject to the offered by Departments.

Department Elective

S No	Course No	Course Name	L	T	P	C
1	MCD501	Classical Mechanics	3	0	0	9
2	MCD502	Graph Theory	3	0	0	9
3	MCD503	Integral Equations and Calculus of Variations	3	0	0	9
4	MCD504	Measure Theory	3	0	0	9
5	MCD505	Basic Number Theory	3	0	0	9
6	MCD506	Parallel Computing	3	0	0	9
7	MCD507	Representation Theory of Finite Groups	3	0	0	9
8	MCD508	Theory of Computation	3	0	0	9
9	MCD509	Algebraic Coding Theory	3	0	0	9
10	MCD510	Complex Analysis	3	0	0	9
11	MCD511	Mathematical Ecology	3	0	0	9
12	MCD512	Non-Linear Dynamics and Chaos	3	0	0	9
13	MCD513	Methods of Applied Mathematics	3	0	0	9
14	MCD514	Sampling Theory	3	0	0	9
15	MCD516	Industrial Statistics	3	0	0	9
16	MCD537	Design of Experiments	3	0	0	9

Department Elective-1 (Pure & Applied Group)

S No	Course No	Course Name	L	T	P	C
1	MCD501	Classical Mechanics	3	0	0	9
3	MCD503	Integral Equations and Calculus of Variations	3	0	0	9
4	MCD504	Measure Theory	3	0	0	9
5	MCD505	Basic Number Theory	3	0	0	9
7	MCD507	Representation Theory of Finite Groups	3	0	0	9
10	MCD510	Complex Analysis	3	0	0	9
11	MCD511	Mathematical Ecology	3	0	0	9
12	MCD512	Non-Linear Dynamics and Chaos	3	0	0	9
13	MCD513	Methods of Applied Mathematics	3	0	0	9

Department Elective-2 (Computer/Statistics/Operations Research)

S No	Course No	Course Name	L	T	P	C
2	MCD502	Graph Theory	3	0	0	9
6	MCD506	Parallel Computing	3	0	0	9
8	MCD508	Theory of Computation	3	0	0	9
9	MCD509	Algebraic Coding Theory	3	0	0	9
14	MCD514	Sampling Theory	3	0	0	9
15	MCD516	Industrial Statistics	3	0	0	9
16	MCD537	Design of Experiments	3	0	0	9

MCC501 **Analysis** **L-T-P: 3-0-0**

Prerequisite: Real Analysis (Functions of one variable: Limit, Continuity, Differentiability and Riemann Integral) and Linear Algebra.

Objective: **1.** To introduce Calculus in several variables (concept of Limit, Continuity, Differentiability in several variables). **2.** To introduce the basics of Riemann Stieltjes and Lebesgue integrals.

Outcome: The students will be able to understand (i) the basic idea of Limit, Continuity, and Differentiability in several variables and its applications in Geometry (ii) the basics of Lebesgue integrals which extends the integral to a larger class of functions and also extends the domains on which these functions can be defined.

Course Content	**Unit I** **12 Lectures** Functions of two or three variables, Limit, Continuity, Differentiability, Directional derivatives, Partial derivatives, Total derivative, Gradient, Tangent Plane, Mixed derivative Theorem, Mean value Theorem, Extended Mean value Theorem, Taylor's Theorem, Chain Rule, Maxima and minima, Saddle point, Method of Lagrange's multipliers. **Unit II** **9 Lectures** Functions of several variables: Differentiation, derivative as a linear Transformation, Jacobians, Contraction mapping principle, Inverse and Implicit function theorems. **Unit III** **9 Lectures** Review of Riemann integral, Riemann Stieltjes integral, existence and its properties, Improper integrals. **Unit IV** **9 Lectures** Lebesgue measure, Measurable functions, Lebesgue integral.
Learning Outcome	**Unit I:** This unit will help students to understand the concept of limit and continuity in several variables and to get Taylors expansion. Students will also learn to find maxima and minima of a function. **Unit II:** Students will be able to understand differentiation in several variables and their applications. **Unit III:** Students will get the idea of Riemann Stieltjes integral and Improper integrals. **Unit IV:** Students will learn the basics of Lebesgue integrals
Text Books	**1.** T. M. Apostol, Mathematical Analysis, 2nd Edition, Narosa, 2002. **2 .**H.L. Royden, Real Analysis, 4th Edition, Prentice Hall India, 2011.
Reference Books	**1.** S. R. Ghorpade and B. V. Limaye, A Course in Multivariable Calculus and Analysis, Springer, 2010. **2**. T. M. Apostol, Calculus, Volume 2, 2nd Edition, Wiley, 2007. **3.** W. Rudin, Principles of Mathematical Analysis, 3rd Edition, McGraw-Hill, 2017. **4.** I. K. Rana, An Introduction to Measure and Integration, 2nd Edition, Narosa, 2004.

MCC502 **Differential Equations** **L-T-P: 3-0-0**

Prerequisite: Real analysis, Fourier series, Elementary topics of differential equations**.**

Objective: To understand the theory of ordinary and partial differential equations and their utility in solving real-world problems arising in mathematical physics and engineering.

Outcome: Students will get expertize to solve problems in mathematical physics and engineering.

Course Content	**Unit I** **5 Lectures** Initial value problems, Existence and uniqueness and continuity theorems, Series solution around an ordinary point and a regular singular point, the method of Frobenius. **Unit II** **7 Lectures** Bessel differential equation, Bessel functions properties, Generating function, Legendre differential equation, Legendre function, Orthogonal property of Legendre polynomials, Generating function. **Unit III** **7 Lectures** Two-point boundary value problems, Green's functions, Self-adjoint Eigen value problems, Sturm-Liouville systems. **Unit IV** **13 Lectures** Linear and Quasi linear equations, Partial Differential Equations of second order with constant and variable coefficients, Classification and reduction of second order equations to canonical form, Cauchy, Neumann and Dirichlet problems. **Unit V** **7 Lectures** Solution of Laplace, wave and unsteady heat equations by variable-separable method, solution of wave and unsteady heat equations innon-homogeneous cases
Learning Outcome	**Unit I:** From this topic, student will understand the criteria for the existence and uniqueness of solutions of differential equations. In addition, student will learn an efficient technique to solve equations with variable coefficients. **Unit II:** From this topic, student will understand the theory of some special functions which often occur when solving physical problems **Unit III:** From this topic, student will understand about boundary value problems and widely used Green's function technique. In addition to this, student will knowledge on eigen-value problems which often occur in solving model equations. **Unit IV:** From this topic, student will get the knowledge on the genesis of partial differential equations. Moreover, it helps to understand various types of boundary value problems based on physical assumptions. **Unit V:** From this topic, student will learn several methods to solve partial differential equations.
Text Books	1.T. Myint-U, Ordinary Differential Equations, North-Holland, New York (1978). 2.T. Amaranath, An Elementary Course in Partial Differential Equations, 2nd Ed. Narosa Publishing House, Chennai (2002).
Reference Books	1.G. F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw-Hill Edition, Delhi (2003). 2.W.W. Bell**,** Special Functions for Scientists and Engineers, Van Nostrand Ltd. (1968).

MCC503 **Numerical Methods** **L-T-P: 3-0-0**

Objective: Due to immense development in the computational technology, numerical methods are more popular as a tool for scientists and engineers. This branch of Mathematics dealt with to find approximation solution of difficult problems such as finding roots of non-linear equations, numerical integration, numerical solutions of the ordinary differential equations and partial differential equations with initial or boundary conditions.

Outcome: It is expected that students will learn many methods to solve mathematical model with real data and also enhance their application skills

Course Content	**Unit I** **12 Lectures** Solution of tridiagonal system, Solution of simultaneous non-linear equations, Central Difference interpolation formulae, Numerical evaluation of double and triple integrals with constant and variable limits and its application, Solution of integral equations, Solution of initial-value problem by single and multistep methods **Unit II** **10 Lectures** Solution of linear and non-linear boundary-value problems, Solution of Characteristics value problems, Solution of Laplace and Poisson equations in two variables by five point formula, Solution of Laplace equation in two variables by ADI method, Solution of mixed boundary value problem **Unit III** **8 Lectures** Algorithm for elliptic equation in three variables, Solution of parabolic partial differential equation in two variables by explicit and implicit methods, Solution of parabolic equation in three variables by ADE and ADI methods **Unit IV** **9 Lectures** Solution of hyperbolic equation in two variables by explicit and implicit methods and algorithm for hyperbolic equation in three variables, Stability of finite difference schemes for parabolic and hyperbolic equations.
Learning Outcome	**Unit I:** In this unit students will learn to solve tridiagonal system, non-linear equations and integral equations and interpolations formulae. **Unit II:** This unit will help students to understand the Application of boundary value problem **Unit III:** This unit will help students to apply the concept of finite difference methods to solve PDE. **Unit IV:** Students will be able to understand the stability conditions of finite difference schemes.
Text Books	1. Numerical Mathematics and Computing, by Ward Cheney and David Kincaid, International Thomson Publishing Company, (2013). 2. Analysis of Numerical Methods, by E. Isaacson & H. B. Keller, John Wiley & Sons. Dover Publications, Inc., New York, 1966
Reference Books	1. Applied Numerical Analysis, by Curtis Gerald and Patrick Wheatley, Addison-Wesley. Pearson Education India; 7 edition (2007) 2. Numerical Solution of Partial Differential Equations : Finite Difference Methods, by G. D. Smith, Oxford University Press, 1985

MCC504 **Data Structures** **L-T-P: 3-0-0**

Objective: Data Structures is the basic course of Computer Science. It is required in every field of Computer Science. Objective of this course is to impart knowledge of Data Structures.

Outcome: Students will learn how to represent the data in various forms and use them in various applications.

Course Content	**Unit I** **10 Lectures** Basic concepts; Mathematical Background; Arrays: one dimensional, multi-dimensional, Sparse Matrix. Elementary Operations: Stacks: Representation, elementary operations and applications such as infix to postfix, postfix evaluation, parenthesis matching, representation of Stack Using Queues, Representation of Stack using single Array. Queues: Simple queues, circular queue, elementary operations, representation of Queue using Stacks. **Unit II** **6 Lectures** Linked lists: Linear, circular and doubly linked lists, elementary operations and applications such as polynomial manipulation, Searching, Representation of Sparse Matrix and Sparse Matrix manipulations using Linked list. **Unit III** **7 Lectures** Trees: Basic definitions, Binary tree representation, tree traversal, binary search tree, height balanced trees like AVL tree and 2 tree, heap, complete binary tree, other operations and applications of trees. **Unit IV** **8 Lectures** Graphs: Basic definitions, Representation, Adjacency list, graph traversal, path matrix, connected components, DAG, topological sort, Spanning tree, Shortest path algorithms: Single pair and All pair shortest path algorithms. **Unit V** **8 Lectures** Searching: Linear and Binary search; Hashing: hash tables, hash functions, open addressing Sorting Algorithms: Selection sort, bubble sort, quick sort, merge sort, heap sort, radix sort, File structures: Introduction, data file types, file organization, file access methods.
Learning Outcome	**Unit I:** This unit will help students to understand basics of Data Structures. It will provide concept of different linear data structures like: Array, Stacks and Queue. **Unit II:** This unit will help students to understand the concept of Linked list, its different variations and its applications. **Unit III:** This unit will help students to understand the concept of Binary Tree and its different applications. **Unit IV:** This unit will help students to understand the concept of Graph and its different applications. **Unit V:** This unit will help students to understand different searching and sorting techniques.
Text Books	1. Y. Langsam, M.J. Augenstein and A.M. Tenenbaum, Data Structures Using C and C++, PHI, 2007.
Reference Books	1. S. Lipschuts, Data Structures with C, Schaum's Outline Series, 2017. 2. E. Horowitz and S. Sahni, Fundamentals of Data Structures, University Press, 2008

MCC505 **Probability & Statistics** **L-T-P: 3-0-0**

Objective: To offer a foundation in probability theory and statistical inference in order to solve applied problems and to prepare for more advanced courses in probability and statistics.

Outcome: This course provides a solid undergraduate foundation in both probability theory and mathematical statistics and at the same time provides an indication of the relevance and importance of the theory in solving practical problems in the real world.

Course Content	**Unit I** **5 Lectures** Evaluation, interpretation of descriptive statistics and assessing the behaviors of data. **Unit II** **10 Lectures** Concept of probability and related theorems, Random variables and probability distributions, mathematical expectation, Moment generating and characteristic functions. **Unit III** **6 Lectures** Inequalities; Markov and Chebyshev inequalities, law of large numbers and the central limit theorem. Distribution of order statistics and range. **Unit IV** **12 Lectures** Probability Distributions: Discrete; uniform, bernoulli, binomial, negative binomial, geometric, hyper geometric, Poisson, continuous; uniform, normal, lognormal, cauchy, exponential, gamma, beta, weibull, Sampling distributions: chi-square, t and F **Unit V** **6 Lectures** Correlation and regression; rank correlation, simple, multiple and partial correlation, plane of regression, estimation of parameters of plan of regression using method of least square.
Learning Outcome	**Unit I:** To understand the nature and deviation of data. **Unit II:** To understand the logic of probability. To find the descriptive statistics of distribution through moment generation function. **Unit III:** To obtain the different probability bounds of data. **Unit IV:** To Understand the concepts of a random variable and analyze the ideal patterns of data. **Unit V:** To know the relationship between variables and predict (estimate) the value of dependent variable.
Text Books	1. Sheldon M. Ross, First Course in Probability, 9th Edition, Pearson, Boston, 2014 2. V.K. Rohatgi and A.K. Md. Ehsanes Saleh, An Introduction to Probability and Statistics, John Wiley & Sons, 3rd Edition, 2015.
Reference Books	3. Hogg, R.V., McKean, J.W. and Craig, A.T., Introduction to Mathematical Statistics. 7th Edition, Pearson, Boston, 2013. 4. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics (A Modern Approach) 10thEdition, Sultan Chand & Sons, 2002

MCC506 **Numerical Methods-Practical** **L-T-P: 0-0-3**

Objective: Due to immense development in the computational technology, numerical methods are more popular as a tool for scientists and engineers. This branch of Mathematics dealt with to find approximation solution of difficult problems such as finding roots of non-linear equations, numerical integration, numerical solutions of the ordinary differential equations and partial differential equations with initial or boundary conditions.

Outcome: It is expected that students will learn many algorithms to solve mathematical model with real data and also enhance their programming skills.

Course Content	1. Solution of tridiagonal system 2. Solution of simultaneous non-linear equations. 3. Numerical evaluation of double and triple integrals with constant limits. 4. Numerical evaluation of double and triple integrals with variable limits. 5. Solution of linear and non-linear boundary-value problems. 6. Solution of Laplace and Poisson equations in two variables by five point formula. 7. Solution of Laplace equation in two variables by ADI method, Solution of mixed boundary value problem 8. Algorithm for elliptic equation in three variables. 9. Solution of parabolic partial differential equation in two variables by explicit and implicit methods 10. Solution of parabolic equation in three variables by ADE and ADI methods 11. Solution of hyperbolic equation in two variables by explicit and implicit methods 12. Algorithm for hyperbolic equation in three variables.
Text Books	1. Numerical Mathematics and Computing, by Ward Cheney and David Kincaid, International Thomson Publishing Company, (2013). 2. Analysis of Numerical Methods, by E. Isaacson & H. B. Keller, John Wiley & Sons. Dover Publications, Inc., New York, 1966
Reference Books	1. Applied Numerical Analysis, by Curtis Gerald and Patrick Wheatley, Addison-Wesley. Pearson Education India; 7 edition (2007) 2. Numerical Solution of Partial Differential Equations : Finite Difference Methods, by G. D. Smith, Oxford University Press, 1985

MCC507 **Data Structures- Practical** **L-T-P: 0-0-2**

Objective: Data Structures is the basic course of Computer Science. It is required in every field of Computer Science. Objective of this course is to impart knowledge of Data Structures.

Outcome: Students will learn how to implement different data structures using C or C++.

Course Content	1. Review of C Programming. 2. Programs related to applications of Array 3. Programs related to Sparse Matrix. 4. Programs related to Stacks & Queues. 5. Programs related to Recursive Algorithm 6. Programs related to applications of Linked List 7. Programs related to Search Algorithms 8. Programs related to Sorting Algorithms 9. Programs related to Binary Trees 10. Program related to Graph algorithms
Text Books	1. Y. Langsam, M.J. Augenstein and A.M. Tenenbaum, Data Structures Using C and C++, PHI, 2007.
Reference Books	1. S. Lipschuts, Data Structures with C, Schaum's Outline Series, 2017. 2. E. Horowitz and S. Sahni, Fundamentals of Data Structures, University Press, 2008

MCC508 **Advanced Algebra** **L-T-P: 3-0-0**

Prerequisite: Group Theory and Ring Theory

Objective: Advanced Algebra plays an important role in the Computer science and Electrical Communications as well as in mathematics itself. Consequently, it becomes more and more desirable to introduce the student to the field theory at an early stage of study.

Outcome: Advanced Algebra is an abstract branch of mathematics that originated from set theory. The main outcome of this course is to develop the capacity for mathematical reasoning through analyzing, proving and explaining concepts from field extensions and Galois theory.

Course Content	**Unit I** **10 Lectures** Review of Ring Theory, irreducibility criteria, Guass Lemma, and Einstein Criteria. Fields, Characteristic and prime subfields, Field extensions, Finite, algebraic and finitely generated field extensions. **Unit II:** **9 Lectures** Classical ruler and compass constructions, Splitting fields and normal extensions, algebraic closures. Finite fields, Cyclotomic fields, Separable and inseparable extensions. **Unit III:** **9 Lectures** Galois groups, Fundamental Theorem of Galois Theory, Composite extensions, Examples (including cyclotomic extensions and extensions of finite fields). **Unit IV:** **11 Lectures** Norm, trace and discriminate. Solvability by radicals, Galois' Theorem on solvability. Cyclic extensions, Abelian extensions, Polynomials with Galois groups Sn. Transcendental extensions.
Learning Outcome	**Unit I:** The main outcome of unit I is to develop the idea of ring theory and field extension. **Unit II:** The main outcome of this unit is to develop the idea of different field extension and constructions of numbers**.** **Unit III:** Learning outcome: From this unit we can learn the Galois theory, fixed field and Galois groups. **Unit IV:** The main outcome of this unit is to discuss the idea of solvability and cyclic extensions.
Text Books	1. D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, John Wiley, 2002.
Reference Books	1. M. Artin, Algebra, Prentice Hall of India, 1994. 2. J.A. Gallian, Contemporary Abstract Algebra, 4th Edition, Narosa, 1999. 3. N. Jacobson, Basic Algebra I, 2nd Edition, Hindustan Publishing Co., 1984, W.H. Freeman, 1985.

MCC509 **Statistical Inference** **L-T-P: 3-0-0**

Objective: Statistical Inference is one of the fundamental course which requires in higher studies for anyone who intends to practices statistical tools and methodologies for data analysis. Keeping these points in view, the course structure of statistical inference has been finalized.

Outcome: After completion of this course, students will be equipped with the knowledge of estimation techniques for population parameters and different statistical tests required in data analysis.

Course Content	**Unit I** **12 Lectures** Estimation: Criteria of a good estimator, related theorems and results, uniformly minimum variance unbiased estimation, Rao-Blackwell theorem, Cramer Rao Inequality. **Unit II** **6 Lectures** Methods of estimation: method of maximum likelihood, method of moments, method of least squares; Interval Estimations. **Unit III** **12 Lectures** Test of Hypothesis: Definition of various terms, Neyman-Pearsons Lemma, Likelihood ratio test. Tests for mean and variance in normal distribution (one and two population case), tests for correlation co-efficient and regression coefficient, pair t-test, Chi-square test for goodness of fit, contingency table, Large sample tests through normal approximations, test of independence of attributes. **Unit IV** **4 Lectures** Sequential analysis, Non-parametric tests for non-normal population: run test, sign test, Mann-Whitney Wilcoxon U-tests. **Unit V** **5 Lectures** Analysis of variance: One-way and Two-ways with their applications.
Learning Outcome	**Unit I:** Introduces the features of good estimators and provides the idea and applications of important theorems useful in statistical inference. **Unit II:** Introduces different methods to find good estimators. **Unit III:** Provides the concept of hypothesis testing and introduces various tests required in data analysis. **Unit IV:** Gives the concepts of sequential analysis where sample size is a random variable and also introduces the non-parametric tests applicable where normality assumption does not holds good. **Unit V:** Give the idea about analyzing the variations creep in the data due to various factors.
Text Books	1. Lehmann, E.L and Casella G., Theory of Point Estimation, 2nd Ed, Springer, 1998. 2. Lehmann, E.L and Joseph P. Romano, Testing Statistical Hypotheses, 3rd Ed, Springer, 2005.
Reference Books	1. Gupta S.C. and Kapoor,V. K., Fundamentals of Mathematical Statistics, Sultan Chand and Sons. 2. Mood M., Graybill F.A. and Boes D.C. Introduction to the Theory of Statistics, Tata McGraw-Hill, New Delhi.

MCC510 **Operating Systems** **L-T-P: 3-0-0**

Prerequisite: Computer Organization
Objective: To inculcate the fundamental ideas from where the computing resources belong.
Outcome: Students will able to know the fact and figures of computing resources available with system.

Course Content	**Unit I** **9 Lectures** **Introduction to Operating System:** Introduction and Role and Goal of Operating systems (OS), Categories of OS, Computer System Architecture, Interrupts, common function of interrupt, Interrupt handling, Operating System Structures, operations and services, Protection and security, system calls, implementation and parameter passing, Operating system design and Implementation, Virtual machines, advantages and its disadvantages. **Unit II** **10 Lectures** **Processes and Threads:** Process Concept, Process Sate, Process Control Block (PCB), Process Scheduling, Schedulers, Process Creation, Process Termination, Co-operating Process, Producer Consumer Problem, Inter-process Communication, Threads, Types of Threads (User level Thread, Kernel level Thread), Advantages and disadvantages, Multithreading models (One to One, Many to One and Many to Many Models), Thread library, Threading issues: Thread Cancellation, Signal handling, Thread Pools. **Unit-III** **10 Lectures** **CPU Scheduling and Process Synchronization:** CPU Scheduler, Scheduling Criteria, Scheduling Algorithms: First Come First Serve Scheduling (FCFS), Shortest Job First Scheduling (SJF), Priority Scheduling, Round Robin Scheduling, Race condition, Critical Section, Busy Waiting, Critical Section Problem, Semaphores, Types of Semaphore, Semaphore with and without busy waiting, Reader's Writer's Problem, Dining Philosopher's Problem. **Unit IV** **10 Lectures** **Deadlock and Memory Management:** Deadlock and its characterization, Resource Allocation Graph Algorithm applicable for single instance of resource type, Deadlock Prevention and Avoidance, Bankers Algorithm applicable for multiple instance of resource type, Deadlock Detection and Recovery, Memory and its Types, Address Binding, Logical and Physical Addresses, Dynamic Loading and Linking, Swapping, Contiguous and Non-contiguous Memory allocations, Fragmentation (Internal and External) and Segmentation, Virtual Memory, Paging, Demand Paging, Page Replacement Algorithms, Thrashing.
Learning Outcome	**Unit I:** Understanding of fundamentals of Operating Systems and its advantages and disadvantages. **Unit II:** This unit will help student in understanding concept of process creation and termination and their advantages. Also, student will come to know about the thread creation and management for multithreading models. **Unit III:** This will help in understanding about the scheduling of processes and its synchronization. **Unit IV:** This will help in understanding about managing the resources and memory available in the system.
Text Books	1. Abraham Silberschatz, Peter Baer Galvin and Greg Gagne, Operating Systems Principles, John Wiley and Sons, 2005
Reference Books	1. J. Archer Harris, Operating Systems, Mc Graw Hill,2002 2. Y P Kanetkar, Unix Shell Programming, BPB Publication, New Delhi,1996.

MCC511 **Data Base Management Systems** **L-T-P: 3-0-0**

Prerequisite: Basic Knowledge of computer
Objective: Understanding of data storage, manipulation and retrieval. Query optimization through DBMS. Database implementation, understanding of file management concepts.
Outcome: As an outcome, the proposed course is supposed to develop the Database management skill of learner.

Course Content	**Unit I** **4 Lectures** Introduction to DBMS, Advantages, Database applications, purpose, accessing and modifying databases, architecture - users and administrators. **Unit II** **6 Lectures** Data Modelling, Database concepts, E-R data model, network and hierarchical data models, Relational Model (database schema, keys, integrity constraints) **Unit III** **15 Lectures** Query Languages, Relational Algebra (Fundamental and derived operators), Relational calculus (tuple and domain calculus), SQL (Basic SQL structure, view, set operations, nested sub-queries, aggregation, null values, database modification, join expressions, triggers). Query facility and query optimization. **Unit IV** **6 Lectures** Functional and multi-valued dependency, data description languages, Introduction to distributed databases implementation issues. **Unit V** **8 Lectures** Storage media and storage structure, file organization. Indexing (concepts, clustered and non-clustered indices), Heap file, indexed file, B+ tree file, file with variable length records, performance and evaluation.
Learning Outcome	**Unit I:** Understanding of DBMS and what it provides. Advantages of using DBMS. It provides idea of DBMS Architecture. **Unit II:** It provides understanding the steps to prepare a data model. One will learn the fundamentals of relational data model its structure, and advantages. This will help in designing the relation model, and to conceptualize data using the relational model. **Unit III:** This enables to express queries using relational algebra, relational calculus and SQL. **Unit IV:** This will help students in further implementation of database for efficient management & outcomes. **Unit V:** Help in understanding the organization of files for keeping databases and how to optimize the data base queries for fast response.
Text Book	R. Ramakrishnan and J. Gehrke, Database Management Systems, 3rd Edition, McGraw Hill, 2003
Reference Book	A. Silberschatz, H.F. Korth and S. Sudarshan, Database System Concepts, 5th Edition, McGraw Hill, 2006.

MCO501 **Discrete Mathematics** **L-T-P: 3-0-0**

Objective(s): To learn about proof techniques, To learn about combinatorics and graph theory, To provide a background of mathematics that will be used in theoretical computer science.

Outcome: To be able to relate the computer science problems using discrete mathematical structures.

Course Content	**Unit I :** **12 Lectures** Propositional and predicate logic, well-formed formulas, tautologies, equivalences, normal forms, rules of inference, Proof Techniques, Boolean Algebra, Boolean Expressions, Optimization of Boolean Expressions, CNF, DNF, Karnaugh Map, Quine McKluskey Method. **Unit II** **5 Lectures** Sets and classes, Relations and functions, Recursive definitions, Posets, Lattices, Zorn's lemma, Cardinal and Ordinal numbers. **Unit III** **8 Lectures** Permutation and Combinations, Pigeonhole principle, Inclusion-Exclusion Principle, Recurrence relations, Methods for solving recurrence relations, Generating Functions., Master Theorem (without proof), Partitions (Stirling and Bell Numbers). **Unit IV** **7 Lectures** Modular Arithmetic, Euclid's Algorithm, primes, Chinese Remainder, Public Key Cryptography, RSA algorithm **Unit V** **7 Lectures** Graphs and Digraphs, Adjacency and Incidence matrices, Eulerian cycle and Hamiltonian cycle, Trees, Counting Spanning Trees.
Learning Outcome	**Unit I:** Students will learn predicate calculus which will help them in converting statements as mathematical statements. They will also learn several proof techniques. Students will learn the algebra behind the optimization of circuits. **Unit II:** Students will learn the concepts of set theory and their uses. **Unit III:** Students will learn combinatorics from this unit. **Unit IV:** This unit will help students in learning basic modular arithmetic which can be used in theoretical computer science. **Unit V:** Students will learn about graph structures and their uses in computer science.
Text Books	**1.** K. H. Rosen, Discrete Mathematics and its Applications, 6th Edition, Tata McGraw Hill, 2007 **2**. J. L. Hein, Discrete Structures, Logic, and Computability, 3rd Edition, Jones & Bartlett Learning, 2009.
Reference Books	**1.** R. P. Grimaldi, Discrete and Combinatorial Mathematics, 5th Edition, Pearson Education, 2002. **2**. J. P. Tremblay, R. Manohar, Discrete Mathematical Structures with Application to Computer Science, McGraw Hill, 1975.

MCC512 **Operating Systems- Practical** **L-T-P: 0-0-3**

Prerequisite: Computer Organization

Objective: To inculcate the fundamental ideas from where the computing resources belong.

Outcome: Students will able to know the fact and figures of computing resources available with system.

Course Content	1. Introduction to Shell Programming, Syntax, various commands etc. 2. Algorithm and Execution for Shell Programming 3. Algorithm and Execution for Shell Programming Continued 4. Programming based on Process 5. Prgramming based on Thread 6. CPU Scheduling algorithm-FCFS 7. CPU Scheduling algorithm-SJF 8. CPU Scheduling algorithm-RR 9. CPU Scheduling algorithm-Priority 10. Programming based on Deadlock
Text Books	1. Abraham Silberschatz, Peter Baer Galvin and Greg Gagne, Operating Systems Principles, John Wiley and Sons, 2005
Reference Books	1. J. Archer Harris, Operating Systems, Mc Graw Hill,2002 2. Y P Kanetkar, Unix Shell Programming, BPB Publication, New Delhi,1996.

MCC513 **Data Base Management Systems- Practical** **L-T-P: 0-0-2**

Objective/Outcome: On successful completion of practical classes, students will be able to

- Implement basic and nested queries in Database through MySQL
- Learn to use view, trigger, aggregate functions, fundamental and derived operators in MySQL queries
- Create index through MySQL.
- Write queries for world problems using DBMS in RDBMS environment.

Course Content	1. Introduction to MySQL. Database creation, Table creation. 2. Data insertion, update/modification/Delete and retrieval through MySQL. Basic SQL structure. Query implementation. 3. Enforcing integrity constraints (Domain, Key constraints (Primary/Foreign keys), NOT NULL, UNIQUE, DEFAULT, Check). 4. Creating and updating View. Query implementation using View. 5. Use of aggregate functions (AVG, COUNT, MIN, MAX, SUM) 6. Use of Join operator (Natural join, Outer join (left, right and full) 7. Query optimization through Nested Query (Use of logical connectives, set comparison operators, Union, Intersect, Except, Exists clauses) 8. Use of Group By and Having clause, Trigger creation 9. Index creation through SQL. 10-12. Mini-projects implementation in RDBMS environment.
Text Books	**1.** R. Ramakrishnan and J. Gehrke, Database Management Systems, 3rd Edition, McGraw Hill, 2003.
Reference Books	**1.** A. Silberschatz, H.F. Korth and S. Sudarshan, Database System Concepts, 5th Edition, McGraw Hill, 2006.

MCC514 **Functional Analysis** **L-T-P: 3-0-0**

Prerequisite: Construction of the field of real numbers, Linear Spaces, Algebra of linear transformations, Dual spaces, Review of sets, countable & uncountable sets and Metric Spaces.

Objective: Functional Analysis plays an important role in the applied sciences as well as in mathematics itself. Consequently, it becomes more and more desirable to introduce the student to the field at an early stage of study.

Outcome: Functional analysis is an abstract branch of mathematics that originated from classical analysis. The impetus came from applications: problems related to ordinary and partial differential equations, numerical analysis, calculus of variations, approximation theory, integral equations, and so on.

Course Content	**Unit I** **8 Lectures** Normed linear spaces and Banach spaces. **Unit II** **8 Lectures** Bounded linear operators, Bounded linear functionals, dual spaces. **Unit III** **7 Lectures** Hahn-Banach theorem, Uniform boundedness principle, Open mapping theorem, Closed graph theorem. **Unit IV** **9 Lectures** Strong and Weak convergence, Inner product spaces, Hilbert spaces, orthonormal sets, Riesz representation theorem. **Unit V** **7 Lectures** Adjoint operators, Self adjoint operators, Normal, Unitary operators on Hilbert Spaces
Learning Outcome	**Unit I:** To study algebraic operations on linear space and the concept of norm, metric of desired type. **Unit II:** In this unit the study and classification of linear operators over the same scalar field has been emphasized. **Unit III:** To study the existence of non-zero bounded linear functionals on arbitrary non-zero normed space. Some basic theorems for the development of general theory of normed spaces has been discussed. **Unit IV:** To study mutual correspondence between Hilbert space and its dual. To investigate the special theory develop around the idea of mutually orthogonal sets. **Unit V:** To design and study the notion of several operators.
Text Books	**1.** E-Kreysing, Introductory Functional Analysis with Applications, John Wiley and Sons, 2019 **2.** B. V. Limaye, Functional Analysis, 2nd edition, New Age International Publishers, 1996
Reference Books	**3.**G. F. Simmons, Introduction to Topology & Modern Analysis, Robert E. Krieger Publishing Company Malabar, Florida 1983 **4.** W Rudin, Functional Analysis Tata McGraw Hill, 1974

MCC515	Topology	L-T-P: 3-0-0

Prerequisite: Real Analysis

Objective: To explore the foundations of mathematics at a level and at depth for someone ambitious to study the higher mathematics.

Outcome: After the course, a student will able to realise what it means to do mathematics, instead of only learning it or to do some computational exercises.

Course Content	**Unit-I** **11 Lectures** Basic Concepts of Topology, The Metric Topology, Basis, Sub-basis, Interior Points, Limit Points, Boundary Points, Closure of a Set, Subspace topology. **Unit-II** **8 Lectures** First and Second Countable Topological Spaces, Continuous Maps, Open Maps, Closed Maps, Homeomorphisms, Product Topology. **Unit-III** **6 Lectures** Connected Spaces, Path Connectedness, Components and its properties, Quotient Topology. **Unit-IV** **8 Lectures** Compact spaces and its properties, Local compactness, One point compactification of a topological Space, Tychonoff theorem. **Unit-V** **6 Lectures** Separation Axioms: Hausdorff Spaces, Regular Spaces and Normal Spaces.
Learning Outcome	**Unit I:** To learn the foundations of topology. **Unit II:** To know the concepts of countable axioms alogwith continuity in topological spaces. One can realize the difference between geometry and topology. **Unit III:** To learn the concept of connected spaces alongwith quotient topology. **Unit IV:** To learn the concept of compact topological spaces. **Unit V:** To learn the concept of separation axioms in topological spaces.
Text Books	1. J. R. Munkres: Topology, Prentice-Hall, 2015.
Reference Books	1. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw-Hill, 2017. 2. M.A. Armstrong, Basic Topology, Springer, 1983.

MCC516 **Computational Fluid Dynamics** **L-T-P: 3-0-0**

Prerequisite: Basics of continuum mechanics is desirable.
Objective: This course would intent the audience to learn fluid flow problems of realistic systems such as flow through channels, heat engines, piston rings, heat transfer analysis using mathematical techniques such as finite difference method, finite element method and so on.
Outcome: CFD is an indispensable area in many areas of real systems such as food processing, oil recovery, heat engines, structural mechanics and so on. After having had this course, the student would be able to solve nonlinear systems where abrupt variations handling is a real challenge like shocks wave of aero plane wings etc. inclusion is prime importance. Also, the student will be able to learn stability of numerical schemes along with convergence criterion.

Course Content	**Unit I** **6 Lectures** **Introduction to Numerical Methods**: Finite Approximations, Discretization Approaches: Finite Difference Method, Finite Volume Method, Finite Element Method. Solution of Linear Systems, Solution of IVP &BVP, Shooting Method, Tridiagonal Systems, LU decomposition, Multigrid Methods, Coupled Equations and their solutions. **Unit II** **10 Lectures** **Basic Concepts of Fluid Flow:** conservation principles, Mass Conservation, Momentum Conservation, Dimensional Forms of Equations, Mathematical Classification of Flows: Hyperbolic, Parabolic, Elliptic and Mixed Type. **Unit III** **6 Lectures** **Methods for Unsteady Problems:** Two level Methods, P-C and Multipoint Methods, Application to the Transport Equation. **Unit IV** **8 Lectures** **Finite Volume Methods**: Approximation of Surface and Volume Integrals, Boundary Conditions, Upwind Interpolation, QUICK Scheme**.** **Unit V** **9 Lectures** Complex Geometries, Efficient, Accuracy and convergency, Stability criterion of Numerical Schemes.
Learning Outcome	**Unit I:** Numerical scheme suitability and solution methodologies for coupled and non-coupled ODE/PDE. **Unit II:** The student would be able to learn fluid flow interactions and real-life application of fluid problems in mathematical representation. **Unit III:** The student will be able to simulate complex fluid flow problems. **Unit IV:** The student will be able to simulate more complex and geometric simulation with FVM. **Unit V:** The student will be able to assess the performance of numerical schemes.
Text Books	1. J.H. Ferziger and M. Peric: Computational Methods for Fluid Dynamics, Springer (South Asian 2003 Reprint).
Reference Books	1. P. Niyogi, S.K. Chakrabarty, M.K. Laha: Introduction to Computational Fluid Dynamics, Pearson Education Asia, 2005. 2. John D. Anderson Jr.: Computational Fluid Dynamics, CRC Press, 2019 (Reprint).

MCC517 **Design and Analysis of Algorithms** **L-T-P: 3-0-0**

Prerequisite: None/Discrete Mathematics
Objective(s): To study the techniques for analyzing algorithms, To study specific algorithm design methodologies such as the greedy method, divide and conquer, dynamic programming, etc.
Outcome: Ability to think, analyze, and design algorithms for optimization problems

Course Content	**Unit I :** **5 Lectures** Introduction to algorithms; Analyzing algorithms: space and time complexity; growth of functions; asymptotic notations (omega, theta, big oh notations), summations; recurrences; **Unit II** **10 Lectures** Greedy Technique: General characteristics; interval selection problem, Huffman algorithm, Knapsack problem, Review of graphs, BFS and DFS, Kruskal and Prim's algorithms and their proof of correctness, Stable matching problem, Dijkstra's shortest path algorithm, union-find data structures, **Unit III** **13 Lectures** Divide and Conquer and Dynamic Programming Technique: Binary search, Merge Sort, Quick Sort, Finding Max Min element, Strassen's matrix multiplication, Closest pair of points, Edit distance, LCS problem, Matrix-chain multiplications, string matching algorithms, Bellman-Ford algorithm, All pairs shortest path problem. **Unit IV** **4 Lectures** Polynomials and FFT: Representation of polynomials; The DFT and FFT; Efficient FFT implementation, **Unit V** **7 Lectures** Beyond Polynomial Solvabilty: NP-hardness and introduction to approximation algorithms
Learning Outcome	**Unit I:** This unit will help students to learn about the asymptotic analysis of the algorithms. **Unit II:** This unit will make students learn about the greedy technique through several examples. **Unit III:** This unit will make students learn about the divide and conquer technique through several examples. **Unit IV:** This unit will make students learn about the dynamic programming technique through several examples. **Unit V:** Students will learn efficient fast fourier transform implementation. Students will be made exposed to techniques to be applied if a problem may not be solved in polynomial time.
Text Books	1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein, Introduction to Algorithms, Second Edition, PHI, 2005. 2. M. T. Goodrich and R. Tamassia, Algorithm Design, Wiley India, 2010.
Reference Books	3. A. V. Aho, J. D. Ullman, J. E. Hopcroft, The Design and Analysis of Computer Algorithms, Pearson India, 2002. 4. E. Horowitz, S. Sahni, S. Rajasekaran, The Fundamentals of Computer Algorithms, University Press, 2008.

MCO502 **Optimization Techniques** **L-T-P: 3-0-0**

Prerequisite: Basic concepts of linear programming and its related terms.
Objective: The course deals with the basic idea of mathematical programming (Linear and Nonlinear). We shall see how simple mathematics plays a significance role in the development of these ideas. Further, explore the different approaches to find the solution for the various Linear and Nonlinear Programming Problems.
Outcome: The student will able to identify the appropriate methods to solve the different kinds of Optimization Problems.

Course Content	**Unit I** **4 Lecturers** **Convex Analysis:** Convex Set, Convex functions, Local and Global Extrema, Convex Hull, Supporting and Separating Hyperplane, Convex Cone, Differentiable Convex function. **Unit II** **8 Lecturers** **Network Analysis:** Basic Concepts, Critical Path Analysis, Program Evaluation Review Techniques. **Unit III** **6 Lecturers** **Dynamic Programming:** Recursive Equation Approach, Dynamic Programming Algorithm, Solution of Discreate D.P.P., Solution of L.P.P. by Dynamic Programming. **Unit IV** **9 Lecturers** **Queueing Theory:** Probability Distributions in Queueing Systems, Classification of Queueing Models, Poisson Queueing Systems:- {(M/M/1):(∞/FIFO)},{(M/M/1):(∞/SIRO)},{(M/M/1):(N/FIFO)}. **Unit V** **12 Lecturers** **Nonlinear Programming:** General Nonlinear Programming Problem, Constrained Optimization with Equality and Inequality Constraints, Saddle Point Problems, Kuhn-Tucker Conditions with Nonnegative Constraints.
Learning Outcome	**Unit I:** Understanding the fundamental concept of the convex set and its solution set. **Unit II:** Student will be able to construct the network diagrams with single and three time estimates of activities involving in a project. **Unit III:** Student will learn the new approach to solve the linear programming problem and their applications in solving a decision-problem. **Unit IV:** This unit will help student to identify and examine all possible queuing system and description of each of them. **Unit V:** Student will be able to drive the optimality conditions for obtaining an optimal solution for nonlinear optimization with Equality and Inequality Constraints.
Text Books	**1.** Kwanti Swarup, P. K. Gupta and Man Mohan: “Operations Research”, Sultan Chand & Sons, 2017.
Reference Book	**1.**Hamdy A. Taha: “Operations Research-An Introduction”, Pearson, 2016. **2.** Hadley G..: “Linear Programming”, Narosa, 2002. **3.** Frederick S. Hillier and Gerald J. Lieberman: “Introduction to Operations Research”, McGraw Hill, 2009.

MCC518 **Computational Fluid Dynamics-Practical** **L-T-P: 0-0-3**

Prerequisite: Basics of continuum mechanics is desirable.

Objective: The students who enrolled would be developing the code either in C or C++ for simple equations of PDE of Flow Problems

Outcome: The students will be able to develop the code for simple form of N-S equations of governing the fluid flow equations using FDM, FVM methods.

Course Content	1. Simple Basic 1d equations of PDE: Elliptic Type 2. Simple Basic 1d equations of PDE: Parabolic Type 3. Solving 2D equations of PDE by FDM (explict) 4. Solving 2D equations of PDE by FDM (Implicit) 5. Solving 2D equations by Finite Volume Discretization's (Heat Eqn) 6. Solving 2D equations by Finite Volume Discretization's (Wave Eqn) 7. Solving 2D equations by Finite Volume Discretization's (Laplace Eqn) 8. SIMPLE Schemes, QUICK Schemes implementations (Mesh Generation) 9. SIMPLE Schemes, QUICK Schemes implementations (Post Processing) 10. Stability Criterion of Schemes using Numerical Code.
Text Books	1. J.H. Ferziger and M. Peric: Computational Methods for Fluid Dynamics, Springer (South Asian 2003 Reprint).
Reference Books	1. P. Niyogi, S.K. Chakrabarty, M.K. Laha: Introduction to Computational Fluid Dynamics, Pearson Education Asia, 2005. 2. John D. Anderson Jr.: Computational Fluid Dynamics, CRC Press, 2019 (Reprint).

MCC519 **Design and Analysis of Algorithms-Practical** **L-T-P: 0-0-2**

Prerequisite: A knowledge of a programming language and basic data structures.

Objective: To make students have the hands on experience/knowledge of implementing the algorithms based on specific algorithm design methodologies such as the greedy method, divide and conquer, dynamic programming, etc.

Outcome: A good programmer to implement algorithms of various optimization problems using data structures.

Course Content	1. Unix kernels and commands, matrix multiplications 2. Complexity of array of numbers, Fibonacci sequence 3. GCD, floor functions computation and complexity both recursive and iterative 4. Sorting algorithms and complexity: Comparison, Radix, Bubble, Merge Sorting 5. Graph algorithms: directed and undirected Algorithms 6. Implementation of algorithms for longest common subsequence problem 7. Implementation of algorithms for matrix chain multiplication 8. Minimum spanning tree algorithms (Kruskal's algorithm, Prim's algorithm and complexity computation) 9. Floyd-Warshall algorithms and complexity 10. Comparison of complexity of different algorithms 11. Implementation Bellman's algorithm and complexity 12. Network and flow problem algorithms
Text Books	1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein, Introduction to Algorithms, Second Edition, PHI, 2005. 2. M. T. Goodrich and R. Tamassia, Algorithm Design, Wiley India, 2010.
Reference Books	3. A. V. Aho, J. D. Ullman, J. E. Hopcroft, The Design and Analysis of Computer Algorithms, Pearson India, 2002. 4. E. Horowitz, S. Sahni, S. Rajasekaran, The Fundamentals of Computer Algorithms, University Press, 2008.

MCD501 **Classical Mechanics** **L-T-P: 3-0-0**

Prerequisite: Differential Equations, Linear Algebra.

Objective: To develop ability to understand concepts of classical mechanics to apply methods used in the study to solve real world models.

Outcome: Mastery of the Lagrangian theory, Kinematics of Rigid Body Motion, Hamilton-Jacobi Theory, Classical Chaos and Canonical Perturbation Theory.

Course Content	**Unit I** **8 Lectures** Survey of the Elementary Principles, Variational Principles and Lagrange's Equations, The Central Force Problem. **Unit II** **8 Lectures** The Kinematics of Rigid Body Motion, The Rigid Body Equations of Motion, Oscillations. **Unit III** **6 Lectures** The Classical Mechanics of the Special Theory of Relativity. **Unit IV** **8 Lectures** The Hamiltonian Equations of Motion, Canonical Transformations, Hamilton-Jacobi Theory and Action Angle Variables. **Unit V** **9 Lectures** Classical Chaos, Canonical Perturbation Theory, Introduction to Lagrangian and Hamiltonian Formulations for Continuous Systems and Fields.
Learning Outcome	**Unit I:** To understand the Variational Principles and Lagrange's Equations, and The Central Force Problem. **Unit II:** Be able to understand the Kinematics of Rigid Body Motion and Oscillations. **Unit III:** To learn the Classical Mechanics of the Special Theory of Relativity. **Unit IV:** To derive the Hamiltonian Equations of Motion. To understand the Canonical Transformations and Hamilton-Jacobi Theory. **Unit V:** Be able to understand the concept of classical Chaos. To understand the canonical perturbation theory. To learn the Lagrangian and Hamiltonian Formulations for Continuous Systems and Fields.
Text Books	1. Classical Mechanics (Third Edition) by Goldstein, Poole & Safko; Addison-Wesley, 2002, 2. Classical Mechanics,by John R. Taylor (University Science Books, 2005)
Reference Books	1. Classical Dynamics by Jose & Saletan; Cambridge University Press, 1998 2. Classical Mechanics By John R. Taylor,University Science Books, 2005 3. Classical Mechanics,By Matthew J. Benacquista, Joseph D. Romano,Springer, 2018

MCD502 **Graph Theory** **L-T-P: 3-0-0**

Objective: To introduce the concepts of graph theory in depth and different structural parameters of graphs.

Outcome: Ability to think and model different practical problems as graph problems.

Course Content	**Unit I :** **10 Lectures** Introduction to graphs, trees and their properties: Graphs, Representation of Graphs, Various Special Graphs, Walk, Path, Trail, Degree Sequence of Graphs, Graph Isomorphism, Trees and its characterizations, Spanning Trees, Counting Spanning trees, Algorithms for minimum weighted spanning trees. **Unit II** **8 Lectures** Matching and Cycles in Graphs: Matching, Perfect matching, Augmenting path, Bipartite matching, Hall Marriage Theorem, Matching in general graphs, Tutte's Theorem, Min-Max Theorems, Konig-Egervary Theorem, Eulerian tour and Seven Bridges problem, Hamiltonian cycles and Travelling Salesman Problem, Necessary Conditions for Hamiltonian Graphs, Sufficient Conditions for Hamiltonian Graphs. **Unit III** **8 Lectures** Coloring and Connectivity in graphs: Vertex Coloring, Edge Coloring, Brook's theorem, Vizing Conjecture. Vertex and Edge Connectivity, Vertex- and edge-disjoint paths, testing connectivity, decomposing connected graph into blocks, Tutte's decomposition, edge-connectivity, Menger's Theorem. **Unit IV** **7 Lectures** Network Flows: Basic concepts on flows and networks, max-flow min-cut theorem, Ford-Fulkerson algorithm. **Unit V** **6 Lectures** Planarity in graphs: Planar graphs, Euler's Formula, Outer Planar Graphs, Kuratowski Theorem, Four Color Theorem.
Learning Outcome	**Unit I:** Students will learn the basic definitions and concepts on graphs such as graphs, graph isomorphism, and trees. **Unit II:** This unit will help the students in understanding the graph parameters such as matching, Hamiltonian cycles, Eulerian cycles with their necessary and sufficient conditions. **Unit III:** This will help in understanding coloring, connectivity, and important theorems such as Tutte's theorem and Menger's theorem. **Unit IV:** Students will learn the concepts of network flows. **Unit V:** Students will learn the famous Four Color Theorem along with the concepts used in Four Color Theorem.
Text Books	**1.** D. B. West, Introduction to graph theory, 2nd Edition, Pearson Education, 2015.
Reference Books	1. A. Bondy and U. S. R. Murthy, Graph Theory, Graduate Texts In Mathematics, Springer, 2008 2. R. Diestal, Graph Theory, Springer-Verlag, New York, 2000

MCD503 **Integral Equations and Calculus of Variations** **L-T-P: 3-0-0**

Prerequisite: Real analysis, Ordinary differential Equations, Transform techniques. **Objective:** To understand the important mathematical methods such as Integral Equations and Calculus of Variations and their utility in solving real-world problems arising in mathematical physics and engineering. **Outcome:** Students will get expertize to solve problems in mathematical physics and engineering.

Course Content	**Unit I** **7 Lectures** Volterra integral equations: Basic concepts, relationship between linear differential equations and Volterra integral equations- resolvent kernel of Volterra integral equations, solution of integral equations by resolvent kernel. **Unit II** **7 Lectures** **T**he method of successive approximations, convolution type equations, Volterra intergral equations of first kind; Fredholm equations of the second kind: fundamentals, iterated kernels, constructing the resolvent kernel with the aid of iterated kernels. **Unit III** **7 Lectures** Integral equations with degenerate kernels, characteristic numbers and eigenfunctions, solution of homogeneous integral equations with degenerate kernel, nonhomogeneous symmetric equations. Fredholm Alternative. **Unit IV** **9 Lectures** Extrema of functionals: The variation of a functional and its properties, Euler's equation, Field of extremals, sufficient and necessary conditions for the extremum of a functional both for weak and strong extrema. Legendre and Weierstrass conditions. **Unit V** **9 Lectures** Hilbert invariant integral theorem, conditional extremum, moving boundary problems, discontinuous problems, one sided variations, Direct methods: Euler's finite difference method and Ritz method
Learning Outcome	**Unit I:** This topic helps student to formulate initial value problems in terms of Volterra integral equations. It enables student to solve it by resolvent kernel. **Unit II:** Student will understand the approximate technique for the solution of integral equation. Further, student will understand the application of Laplace transform as a method of solution. Student will learn another kind of integral equation and its methods of solution. **Unit III:** This topic will help student to find solutions through characteristic numbers and eigenfunctons. Moreover, student will investigate solvability of the integral equations. **Unit IV:** Student will understand the relation between a boundary value problem and equivalent functional. Further, student will learn certain conditions of extremums for functional. **Unit V:** Student will understand problems with moving boundaries and their variational formulation. Moreover, student will learn approximate techniques to get extremum of functional.
Text Books	**1.**M. L. Krasnov, G. I. Makarenko and A. I. Kiselev, Problems and Exercises in Integral Equations, translated from the Russian by George Yankovsky, 1975. **2.**M. L. Krasnov, G. I. Makarenko and A. I. Kiselev, Problems and Exercises in the Calculus of Variations, translated from the Russian by George Yankovsky, 1975
Reference Books	**1.**R. P. Kanwal, Linear Integral Equations, second edition, Birkhauser, Boston, Inc., Boston, MA, 1997. **2.**L. Elsgoltz, Differential Equations and the Calculus of Variations, Mir Pub. Moscow, 1977.

MCD504 **Measure Theory** **L-T-P: 3-0-0**

Prerequisite: Real Analysis (Functions of one variable: Limit, Continuity, Differentiability and Riemann Integral).

Objective: The modern notion of measure, developed in the late 19th century, is an extension of the notions of length, area or volume. The objective of this course is to introduce the concepts of measure and integral with respect to a measure, to show their basic properties, and to provide a basis for further studies in Analysis, Probability, and Dynamical Systems.

Outcome: The student will be able (i) to understand the abstract measure theory and definition and main properties of the integral (ii) to construct Lebesgue's measure on the real line and in *n*-dimensional Euclidean space. (iii) use the concept of measure theory to solve the problems related to probability theory, stochastic calculus and functional analysis.

Course Content	**Unit I:** **8 Lectures** Semi-algebra, Algebra, Monotone class, Sigma-algebra, Monotone class theorem, Outer measures, measures and measurable sets, Outline of extension of measures from algebras to the generated sigma-algebras: Measurable sets; Review of Lebesgue Measure and its properties, Borel measure. **Unit II:** **9 Lectures** Measurable functions, simple functions, Egoroff's theorem, Review of Lebesgue integral and its properties, monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem, various modes of convergence and their relations. **Unit III:** **9 Lectures** Signed measures, Hahn and Jordan decomposition theorems, Lebesgue-Radon-Nikodym theorem, Lebesgue decomposition theorem, the representation of positive linear functionals on $C_c(X)$. **Unit IV:** **7 Lectures** Introduction to L^p-spaces, Riesz-Fischer theorem; Riesz Representation theorem for L^2-spaces. Absolute continuity of measures, Dual of L^2-spaces. **Unit V:** **6 Lectures** Product measure spaces, iterated integrals, Fubini's and Tonelli's theorems, Outline of fundamental theorem of calculus for Lebesgue integrals.
Learning Outcome	**Unit I:** Students will be able to understand outer measure, Lebesgue measure and Borel Measure and their properties. **Unit II:** This unit will help student to understand Lebesgue integrals and different convergence theorem. **Unit III:** Students will learn signed measures and the different decomposition theorems. **Unit IV:** Students will be able to understand the basics of L^p-spaces and absolute continuity of measures. **Unit V:** Students will get the idea of products measures spaces and iterated integrals.
Text Books	1H.L. Royden, Real Analysis, 4th Edition, Prentice Hall India, 2011.
Reference Books	**1.** I. K. Rana, An Introduction to Measure and Integration, 2nd Edition, Narosa, 2004. **2.**G. D. Barra, Measure Theory and Integration, 2nd Edition, Woodhead Publishing, 2003.

MCD505 **Basic Number Theory** **L-T-P: 3-0-0**

Prerequisite: Basic Algebra.

Objective: To present a rigorous development of Number Theory using axioms, definitions, examples, theorems and their proofs.

Outcome: Students will be able to (i) effectively express the concepts and results of Number Theory (ii) construct mathematical proofs of statements and find counterexamples to false statements in Number Theory (iii) solve certain systems of Diophantine equations.

Course Content	**Unit I** **10 Lectures** Prime number, Infinitude of primes, discussion of the Prime Number Theorem, infinitude of primes in specific arithmetic progressions, Dirichlet's theorem (without proof), Arithmetic functions, Mobius inversion formula. Structure of units modulo *n*, Euler's phi function. **Unit II** **9 Lectures** Congruences, theorems of Fermat and Euler, Wilson's theorem, linear congruences, quadratic residues, law of quadratic reciprocity. **Unit III** **6 Lectures** Binary quadratics forms, equivalence, reduction, Fermat's two square theorem, Lagrange's four square theorem. **Unit IV** **14 Lectures** Continued fractions, rational approximations, Liouville's theorem, discussion of Roth's theorem, transcendental numbers, transcendence of *e* and π, Diophantine equations: Brahmagupta's equation (Pell's equation), the Fermat's method of descent, discussion of the Mordell equation.
Learning Outcome	**Unit I:** Students will learn the different properties of prime numbers and Arithmetic functions. **Unit II:** Students will learn the techniques of congruences and quadratic residues. **Unit III:** This unit will help students to understand quadratic forms and their applications. **Unit IV:** Students will learn the technique of continued fractions and the Fermat's method of descent, to solve different Diophantine equations.
Text Books	**1.** I. Niven and H.S. Zuckerman, An Introduction to the Theory of Numbers, 5th Edition, Wiley, 2008.
Reference Books	**2.** A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, 1985. **3.** W. W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd Edition,Wiley Eastern, 1976.

MCD506 **Parallel Computing** **L-T-P: 3-0-0**

Prerequisite: Basics of computer Programming either C or C++ or Python is desirable.

Objective: This course would intend the audience to learn about the Parallel Computing aspects of algorithms such as sorting, graph and other algorithms of interest.

Outcome: Parallel Computing is an indispensable tool for solving large systems where space and time complexity is of prime importance and the student would learn and will come out with suitable algorithms of real-life systems such as Numerical Weather Prediction, Image Processing and so on.

Course Content	**Unit-I** **9 Lectures** Parallel Algorithms, MPI collective communications algorithms, prefix computations, Sorting, graph algorithms, list ranking, pre-order tree traversal. **Unit-II** **10 Lectures** Processor Arrays, Multiprocessors, and Multicomputer, speedup, scaled speedup and parallelizability, Flynn's Taxonomy, Parallel Programming Languages. **Unit-III** **10 Lectures** Mapping and Scheduling, Elementary Parallel Algorithms, Matrix Computations. **Unit-IV** **10 Lectures** The Fast Fourier Transforms, Solving Linear Systems, Graph Algorithms, Applications of Parallel Algorithms for real life systems such as Numerical weather prediction, CFD, Image Processing.
Learning Outcome	**Unit I:** The students will learn algorithms using C, C++. Python for parallel computing. **Unit II:** The student will be able to learn Architecture of parallel computing issues. **Unit III:** The student will be in a position to do matrix computation in parallel programming. **Unit IV:** Application of Mathematical methods for real life systems with use of parallel computing.
Text Books	**1.** Michael J Quinn: Parallel Computing Theory and Practice, Tata McGraw-Hill, India, 2002.
Reference Books	1. Ananth Grama et al: Introduction to Parallel Computing, Addison Wisely, 2003.

MCD507 **Representation Theory of Finite Groups** **L-T-P: 3-0-0**

Prerequisite: Group Theory and Linear Algebra

Objective: (i) To represent abstract algebraic objects like groups as subobjects of matrix groups and study linear representations of finite groups. (ii) To classify all the irreducible representations of a finite group, up to isomorphism.

Outcome: (i) Representation theory is used in many parts of mathematics, as well as in quantum physics. After the course the students will be able to understand that. (ii) The students will be able to use tools from linear algebra to solve abstract algebraic problems.

Course Content	**Unit I** **7 Lectures** Revision of basic group theory, Representations, Subrepresentations, Sum and tensor product of representations, Symmetric and Alternating Squares representations, Irreducible representations **Unit II** **10 Lectures** Characters, Schur's lemma, Maschke's theorem, Orthogonality relations, Decomposition of regular representation, Number of irreducible representations, canonical decomposition and explicit decompositions. **Unit III** **8 Lectures** Representation of subgroups and Product groups, Induced representations. Examples of Representations for Cyclic groups, alternating and symmetric groups **Unit IV** **14 Lectures** Integrality properties of characters, Burnside's $p^a q^b$ theorem. The character of induced representation, Frobenius Reciprocity Theorem, Meckey's irreducibility criterion, Examples of induced representations, Representations of supersolvable groups.
Learning Outcome	**Unit I:** This unit will help students to represent abstract algebraic objects like groups as subobjects of matrix groups and learn their properties. **Unit II:** Students will learn the basic idea of characters and irreducible representations **Unit III:** This unit will help students to understand the representation of subgroups and product groups and to classify all representations of cyclic and symmetric groups. **Unit IV:** Students will be able undertand irreducibility criterion and different applications of representation theory.
Text Books	**1.** J. P. Serre, Linear Representation of Finite Groups, Springer-Verlag, 1977.
Reference Books	**2.** M. Burrow, Representation Theory of Finite Groups, Dover Publications, 2011. **3.** N. Jacobson, Basic Algebra 2nd Edition, Dover Publications, 2009. **4.** S. Lang, Algebra, 3rd Edition, Springer, 2005.

MCD508 **Theory of Computation** **L-T-P: 3-0-0**

Objective: To explore and understand the challenges for Theoretical Computer Science and its contribution to other sciences.

Outcome: After the course, a student will be able to model, compare and analyse different models of computation, and can identify limitations of some computational models and possible methods of proving them.

Course Content	**Unit-I** **12 Lectures** Deterministic finite automaton (DFA), Non-deterministic finite automaton (NFA), Equivalence between DFA and NFA, States minimization of DFA, Regular languages and their acceptance, Regular Grammar, NFA with epsilon transitions, Regular expressions, Pumping lemma for regular languages Myhill-Nerode theorem as characterization of regular languages. **Unit-II** **12 Lectures** Context free grammars, Context free languages, Ambiguity, Pushdown automaton (PDA), Instantaneous descriptions of PDA, Language acceptance by final states and by empty stack, Equivalence of these two, Pumping lemma for Context free languages. **Unit-III** **10 Lectures** Turing machine (TM), their instantaneous descriptions, Language acceptance by a TM, Church-Turing hypothesis, Code for TM, Recursively enumerable and recursive languages, Existence of non- recursive enumerable languages, Notion of undecidable problems, Universal language and universal TM. **Unit-IV** **5 Lectures** Decidability and Undecidability; Introduction to Computational Complexity.
Learning Outcome	**Unit I:** To learn the basic mathematical model of a computing device. **Unit II:** To learn the concepts of Pushdown automaton and their languages. **Unit III:** To learn general mathematical model of a computing devices including Church Turing hypothesis. **Unit IV:** To learn computability and complexity theory.
Text Books	1. M. Sipser, Introduction to the Theory of Computation, Thomson, 2005.
Reference Books	1. P. Linz, An Introduction to Formal Languages and Automata, Narosa Publishing House, 2011. 2. J Hopcroft, J.D. Ullman, R Motwani, Introduction to Automata Theory, Languages and Computation, Pearson, 2008.

MCD509 **Algebraic Coding Theory** **L-T-P: 3-0-0**

Prerequisite: Advanced Algebra

Objective: The objective of this course is to introduce the fundamental idea of the Coding Theory

Outcome: applicable in Information and Communication theory.

Course Content	**Unit I** **8 Lectures** Basic Concepts: Idea behind use of codes, block codes and linear codes, repetition codes, nearest neighbour decoding, syndrome decoding, requisite basic ideas in probability, Shannon's theorem (without proof). **Unit II** **8 Lectures** Good linear and nonlinear codes: Binary Hamming codes, dual of a code, constructing codes by various operations, simplex codes, Hadamard matrices and codes constructed from Hadamard and conference matrices, Plotkin bound and various other bounds, Gilbert-Varshamov bound. **Unit III** **8 Lectures** Reed-Muller and related codes: First order Reed-Muller codes, RM code of order r, Decoding and Encoding using the algebra of finite field with characteristic two. **Unit IV** **8 Lectures** Perfect codes: Weight enumerators, Kratchouwk polynomials, Lloyd's theorem, Binary and ternary Golay codes, connections with Steiner systems. **Unit V** **10 Lectures** Cyclic codes: The generator and the check polynomial, zeros of a cyclic code, the idempotent generators, BCH codes, Reed Solomon codes, Quadratic residue codes, generalized RM codes.
Learning Outcome	**Unit I:** The main outcome of this unit is to develop the idea of Linear codes and repetition codes and their applications in decoding. **Unit II:** The main outcome of this unit to develop the idea of different kind of linear and nonlinear codes and their corresponding bounds. **Unit III:** The main outcome of this unite to develop the idea of Reed Muller codes which is very useful in study of public key cryptosystem. **Unit IV:** The main outcome of this unit is to develop the idea of some important codes like Golay codes, and Perfect codes which are use full in decoding. **Unit V:** Learning outcome: The main outcome of this unit is discuss the different codes like BCH, Reed Soloman codes which are very useful in Study of public key cryptosystem.
Text Books	S. Ling and C. Xing, Coding Theory: A First Course, Cambridge University Press, 2004
Reference Books	1. J. H. van Lint, Introduction to Coding Theory, Springer, 1999. 2. W. C. Huffman and V. Pless, Fundamentals of Error Correcting Codes, Cambridge University Press, 2003. 3. J. MacWilliams and N. J. A. Sloane, The Theory of Error Correcting Codes, NorthHolland, 1977.

MCD510	**Complex Analysis**	**L-T-P: 3-0-0**

Prerequisite: Construction of the field of real numbers, Review of sets, Sequences and series. Definitions and Basic Theorems of Limit, Continuity and Differentiability on the real line. Mean Value Theorem. Uniform convergence, Weierstrass Approximation Theorem. Partial derivatives, Characterization of continuously-differentiable functions. Higher-order derivatives, Complex Numbers, Function of complex arguments and Hyperbolic functions.

Objective: The objective of this course is to introduce the fundamental ideas of the functions of complex variables and developing a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, complex integrals and a range of skills which will allow students to work effectively with the concepts.

Outcome: After completing this course, students should demonstrate competency in the following skills: **1.** Becoming familiar with the concepts Complex numbers and their properties and operations with Complex number. **2.** Evaluating limits and checking the continuity of complex function. **3.** Checking differentiability and Analyticity of functions. **4.** Evaluate Complex integrals and applying Cauchy integral.

Course Content	**Unit-I** **8 Lectures** Limits and continuity, differentiability of complex functions, Analytic functions, analytic branches of inverse of functions, branches of logarithm, Cauchy-Riemann equations, and harmonic conjugates. **Unit-II** **8 Lectures** Complex integration, Cauchy's theorem, integral formula, Morera's Theorem, Liouville's theorem, Cauchy's inequality. **Unit-III** **6 Lectures** Series of complex functions, Taylor series, Laurent series. **Unit-IV** **8 Lectures** Zeros of an analytic function, Singularities and their classification, residue at a singularity, residue at infinity and residue theorem, contour integrals. **Unit-V** **9 Lectures** Bilinear transformation: Bilinear transformation, conformal mapping, elementary properties of the mapping of exponential, sine and cosine functions, fundamental theorem of algebra, Identity Theorem Rouche's Theorem.
Learning Outcome	**Unit-I:** To introduce fundamental results concerning limits, continuity and careful treatment of analytic functions of complex variable. **Unit-II:** To study the technical machinery that is required to introduce the complex line integral, also called the contour integral. **Unit-III:** To study the power series expansions for analytic functions. **Unit-IV:** To discuss the zeros of analytic functions using Taylor's series expansion tool. Further, classification of isolated singularities in a simple way using Laurent's series has been emphasized. Later the method of residue calculus for evaluating certain types of definite and improper integrals has been studied. **Unit-V:** To study bilinear transformation, its various types and properties. Also, how the number of zeros of analytic functions remains constant under small perturbations have been studied.
Text Books	**1.** R.V Churchill & J.W. Brown: Complex Variables and Applications, Mc-Graw Hill, 1990. **2.** Alan Jaffery, Complex Analysis and Applications, Chapman and Hall/CRC, 2005
Reference Books	**3.** J. H. Mathews and R. W. Howell, Complex Analysis for Mathematics and Engineering, Narosa, 1998 **4.** E. Kreyszig, Advanced Engineering Mathematics, 10th Ed., John Willey & Sons, 2010.

MCD511 **Mathematical Ecology** **L-T-P: 3-0-0**

Prerequisite: Basic **k**nowledge of ODE, PDE, Numerical Analysis and basics of Mathematical modeling concept is required.

Objective: Mathematical models are used extensively in many areas of the Biological Sciences. This course aims to give an ample knowledge of the constructions/formulations and analysis of such models in Population Ecology.

Outcome: Mathematical Ecology is an applied branch of mathematics that originated from classical differential equations and population dynamics. After studying this course, students will be able to know more about temporal as well as spatial dynamics of the real world systems/problems like Food- chain and food web dynamics.

Course Content	**Unit-I** **9 Lectures** Single species models, Exponential, logistic, Gompertz growth, Harvest model, Delay model and Discrete-time model. **Unit II** **11 Lectures** Interacting population model, prey-predator, competition, mutualism models and Chemostate model. Kolmogorov Analysis. Equilibria and Stability Analysis. **Unit III** **8 Lectures** Spatially structured models, Reaction–diffusion systems, Dynamics of exploited populations. **Unit IV** **11 Lectures** Age-structured models, models of spread, sex-structured models, two sex models, Leslie matrix. The Lokta integral equation, The McKendrick-von Foerster PDE. Gender-Structured Models.
Learning Outcome	**Unit I:** It provides idea about how to model the real life situations for a single population. It gives broad Idea about continuous, discrete and delay situations. **Unit II:** It provides idea of formulating the model of two, three and many interacting populations. How to effectively analyze the evolutionary trend of such models and its stability behaviour **Unit III:** It helps students in formulating the spatial and spatiotemporal dynamics. Also in understanding the dynamics of exploited populations **Unit IV:** It helps to understand the modeling and dynamics of age and sex structured model. It gives broad idea about well-known Lotka integral equations and its real applications.
Text Books	1. M. Kot, Elements of Mathematical Ecology. Cambridge University Press, 2001. 2. J. D. Murray, Mathematical Biology I: An Introduction, Springer-Verlag, 1989.
Reference Books	1. R.K. Upadhyay, S.R. Iyengar, Introduction to mathematical modeling and chaotic dynamics. Chapman and Hall/CRC, 2013. 2. H. Malchow, S.V. Petrovskii, E. Venturino Spatiotemporal Patterns in Ecology & Epidemiology: Theory, models and Simulation. Chapman and Hall/CRC, 2008

MCD512 **Nonlinear Dynamics and Chaos** **L-T-P: 3-0-0**

Prerequisite: Basic **k**nowledge of ODE, PDE, Numerical Analysis and basics of mapping, and Mathematical software likes Matlab, Mathematica, Chaos data Analyzer is required.
Objective: To foster the knowledge of dynamical system Theory and its wide range of Application to the students. It will help the students to visualize the various interesting dynamics in real world scenario.
Outcome: After completing this course, students should demonstrate competency in the following skills: **1.** Becoming familiar with the concepts Dynamical System Theory and their applications. **2.** Analyzing the bifurcation scenario of different continuous and discrete dynamical systems.

Course Content	**Unit I** **9 Lectures** Dynamical systems- Attractors, SIC, 1D map, Logistic map, Poincare' maps, generalized Baker's map, Circle map. **Unit II** **9 Lectures** Bifurcations - Saddle-node bifurcation, Transcritical bifurcation, Pitchfork bifurcation, PD bifurcation, Hopf-bifurcation, Global bifurcations of cycles, Melnikov's method for homoclinic orbits. **Unit III** **9 Lectures** Strange attractors and fractals dimentions, Henon map and Rossler system, Box-counting, pointwise and correlation, Hausdorff dimensions, Lyapunov exponent, Horseshoe map and symbolic dynamics. **Unit IV** **7 Lectures** Chaotic transitions, intermittency, crisis, quasiperiodicity, controlling and synchronization of chaos. **Unit V** **5 Lectures** Central manifold theory and Normal form theory and its Applications
Learning Outcome	**Unit I:** Broad understand of the concepts of Dynamical System Theory and their real world applications **Unit II:** It provides idea of analyzing the bifurcation scenario of different continuous and discrete dynamical systems. How to handle the extreme situation when dynamics changes? **Unit III:** It helps students in understanding the concept of chaotic dynamics and its visualization. Also the concept of fractal dynamics in real life situations. **Unit IV:** It helps to understand the different types of extreme situation/dynamics including crisis, transient state, intermittency. Also idea about synchronization and control of chaos. **Unit V:** Different approaches to solve nonlinear dynamical systems either by reducing the dimensionality or removing the nonlinearity.
Text Books	1. S. Wiggins, Introduction to applied nonlinear dynamical systems and chaos (Vol. 2). Springer Science & Business Media, 2003. 2. S.H. Strogatz, Nonlinear Dynamics and Chaos with Applications to Physics, Biology, Chemistry, and Engineering, 1994.
Reference Books	1. R.K. Upadhyay, S.R. Iyengar, Introduction to mathematical modeling and chaotic dynamics. Chapman and Hall/CRC, 2013. 2. L. Perko, Differential equations and dynamical systems, Springer Science & Business Media, 1991.

MCD513	**Methods of Applied Mathematics**	**L-T-P: 3-0-0**

Prerequisite: Basic **k**nowledge of linear transformation, continuity, differentiability, differentiation and integration is required
Objective: Objectives: Mathematical methods are used extensively in the different area of applied sciences. This course aims to give a different kind of methods to solve the mathematical problems of the applied sciences and technological fields.
Outcome: After completing this course, students should demonstrate competency in the concepts integral transformations and integral equations. They can easily handles the solutions of differential equations and initial and boundary value problems without first finding the solution of the general solutions and homogeneous part.

Course Content	**Unite –I** **11 Lectures** Definition of Laplace Transform, Linearity property, condition for existence of Laplace Transform; First & Second Shifting properties, Laplace Transform of derivatives and integrals, Unit step functions, Dirac delta-function, Differentiation and Integration of transforms, Convolution Theorem, Inversion, Periodic functions, Evaluation of integrals by L.T., Solution of boundary value problems, **Unit II** **9 Lectures** Fourier Integral formula, Fourier Transform, Fourier sine and cosine transforms, Linearity, Scaling, frequency shifting and time shifting properties, Self-reciprocity of Fourier Transform, Convolution theorem, Application to boundary value problems. **Unit III** **11 Lectures** Integral Equations: Basic concepts, Volterra integral equations, Relationship between linear differential equations and Volterra equations, Resolvent kernel, Method of successive approximations, Convolution type equations, Volterra equation of first kind, Abel's integral equation, Fredholm integral equations, Fredholm equations of the second kind, the method of Fredholm determinants, **Unit IV** **8 Lectures** Iterated kernels, Integral equations with degenerate kernels, Eigen values and eigen functions of a Fredholm alternative. Construction of Green's function for BVP, Singular integral equations.
Learning Outcome	**Unit I:** Students will understand Laplace transform and its properties. Further, the application of the transform to the problems involving differential equations. **Unit II:** Students will understand Fourier transform and its properties. Further, the application of the transform to the problems involving differential equations. **Unit III:** This topic helps student to convert initial value problems involving differential equations into integral equations. Further, it enables student to solve it by analytical and approximate techniques. **Unit IV:** This topic will help to find solutions through characteristic numbers and eigenfunctons. Student will investigate solvability of the integral equations. Further, student will study another technique of Green's function which is useful for formation of integral equations.
Text Books	1.Murray Spiegel, Laplace Transforms. Schaum's Outlines of Theory and Problems, McGraw-Hill Education, 1965. 2.R.K. Jain, S.R.K. Iyengar, Advanced Engineering Mathematics, Narosa, 2002.
Reference Books	1. A. M. Wazwaz, A First Course in Integral Equations, World Scientific 1997. 2. C. Corduneanu, Integral Equations and Applications, Cambridge University Press, 1991.

MCD514 **Sampling Theory** **L-T-P: 3-0-0**

Objective Government organizations and industries in private and public sectors need reliable data for precise planning and its implementations. Sampling theory deals with the techniques for collecting such required data in economical way.

Outcome: After completion of this course, students will be equipped with the knowledge of different survey methodologies and data collection techniques required for planning and generation of reliable estimates.

Course Content	**Unit-I** **6 Lectures** Basic principles of sample surveys, simple random sampling with and without replacement and related results. **Unit-II** **8 Lectures** Probability proportional to size sampling, Horvitz-Thompson estimator, ordered and unordered estimates, stratified random sampling, allocation problems, post-stratification. **Unit-III** **10 Lectures** Use of auxiliary information at estimation stage: Ratio, regression and product methods of estimation for population mean, two-phase (double) sampling, cost consideration under double sampling. **Unit-IV** **9 Lectures** Cluster sampling, two-stage sampling and systematic sampling. **Unit-V** **6 Lectures** Non-sampling errors, non-response problems, Warner's randomized response technique for sensitive characteristics, measurement errors in sample surveys.
Learning Outcome	**Unit I:** Gives the idea about fundamentals of survey sampling and some basic sampling schemes. **Unit II:** Gives the idea and exposure about advance sampling schemes. **Unit III:** Gives the methods and techniques for using the auxiliary information at estimation stage in survey sampling. **Unit IV:** Gives the idea and exposure of sampling schemes applicable in more practicable situations. **Unit V:** Tackles the situations of non-sampling errors arise due to non-response and measurement errors.
Text Books	1. Cochran, W.G , Sampling Techniques, (1977) 3rd Ed, Wiley Eastern Ltd. 2. Parimal Mukhopadhyay: Theory and Methods of Survey Sampling, 2nd Ed (2014), PHI Learning Pvt. Limitrd, Delhi.
Reference Books	1. Sukhatme P V., Sukhatme B. V. and Sukhatme S., and Ashok C.: Sampling Theory of Surveys with Applications, IASRI New Delhi, 1984 Ed. 2. Murthy, M.N.: Sampling Theory and Methods, Statistical Publishing Society (1967), Calcutta. 3. Desraj and Chandhok P: Sampling Theory, Narosa Publications (1998), New Delhi

MCD516 **Industrial Statistics** **L-T-P: 3-0-0**

Prerequisite: Probability and Statistics.
Objectives: To discover flaws or variations in the raw materials and the manufacturing processes in order to ensure smooth and uninterrupted production.

1. To evaluate the methods and processes of production and suggest further improvements in their functioning.
2. To study and determine the extent of quality deviation in a product during the manufacturing process and to analyze in detail the causes responsible for such deviation.
3. To undertake such steps which are helpful in achieving the desired quality of the product.

Outcomes: After successfully completing the course, expected outcomes are: 1. Understand the philosophy and basic concepts of quality improvement and describe the DMAIC process (define, measure, analyze, improve, and control). 2. Students will be able to use the methods of statistical process control and able to design, use, and interpret control charts for variables and attributes. 3. Perform analysis of process capability and measurement system capability. 4. Design, use and interpret exponentially weighted moving average and moving average control charts.

Course Content	**Unit I** **4 Lectures** Quality and quality assurance, Methods of quality assurance, Introduction to TQM and ISO 9000 standards **Unit II** **12 Lectures** Introduction to statistical quality control, chance and assignable causes of variation, Choice of Control Charts, Rational Subgroups, Control Charts for Variables: $\bar{x}$ and R Chart, $\bar{x}$ and S Chart, Control Chart for Attributes: Control Chart for Fraction Defectives, Control Chart for Defects, Choice between Variable and Attribute Control Charts, Shewhart Control Chart, Modified Control Charts, Process Capability Analysis- using Histogram, Probability Plot. **Unit III** **12 Lectures** Acceptance Sampling Plan, Single-sampling for Attributes, OC curve, Double, multiple and sequential sampling plans, Dodge-Romig sampling plan, Acceptance sampling by variables, Designing a sampling plan with a specified OC curve, sequential sampling by variables, continuous sampling plans. **Unit IV** **11 Lectures** Process capability studies, Statistical aspect of six sigma philosophy, Control charts with memory: CUSUM charts, EWMA-mean charts, OC and ARL for control charts; The Taguchi Method: The Taguchi philosophy of quality, Loss functions, SN ratios, Performance measures.
Learning Outcome	**Unit I:** Understand the philosophy and basic concepts of quality improvement and international standards on quality management and quality assurance **Unit II:** Students will be able to use the methods of statistical process control and able to design, use, and interpret control charts for variables and attributes. **Unit III:** Perform analysis of process capability and measurement system capability and learn the DMAIC process (define, measure, analyze, improve, and control). **Unit IV:** Students will learn to design, use and interpret exponentially weighted moving average and moving average control charts.
Text Books	**1**. D.C. Montgomery (2012). Introduction to Statistical Quality Control, 7th Ed., Wiley. **2**. J.T. Rabbit and PA Bergle, The ISO 9000 book, 2nd Ed., Quality resources, Chapter-I
Reference Books	**1.** H.J. Mittag and H. Rinne (1993) Statistical Methods for Quality Assurance, Chapman & Hall, Chapters 1, 3 and 4. **2**. E.G. Schilling, (1982) Acceptance Sampling in Quality Control, Marcel Dekker **3**. A.J. Duncan (1986) Quality Control and Industrial Statistics, 5th Ed., Irwin **4**. E.L. Grant and R.S. Leaven Worth (1980) Statistical Quality Control, McGraw-Hill

MCD537 **Design of Experiments** **L-T-P: 3-0-0**

Prerequisite:
Objective: In Statistics designing of an experiment means to decide how the measurements or observations should be taken during the experiment so that a valid statistical analysis in economical way may be provided.
Outcome: During the scientific experiments or industrial studies huge data are being generated and to draw meaningful conclusions for the data, design of experiments help in providing the relevant results and interpretations.

Course Content	**Unit I** **5 Lectures** Analysis of variance one way and two-way (with m observations per cell) classifications **Unit II** **11 Lectures** Basic principles of design of experiments, CRD, RBD and LSD and their analysis, estimation of missing observations. **Unit III** **11 Lectures** Factorial experiments: 2^2, 2^3, 3^2 and 3^3 experiments, confounding in 2^3 factorial experiment. **Unit** **7 Lectures** Balanced Incomplete Block Design (BIBD), relation between their parameters. Intra and Inter block analysis of BIBD. **Unit V** **5 Lectures** Split plot and simple lattice designs**.**
Learning Outcome	**Unit I:** Gives the idea about analyzing the variations creep in the data due to various factors for complicated situations. **Unit II:** Gives the idea about fundamentals of design of experiments and some basic designs. **Unit III:** Gives the idea about factorial experiments, where different factors are considered at different levels. **Unit IV:** Gives the idea about incomplete block designs arises in many practical situations. **Unit V:** Gives the idea about split plots and lattice designs when some factors are harder to vary than other factors.
Text Books	1. Design and Analysis of Experiments, 1986, 2nd Ed. by M. N. Das & N. C. Giri, Wiley Eastern Ltd. New Delhi.
Reference Books	1. Design and Analysis of Experiments by D. C. Montgomery, 1984, 2nd Ed., John Wiley & Sons, New York. 2. Fundamentals of Applied Statistics by S. C. Gupta and V. K. Kapoor, 1993, 3rd Ed., Sultan Chand, New Delhi. 3. Experimental Designs, (1992 2nd Ed.) , William G. Cochran, Gertrude M. Cox, Wiley