Sri Sai University, Palampur

DEPARTMENT OF MATHEMATICS

SCHEME/STRUCTURE and SYLLABUS

OF

Master of Science in Mathematics

Choice Based Credit System (CBCS)

Course Effective from Academic Session 2022-23

M.Sc. (Mathematics) Program

The main objective of this program is to cultivate a mathematical aptitude and nurture the interests of the students towards problem solving aptitude. Further, it aims at motivating the young minds for research in mathematical sciences and to train computational scientists who can work on real life challenging problems.

Duration: M.Sc. (Mathematics) is a postgraduate level program offered by the Department of Mathematics. This is a 2-years program, consisting of four semesters with two semesters per year.

Duration of the course:

(a) The degree programme leading to the award of Master of Science (M.Sc.) in Mathematics shall be of TWO years duration and include four continuous semesters under Choice Based Credit System (CBCS).

The M.Sc. Mathematics programme is a two-year programme divided into four semesters. A student is required to complete at least 98 credits for the completion of the course and the award of degree. Of these, 74 credits have to be earned from Core Courses, 16 from Elective Courses, 4 from Ability Enhancement Course and 4 credits from Open Elective Courses.

	SEMESTER	**SEMESTER**
PART-I (FIRST YEAR)	Semester I	Semester II
PART-II (SECOND YEAR)	Semester III	Semester IV

This Scheme will be effective in phased manner from the session 2022-23.

1. PROGRAMME STRUCTURE

(b) The syllabi for M.Sc. in Mathematics is drafted as per the UGC guidelines for Learning Outcomes based Curriculum Framework (LOCF) based approach with an aim to equip the students with knowledge, skill, values and attitude.

(c) Usually a course refers to a 'paper' and is a component of an academic programme.

(d) The programmes shall include:

(i) **Core Course**: A core course is a compulsory paper to be studied by all the students to complete the requirements for the postgraduate degree.

(ii) **Elective Course**: Elective course is a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.

1. *Discipline Specific Elective (DSE) Course*: Elective courses offered by the main discipline/subject of study is referred to as Discipline Specific Elective.
2. *Open Elective Course*: An elective course chosen generally from other discipline(s)/subject(s), with an intention to seek exposure is called a Generic Elective.

(iii) **Self Study /Skill Enhancement Courses/Value Added Courses:** These courses are not mandatory and are thus non credit courses**.** Their performance of students in these courses will be either be indicated as Satisfactory or Unsatisfactory.

(iv) **Ability Enhancement Courses:** These courses are mandatory for students as it enhances the ability of students in specific discipline.

(e) The number of credits is given in the form L:T:P, where L, T and P indicates lecture, tutorial and practical laboratory credits respectively. Each lecture credit corresponds to one lecture hour per week, each tutorial credit corresponds to one tutorial hour per week while each laboratory credit corresponds to two laboratory hours per week. For example, 4:0:2 credits indicate that the course has 4 lectures, no tutorial session and two laboratory hours each week.

(f) The total credit required to complete the programme shall be a minimum of **98 credits**. Students may pursue courses for additional credits on their own.

(g) The detailed structure of courses under M.Sc. Mathematics Programme shall be:

Sl. No.	Details of Courses	Credits		
		Theory	Practical	TOTAL
I	**Core Courses** (15 Theory of 4 credits each + 2 Practical of 2 credits each+ 1 Seminar of 2 credits+ 8 credits for Project)	15 X4 = 60	2X 2 = 04 1X 2 = 02 1X 8 =8	74
II	**Elective Courses** (4 Credits) (**4 Courses**)			
	(a) Discipline Specific Elective Courses (EC) (**4 Courses**)	4 X 4 = 16	--------	16
	(b) Open Elective (OE) Courses	2x2=4	-	4
III	**Ability Enhancement/Self Study/Skill Enhancement/Value Added Courses (2 Courses)**			
	(a) Value Added Courses (VAC) (Non Credit) (**2 Courses**) (On satisfactory completion of Course "S" will be awarded, either wise 'US' will be awarded) (**Non Credit**)	-		0
	(b) Self Study/Skill Enhancement Courses (SEC)	-		-
	(c) **Ability Enhancement Courses (1 course)**	1 X 4 = 4	4	4
Grand Total Credit				**98**

2. Course Credit Scheme:

Semester	Core Courses		Elective Courses		Open Elective Courses		Ability Enhancement Courses		
	No. of Courses	Total Credits	No. of Courses	Total Credits	No. of Courses	Total Credits	No. of Courses	Total Credits	**Total Credits**
I	5	20	Nil	Nil	Nil	Nil	1	4	24
II	6	22	Nil	Nil	1	2	Nil	Nil	24
III	6	20	1	4	1	2	Nil	Nil	26
IV	2	12	3	12	Nil	Nil	Nil	Nil	24
Total	74		16		4		4		**98**
Maximum Credits including Open Elective offered by the other departments =4*									

3. Scheme/ Structure for M.Sc.(Mathematics) as per CBCS Programme

Semester	Core Courses	Elective Courses	Open Elective Courses
I	Core Course 1 Real Analysis Core Course 2 Algebra-I Core Course 3 Ordinary Differential Equations Core Course 4 Fluid Mechanics Core Course 5 Linear Algebra	Ability Enhancement Courses: AECI Advance Discrete Mathematics AEC II Wavelets and its Applications AEC III Integral Equations	
II	Core Course 6 Real Analysis-II Core Course 7 Algebra-II Core Course 8 Partial Differential Equations Core Course 9 Solid Mechanics Core Course 10 Number Theory Core Course 11 Basic Introduction to MATLAB		Open Elective 1
III	Core Course 12 Research Methodology Core Course 13 Complex Analysis-I Core Course 14 Topology Core Course 15 Functional Analysis Core Course 16 Seminar Core Course 17 Mathematica and its applications	Elective 1 Mathematical Statistics-I or Operational Research-I or Graph Theory	Open Elective 2
IV	Core Course 18 Complex Analysis-II Core Course 19 Dissertation	Elective 2 Elective 3 Elective 4	

Note: In each of the Semester II and Semester III one open elective course is to be opted out of the list of such courses offered at the University/Institute/College level OR one can choose a MOOC course of minimum credit 2 offered at SWAYAM Portal in that semester.

Note: The open elective courses, offered by the department will be offered to the students other than students of M.Sc. Mathematics Programme.

Elective 1- A student will opt for one of the following courses:

i.	MATH-EC-435	Mathematical Statistics-I
ii.	MATH-EC-436	Operational Research-I
iii.	MATH-EC-437	Graph Theory

Elective 2, Elective 3, Elective 4 (A student will opt for three elective courses out of the following courses:

i.	MATH-EC-442	Mathematical Statistics-II
ii.	MATH-EC-443	Operational Research-II
iii.	MATH-EC-444	Differential Geometry
iv.	MATH-EC-445	Linear algebra and Matrix analysis
v.	MATH-EC-446	Calculus of Several Variable
vi.	MATH-EC-447	Method of applied Mathematics
vii.	MATH-EC-448	Classical Mechanics
viii.	MATH-EC-449	Magneto Fluid Dynamics
ix.	MATH-EC-450	Theory of Sample Survey

Choice of Elective Courses:

Under each Elective course a student may choose one course from a the given first basket and three electives from the other basket of courses actually offered by the Department/Institute/College. In case a particular course is over-subscribed, merit in the previous semester(s) examination(s) or the number of preferences or the availability of teacher(s) or feasibility of the option will be taken into account to determine course allocations. The decision of the Department shall be final in this regard.

Scheme of M.Sc. (Mathematics)
CBCS Four Semester Course for Department of Mathematics, SSU, Palampur
(w.e.f. Session 2022-23)

Semester – I

Paper Code	C / E / OE	Name of Paper	Marks				Credits			
			Theory	Practical	Internal Assessme	Total Marks	L	T	P	Total
Core Papers										
MATH-CC-411	**C**	Real Analysis -I	60	-	40	100	4	0	0	4
MATH-CC-412	**C**	Algebra-I	60	-	40	100	4	0	0	4
MATH-CC-413	**C**	Ordinary Differential Equations.	60	-	40	100	4	0	0	4
MATH-CC-414	**C**	Fluid Mechanics.	60	-	40	100	4	0	0	4
MATH-CC-415	**C**	Linear Algebra	60	-	40	100	4	0	0	4
Ability Enhancement Course										
	One Ability Enhancement Course Paper is to be Opted out of the list of optional papers offered by the department.									
MATH-AEC-416 (I)	**AEC**	Advance Discrete Mathematics	60	-	40	100	4	0	0	4
MATH-AEC-416 (II)	**AEC**	Wavelets and its applications	60	-	40	100	4	0	0	4
MATH-AEC-416 (III)	**AEC**	Integral Equations	60	-	40	100	4	0	0	4
Total										**24**

Semester – II

Paper Code	C / E /OE	Name of Paper	Marks				Credits			
			Theory	Practical	Internal assessment	Total Marks	L	T	P	Total
Core Papers										
MATH-CC-421	**C**	Real Analysis –II	60	-	40	100	4	0	0	4
MATH-CC-422	**C**	Algebra-II	60	-	40	100	4	0	0	4
MATH-CC-423	**C**	Partial Differential Equations.	60	-	40	100	4	0	0	4
MATH-CC-424	**C**	Solid Mechanics.	60	-	40	100	4	0	0	4
MATH-CC-425	**C**	Number Theory	60	-	40	100	4	0	0	4
MATH-CC-426(P)	**C**	Basic Introduction Of MATLAB		30	20	50	0	0	2	2
Open Elective Papers										
	OE	One open elective paper is to be opted out of the list of optional papers offered by the university in even semester	30	-	20	50	2	0	0	2
		Total								**24**
MATH-OE-001	**OE**	**Foundation Course Of Mathematics** (This open elective paper will be offered to all the students except the students of Department of Mathematics)	30	-	20	50	2	0	0	2

Semester – III

Paper Code	C / E / OE	Name of Paper	Marks				Credits			
			Theory	Practical	Internal assessment	Total Marks	L	T	P	Total
Core Papers										
RM-CC-022	**C**	Research Methodology	60	-	40	100	4	0	0	4
MATH-CC-431	**C**	Complex Analysis-I	60	-	40	100	4	0	0	4
MATH-CC-432	**C**	Topology	60	-	40	100	4	0	0	4
MATH-CC-433	**C**	Functional Analysis	60	-	40	100	4	0	0	4
MATH-CC-500	**C**	Seminar		-	50	50	2	0	0	2
MATH-CC-434(P)	**C**	Mathematica and its application		30	20	50	0	0	2	2
Elective Papers		**Student can choose any one out of the following Elective Papers**								
MATH-EC-435	**E**	Mathematical Statistics-I	60	-	40	100	4	0	0	4
MATH-EC-436	**E**	Operational Research-I	60	-	40	100	4	0	0	4
MATH-EC-437	**E**	Graph Theory	60	-	40	100	4	0	0	4
Open Elective Papers										
	OE	One open elective paper is to be opted out of the list of optional papers offered by the university in the odd semester.	30	-	20	50	2	0	0	2
		Total								**26**
MATH-OE-002	**OE**	**Basics of Probability and Statistics** (This open elective paper will be offered to the students except the students of Department of Mathematics)	30	-	20	50	2	0	0	2

Semester – IV

Paper Code	C / E /OE	Name of Paper	Marks				Credits			
			Theory	Practical	Internal assessment	Total Marks	L	T	P	Total
Core Papers										
MATH-CC-441	**C**	Complex Analysis-II	60	-	40	100	4	0	0	4
MATH-CC-501	**C**	Dissertation/ Project				150			8	8
Elective Papers		**Student can choose any three out of the following Elective Papers**								
MATH-EC-442	**E**	Mathematical Statistics-II	60	-	40	100	4	0	0	4
MATH-EC-443	**E**	Operational Research-II	60	-	40	100	4	0	0	4
MATH-EC-444	**E**	Differential Geometry	60	-	40	100	4	0	0	4
MATH-EC-445	**E**	Linear Algebra and Matrix Analysis	60	-	40	100	4	0	0	4
MATH-EC-446	**E**	Calculus of Several Variables	60	-	40	100	4	0	0	4
MATH-EC-447	**E**	Methods of Applied Mathematics	60	-	40	100	4	0	0	4
MATH-EC-448	**E**	Classical Mechanics	60	-	40	100	4	0	0	4
MATH-EC-449	**E**	Magneto Fluid Dynamics	60	-	40	100	4	0	0	4
MATH-EC-450		Theory Of Sample Survey	60	-	40	100	4	0	0	4
		Total								**24**

Sr. No.	Details of Courses	Credits		
		Theory	Practical	TOTAL
I	**Core Courses** (15 Theory of 4 credits each + 2 Practical of 2 credits each+ 1 Seminar of 2 credits+ 8 credits for Project)	15 X4 = 60	2X 2 = 4 1X 2 = 2 1X 8 =8	74
II	4 Elective Courses each of 4 Credits and 2 open elective Courses of 2 Credits			16 4
III	**Ability Enhancement/Self Study/Skill Enhancement/Value Added Courses (2 Courses)**			
	(b) Value Added Courses (VAC) (Non Credit) (**2 Courses**) (On satisfactory completion of Course "S" will be awarded, either wise 'US' will be awarded)	-		0
	(b) Self Study/Skill Enhancement Courses (SEC) (**Non Credit**)	-		-
	(c) **Ability Enhancement Courses (1 course)**	1 X 4 = 4		4
Grand Total Credit				**98**

SEMESTER – I

MATH-CC- 411 (REAL ANALYSIS-I)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Calculus.

Course Objectives: This course is designed to provide a deeper and rigorous understanding of fundamental concepts viz. metric spaces, continuous functions, sequences and series of numbers as well as functions, and the Riemann-Stieltjes integral etc. The main focus of this course will be ontheoreticalfoundationoftheabovesaidconceptsanditwillcultivatetherigorousmathematical logics and skills in the students.

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

- Apply the knowledge of concepts of real analysis in order to study theoretical development of different mathematical techniques and their applications.
- Understand the nature of abstract mathematics and explore the concepts in further details.
- Identify challenging problems in real variable theory and find their appropriate solutions.
- Deal with axiomatic structure of metric spaces and generalize the concepts of sequences and series, and continuous functions in metric spaces.
- Use theory of Riemann-Stieltjes integral in solving definite integrals arising in different fields of science and engineering.
- Extend their knowledge of real variable theory for further exploration of the subject for going into research.

Module I

Numerical Sequences and Series

Convergent Sequences, Sub-sequences, Cauchy Sequences (in metric spaces), Absolute Convergence, Addition and Multiplication of Series, Rearrangements of Series of Real Number.

Module II

Continuity Sequences and Series

Limits of Functions (in Metric Spaces),Continuous Functions, Continuity, Uniform Continuity and Compactness, Limit Inferior and Limit Superior, Integral Test, Comparison Test.

Module III

The Riemann-Stieltjes Integral

Definition and existence of Riemann-Stieltjes integral, Properties of the integral, Integration and differentiation, The Fundamental theorem of calculus, Integration of vector–valued functions, Rectifiable curves.

Module IV

Sequences and Series of Functions

Pointwise and uniform convergence, Cauchy criterion for uniform convergence, Weierstrass M-Test, Abel's and Dirichlet's tests for uniform convergence, Uniform convergence and continuity.

Module V

Riemann-Stieltjes Integration

Uniform convergence and differentiation, Weierstrass approximation theorem, Power series, Uniqueness theorem for power series, Abel's and Taylor's theorems.

Books Recommended:

1. Principles of Mathematical Analysis, Walter Rudin, McGraw Hill.
2. Mathematical Analysis,T.M. Apostol, Narosa Publishing House, New Delhi.
3. Mathematical Analysis, S.C. Malik and Savita Arora, New Age International Pvt. Ltd.

MATH-CC- 412 (ALGEBRA-I)

L	T	P	Credit
4	0	0	4

Pre-requisite: Discrete Structures.

Course Objectives: This course is designed to give students a foundation for all future mathematics courses. The fundamentals of algebraic problem-solving are explained. Students will explore: foundations of Algebraic structures, Groups, Rings, Ideals, Fields, Homomorphisms etc. The course also fulfills the objective to make students aware of the applicability of abstract mathematics in real world problems.

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

- Apply the knowledge of Algebra to attain a good mathematical maturity and enables to build mathematical thinking and skill.
- Utilize the class equation and Sylow Theorems to solve different related problems.
- Identify and analyze different types of algebraic structures such as Solvable groups, Simple groups, Alternate groups to understand and use the fundamental results in Algebra
- Design, analyze and implement the concepts of homomorphism and isomorphism between groups and rings for solving different types of problems, for example, Isomorphism theorems, quotient groups, conjugacy etc.
- Create, select and apply appropriate algebraic structures such as finitely generated abelian groups, Ideals, Fields to explore the existing results.
- Identify the challenging problems in modern mathematics and find their appropriate solutions.

Module I

Group Theory

Conjugacy and G-Sets. Normal Series, Solvable Groups, Nilpotent Groups, Direct Products.

Module II

Classification of Groups

Finitely Generated Abelian Groups, Invariants of a Finite Abelian Groups, The Sylow Theorems: Cauchy's Theorem for Abelian and Finite Group, Applications of Sylow Theorem with examples, Decomposable Group.

Module III

Introduction to Rings

Definition and examples of Rings, Some special classes of Rings, Homomorphisms, Ideals and quotient Rings, More ideals and quotient Rings, The field of quotients of an integral domain.

Module IV

Classification of Rings

Euclidean rings, Particular Euclidean ring, Polynomial rings, Polynomials over the rational field, Polynomial rings over commutative rings.

Module V

Modules

Definition and examples, Submodule, Direct sums, Homomorphisms, Quotient modules, Completely reducible modules, Free modules.

Books Recommended:

1. Basic Abstract Algebra, P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Cambridge University Press.
2. Topics in Algebra, I.N. Herstein, John Wiley and Sons, New York.
3. Linear Algebra, Kenneth Hoffman and Ray Kunze, Prentice-Hall of India Private Limited, New Delhi.

MATH-CC- 413 (ORDINARY DIFFERENTIAL EQUATIONS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Differential Calculus, Integral Calculus and some introduction to linear algebra.

Course Objectives: The Objective of this course is to introduce ordinary differential equations and fundamental theorems for existence and uniqueness. This course further explains the analytic techniques in computing the solutions of various ordinary differential equations appearing in various fields of science and technology.

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

- Understand ordinary differential equations of various types, their solutions, and fundamental concepts about their existence.
- Understand the concept and applications of eigen value problems.
- Understand differential equations of Strum Liouville type.
- Apply various power series methods to obtain series solutions of differential equations.
- Discuss various kinds of special functions in detail, their properties and relations.
- Solve problems of ordinary differential equations arising in various fields.

Module I

Existence and Uniqueness Theory

Some concepts from real function theory, The fundamental existence and uniqueness theorem, Dependence of solutions on initial conditions and on the function, Existence and uniqueness theorem for systems and higher order equations.

Module II

The Theory of Linear Differential Equations

Introduction, Basic theory of the homogeneous linear system, Further theory of the homogeneous linear system, The non-homogeneous linear system, Basic theory of the n^{th}-order homogeneous linear differential equation, The n^{th}-order non-homogeneous linear equation.

Module III

Sturm-Liouville Boundary-Value Problems

Sturm-Liouville problems, Orthogonality of characteristic functions, The expansion of a function in a series of orthonormal functions.

Module IV

Strumian Theory

The Separation theorem, Sturm's fundamental theorem modification due to Picone, Conditions for oscillatory or non-oscillatory solution, First and second comparison theorems, Sturm's oscillation theorems, Application to Sturm Liouville system.

Module V

Nonlinear Differential Equations

Phase plane, Paths, Critical points, Critical points and paths of linear systems, Critical points and paths of nonlinear systems, Limit cycles and periodic solutions, The methods of Kryloff and Bogoliuboff.

Books Recommended:

1. Differential Equations, S.L. Ross, John Wiley and Sons, Inc.
2. Ordinary Differential Equations, E.L.Dover Publication Inc.
3. Elementary Differential Equations and Boundary Value Problems, W. Boyce and R. Diprima, New York.

MATH-CC- 414 (FLUID MECHANICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Mechanics and Continuum Mechanics.

Course Objectives: This course is intended to provide a treatment of advanced topics in fluid mechanics where the students will be able to apply the techniques used in deriving arrange of important results and in research problems. The objective is to provide the student with knowledge of the fluid mechanics and an appreciation of their application to real world problems.

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

- Understand the concept of rotational and irrotational flow, stream functions, velocity potential, sink, source, vortex etc.
- Analyze simple fluid flow problems (flow between parallel plates, flow through pipe etc.) with Navier-Stoke's equation of motion.
- Understand the phenomenon of flow separation and boundary layer theory.
- Understand the concept of thermal conductivity.
- Learn about the fundamental equations of the flow and energy.

Module I

Basic Concepts of Fluid Mechanics

Fluid and fluid mechanics, Fields and continuum concepts, Lagrangian and Eulerian specifications material derivative, Kinematics of fluid in motion, Viscosity and Newton's viscosity law, Types of flow, Lines of flow: Stream line, Streak lines, Path lines, Stream function, Complex potential, Sources, Sinks, Surface and body forces, Stress at a point, Some cartesian tensor notations, General analysis of fluid motion, Thermal conductivity, Generalized heat conduction.

Module II

Fundamental Equations of Motion of Viscous Fluid

Equation of State, Equation of continuity, Navier–Stokes equations (Equations of Motion), Equation of energy, Vorticity and circulation (Kelvin's circulation theorem).

Module III

Dynamical Similarity

Reynold's Law, Inspection analysis, Dimensional analysis, Buckingham-π theorem, and its Applications, π –products and coefficients, Non-dimensional parameters and their physical importance.

Module IV

Exact Solutions of Flow between Parallel Plates

Velocity and temperature distribution: Steady motion between parallel plates, Plane Couette flow, Plane Poiseuille flow, Generalized plane Couette flow, Plane Couette flow with transpiration cooling, Velocity distribution: Flow due to a plane wall suddenly set in motion, Flow due to an oscillating plane wall.

Module V

Exact Solutions of Flow between Pipe and Cylinder

Velocity and temperature distribution: Flow in a circular pipe (Hagen-Poiseuille flow): pipe wall at a constant temperature, Pipe wall at a uniform temperature gradient, Flow between two concentric rotating cylinders (Couette flow).

Books Recommended:

1. Viscous Fluid Dynamics, J.L. Bansal, Oxford and IBH Publishing Co. Pvt. Ltd.
2. Textbook of Fluid Dynamics, F. Chorlton, CBS Publishers and Distributors.
3. An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press.

MATH-CC- 415 (LINEAR ALGEBRA)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Mathematics.

Course Objectives: This course will provide algebraic statements about vector addition, scalar multiplication etc. The main objective of this course is to provide basic knowledge of vector spaces along with different operation to the students. Other objectives is to make them aware about Linear transformations, operations on Linear operator, Linear Functionals and Dual Spaces and Inner Product Space.

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

- Understand the concept of linear transformations.
- Apply elementary operations of linear transformations.
- Find Eigen values and Eigen vectors of linear operators.
- Understand the concept of inner product space.
- Understand the concept of Gram-Schmidt Orthogonalization.

Module I

Vector Space

Vector Spaces, Subspaces, Quotient Spaces, Basis and Dimension Theorems, Sum of Subspaces, Direct Sum Decompositions, Linear Transformations, Algebra of Linear Transformations.

Module II

Linear Transformations

Matrices Associated with Linear Transformations, Effect of Change of Ordered Bases on the Matrix Of Linear Transformations, Elementary Matrix Operations and Elementary Matrices, Row Rank, Column Rank and Their Equality, System of Linear Equations.

Module III

Operations on Linear Operator

Eigen Values and Eigen Vectors of Linear Operators, Characteristic and Minimal Polynomials, Companion Matrix, Subspaces Invariant Under Linear Operators.

Module IV

Linear Functionals and Dual Spaces

Triangulation, Diagonalization, Linear Functionals, Dual Spaces and Dual Basis, Double dual.

Module V

Inner Product Space

Inner Product Spaces, Gram-Schmidt Orthogonalization, Orthogonal Complements, Adjoint of a Linear Operator on an Inner Product Space, Normal and Self-Adjoint Operators,Unitary and Normal Operators, Spectral Theorem.

Books Recommended:

1., Linear Algebra, K. Hoffman, and R. Kunze, Second Edition, Prentice Hall, 1971.
2. Linear Algebra, S.H. Friedberg, A.J. Insel, and L.E. Spence,: Fourth Edition, Prentice Hall, 2003.
3. Linear Algebra, S.Lang, Third Edition, Springer-Verlag, 1987.
4. Linear Algebra, Vivek Sahai, and Vikas Bist, Narosa Publishing House, 2008.

MATH-AEC- 416 (I) (ADVANCED DISCRETE MATHEMATICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Set theory, Relations, Functions.

Course Objectives: Prepare students to develop mathematical foundations to understand and create mathematical arguments require in learning many mathematics and computer sciences courses, to motivate them how to solve practical problems using discrete mathematics. Also, in this course basic concepts of Graph theory such as Trees, Eulerian Graphs, Matching, Vertex coloring, Edge coloring, Planarity, are introduced.

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

- Construct mathematical arguments using logical connectives and quantifiers.
- Understand how lattices and Boolean algebra are used as tools and mathematical models in the study of networks.
- Validate the correctness of an argument using statement and predicate calculus. learn how to work with some of the discrete structures which include sets, relations, functions, graphs and recurrence relation.
- Understand the concepts Planarity including Euler identity and concepts like Coloring.

Module I

Boolean Algebras

Logic, Propositional Equivalences, Predicates and Quantifiers, Partial Ordered Sets, Lattices and Algebraic Systems, Principle of Duality, Basic Properties of Algebraic Systems Defined by Lattices, Distributive and Complemented Lattices, Boolean Lattices and Boolean Algebra, Uniqueness of Finite Boolean Algebra, Boolean Functions and Boolean Expressions, Propositional Calculus, Switching Circuits.

The Pigeonhole Principle:

Pigeonhole Principle, Simple Form, Pigeonhole Principle, Strong Form, Theorem of Ramsey.

Module II

Permutations and Combinations & Generating Permutations and Combinations

Two Basic Counting Principles, Permutations and Combinations of Sets, Permutations and Combinations of Multisets, Generating Permutations, Inversions in Permutations, Generating Combinations, Partial Orders and Equivalence Relations.

Module III

The Binomial Coefficients

Pascal's Formula, The Binomial Theorem, Identities, Unimodality of Binomial Coefficients, The Multinomial Theorem, Newton's Binomial Theorem.

The Inclusion-Exclusion Principle and Applications

The Inclusion-Exclusion Principle, Combinations with Repetition, Derangements, Permutations with Forbidden Positions.

Module IV

Recurrence Relations and Generating Functions

Some Number Sequences, Linear Homogeneous Recurrence Relations, Non-Homogeneous Recurrence relations, Generating Functions, Recurrences and Generating Functions, Exponential Generating Functions.

Module V

Introduction to Graph Theory

Basic Properties, Eulerian Trails, Hamilton Chains and Cycles, Bipartite Multigraphs, Trees, The Shannon Switching Game, Digraphs and Networks, Chromatic Number, Plane and Planar Graphs, A 5-Color Theorem, Independence Number and Clique Number, Connectivity.

Books Recommended:

1. Elements of Discrete Mathematics, C.L. Liu, Tata McGraw-Hill.

MATH-AEC- 416 (II) (WAVELETS AND ITS APPLICATIONS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basics of vector space.

Course Objectives: This course is designed to understand some basic concepts of Wavelets and its applications.

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

- To learn the basic features of wavelets.
- To learn about the application of Wavelets in different-different fields.
- Students will learn about the characterization of wavelets.
- Students will learn about the most powerful technique MRA.

Module I

Continuous wavelet transformation (CWT))

Introduction, Definition of CWT, The CWT as a correlation. Constant Q-factor, Filtering interpolation and time frequency resolution, Inverse CWT.

Module II

Introduction to discrete wavelet transformation and orthogonal wavelet decomposition

Introduction, approximation of vectors in nested linear vector space, Examples of approximating vectors in nested subspace of a finite dimensional linear vector space, Bases for the approximation's subspaces and Haar scaling function, Bases for detail subspaces and Haar wavelet.

Module III

Multi-resolution analysis (MRA) orthonormal/ orthogonal wavelets

Formal definition of MRA, scaling function and subspaces, Translation and dilation function, orthogonality, direct sum decomposition.

Module IV

Examples of wavelets

Daubechies wavelets, Taylor wavelets, Chebyshev wavelets, Legendre wavelets, Luc as wavelets, Hermite wavelets.

Module V

Alternative wavelet representation

Introduction of Bi-orthogonal wavelet bases, Filtering relationship for bi-orthogonal filters, Examples of Bi-orthogonal wavelets.

Books Recommended:

1. Wavelets Analysis and its Applications, Archit Yajnik.

MATH-AEC- 416 (III) (INTEGRAL EQUATIONS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Calculus and Linear Algebra.

Course Objectives: The objective of the course is to acquaint the students with the knowledge of mathematical techniques frequently applied in various branches of engineering and sciences. Also, one of the objectives of this course is to equip the students with the mathematical background required for the development of such techniques.

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

- Explain how integral transforms can be used to solve a variety of differential equations.
- Solve integro-differential equations of Fredholm and Volterra type.
- Understand the properties of various kinds of integral equations.
- Develop their attitude towards problem solving.
- Understand the theory and applications of integral transforms.

Module I

Introduction to integral equation

Definition and types of integral equation, Fredholm and Volterra integral equations, Singular integral equation, Kernel and its types, Eigen values and Eigen functions, Verification of given function as a solution of given integral equation, Conversion of ordinary differential equation into integral equations.

Module II

Solution of Fredholm integral equation

Solution of homogenous Fredholm integral equation of second kind with separable kernels, Solution of Fredholm integral equation of second kind with separable kernels, Fredholm theorem.

Module III

Method of successive approximation: Fredholm Integral Equation

Iterative and resolvent kernel, Solution of Fredholm integral equation of second kind by successive substitution and successive approximation.

Module IV

Method of successive approximation: Volterra Integral Equation

Solution of Volterra integral equation of second kind by successive substitution and successive approximation. Solution of Volterra integral equation of second kind when it its kernel is of some particular form, Solution of Volterra integral equation of second kind by reducing to differential equation.

Module V

Integral transform method

Laplace transform, some useful results of Laplace transform, Integro-differential equation, Integral equation of convolution types, Application of Laplace transform to determine the solution of Volterra integral equation with convolution types kernel. Fourier transform, some useful results of Fourier transform, Application of Fourier transform to determine the solution of integral equation.

Books Recommended:

1. Linear integral equation ,Ram P. Kanwal, Academic Press
2. Integral Equations and Boundary Value Problems, M.D. Raisinghania, S.Chand.

SEMESTER-II
MATH-CC- 421(REAL ANALYSIS-II)

L	T	P	Credit
4	0	0	4

Pre-requisite: Calculus of several variables and Real Analysis-I.

Course Objectives: This course is designed to consider theoretical foundations of concepts of mathematical analysis, viz. derivative, functions of several variables, measure theory and integration that have many important applications in different branches of pure and applied mathematics. Further, the objective is to enable students familiar with the concepts and their fruitful applications.

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

- Applytheknowledgeofconceptsoffunctionsofseveralvariablesandmeasuretheory inordertostudytheoreticaldevelopmentofdifferentmathematicalconceptsandtheir applications.
- Understand the nature of abstract mathematics and explore the concepts in further details.
- Utilize the concepts of derivative, Recognize the need of concept of measure from a practical view point.
- Understand measure theory and integration from theoretical point of view and apply its tools in different fields of applications.
- Extend their knowledge of Lebesgue theory of integration by selecting and applying its tools for further research in this and other related areas.

Module I

Lebesgue Measure

Introduction, Outer measure, Measurable sets and Lebesgue measure, A non-measurable set, Measurable functions, Littlewood's three principles.

Module II

The Lebesgue Integral and Integration

The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, The integral of a nonnegative function, The general Lebesgue integral, Convergence in measure.
Differentiation of an integral, Absolute continuity, Convex functions.

Module III

Differentiation and The Classical Banach Spaces

Differentiation of monotone functions, Functions of bounded variation.
The L^pspaces, The Minkowski's and Holder's inequalities, Convergence and completeness, Approximation in L^p,Bounded linear functionals on the L^pspaces.

Module IV

Functions of Several Variables

Linear transformations, Differentiation, Chain rule, Derivatives in an open subset of R^n, Partial derivatives, Continuity of partial derivatives, Derivatives of higher orders.

Module V

Some Special Theorems

The contraction principle, The inverse function theorem, The implicit function theorem, The rank theorem, Jacobians.

Books Recommended:

1. Real Analysis, H.L. Royden, Prentice-Hall of India, Private Limited, New Delhi.
2. Mathematical Analysis, S.C. Malik and SavitaArora, New Age International Private Limited.
3. Real Analysis, N. P. Bali, Firewall Laxmi publication.

MATH-CC- 422 (ALGEBRA-II)

L	T	P	Credit
4	0	0	4

Pre-requisite: Algebra-I.

Course Objectives: This course is designed to give students a foundation for advanced study in Algebra.Thefundamentaltheoremsofalgebraicstructuresareexplained.Studentswillexplorethe concepts of Polynomial rings, UFD, ED, PID, Field extensions, Einstein's irreducibility criterion, Galois extensions etc. Throughout the course, Advanced Core standards are taught and reinforced as the student learns how to apply the concepts in real-life situations.

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

- Apply the knowledge of Algebra to attain a good mathematical maturity and enables to build mathematical thinking and reasoning.
- Utilize the Polynomial rings, UFD, ED, PID to solve different related problems.
- Identify and analyze different types of algebraic structures such as Algebraically closed fields, Splitting fields, Finite field extensions to understand and use the fundamental results in Algebra
- Design, analyze and implement the concepts of Gauss Lemma, Einstein's irreducibility criterion, separable extensions etc.
- Create, select and apply appropriate algebraic structures such as Galois extensions, Automorphisms of groups and fixed fields, Fundamental theorem of Galois theory to understand and use the Fundamental theorem of Algebra.
- Identify the challenging problems in advanced Algebra to pursue further research.

Module I

Field Theory-I

Irreducible Polynomials and Eisenstein Criterion, Adjunction of Roots, Algebraic Extensions.

Module II

Field Theory-II

Algebraically Closed Fields, Splitting Fields, Normal Extensions, Multiple Roots.

Module III

Finite Fields-I

Prime Fields, Finite Fields, Roots of Irreducible Polynomials, Roots of Unity and Cyclotomic Polynomials.

Module IV

Finite Fields-II

Representation of Elements of Finite Fields, Order of Polynomials and Primitive Polynomials, Irreducible Polynomials.

Module V

Galois Theory and its Applications

Separable Extensions, Automorphism Groups and Fixed Fields, Fundamental Theorem of Galois Theory, Fundamental theorem of algebra.

Books Recommended:

1. Basic Abstract Algebra, P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Cambridge University Press.
2. Topics in Algebra, I.N. Herstein, John Wiley and Sons, New York.
3. Linear Algebra, Kenneth Hoffman and Ray Kunze, Prentice-Hall of India Private Limited, New Delhi

MATH-CC- 423 (PARTIAL DIFFERENTIAL EQUATIONS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Calculus of several variables and ODE.

Course Objectives: The Objective of this course is to introduce first and higher order partial differential equations and their classification. This course explains various analytic methods for computing the solutions of various partial differential equations. It also explains various applications of partial differential equations in real physical phenomenon like wave equation of string, diffusion equations and heat flow equation to students

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

- Understand partial differential equations of first order (linear and nonlinear), second and higher order.
- Apply various analytic methods for computing solutions of various PDEs.
- Determine integral surfaces passing through a curve, characteristic curves of second order PDE and compatible systems.
- Understand the formation and solution of some significant PDEs like wave equation, heat equation and diffusion equation.
- Apply the knowledge of PDEs and their solutions in order to understand physical phenomena.

Module I

Fundamental Concepts

Classification of second order partial differential equations, Canonical forms: Canonical form for hyperbolic equation, Canonical form for parabolic equation, Canonical form for elliptic equation, adjoint operators.

Module II

Elliptic Differential Equations

Occurrence of the Laplace and Poisson equations: Derivation of Laplace equation, Derivation of Poisson equation, Boundary Value Problems, Some important mathematical tools, Properties of Harmonic functions, Separation of variables.

Module III

Parabolic Differential Equations

Occurrence of the diffusion equation, Boundary conditions, Elementary solutions of the diffusion equation, Dirac Delta function, Separation of variables method. .

Module IV

Hyperbolic Differential Equations

Occurrence of the wave equation, Derivation of one-dimensional wave equation, Solution of one-dimensional wave equation by canonical reduction, The initial value problem, D'Alemberts solution, Vibrating string–variables separable solution, Forced vibrations–solution of non-homogeneous equation.

Module V

Boundary and Initial Value Problem

Boundary and initial value problem for two-dimensional wave equation, Method of Eigen function, Periodic solution of one dimensional wave equation in cylindrical coordinates, Periodic solution of one-dimensional wave equation in spherical polar coordinates.

Books Recommended:

1. Introduction to Partial Differential Equations, K. Sankara Rao, Prentice Hall of India Private Limited, New Delhi.
2. Differential Equations, S.L. Ross, John Wiley and Sons, Inc.,
3. Partial Differential Equations for Engineers and Scientists, J. N. Sharma and Kehar Singh, Narosa Publication

MATH-CC-424 (SOLID MECHANICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Continuum Mechanics, Tensor analysis.

Course Objectives: The primary course objective is to solve advanced solid mechanics problems using classical methods and equip the students with the tools necessary to solve mechanics problems, which involves (a) static analysis of a component to find the internal actions (forces and moments), and determine stresses, strains and deformation due to internal actions.

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

- Understand the theory of elasticity including strain/displacement and Hooke's law relationships.
- Analyze solid mechanics problems using classical methods and energy methods.
- Solve for stresses and deflections of beams under unsymmetrical loading.
- Obtain stresses and deflections of beams on elastic foundations.
- Solve torsion problems in bars and thin walled members.

Module I

Analysis of Strain

Affine transformation, Infinitesimal Affine deformations, Geometrical interpretation of the components of Strain, Strain quadric of Cauchy, Principal strains, Invariants, General infinitesimal deformation, Equation of compatibility, Finite deformation.

Module II

Analysis of Stress

Stress Tensor, Equations of equilibrium, Transformation of coordinates, Stress quadric of Cauchy, Principal stress and invariants, Maximum normal and shear stresses, Mohr's circle diagram.

Module III

Equations of Elasticity

Generalized Hooke's law, Stress-strain relations for a medium having one plane elastic symmetry, Three orthogonal planes symmetry and for homogeneous isotropic media, Elastic-moduli for isotropic media, Equilibrium and dynamic equations for an isotropic solid.

Module IV

Strain Energy Function

Strain energy function and its connection with Hooke's law, Unique solution of boundary value problem, Derivation of Navier's equations and Beltrami-Michal compatibility equations.

Module V

Beam Problems

Extension of beams by longitudinal forces, Beam stretched by its own weight, Bending of beams by terminal couples, Torsion of a circular shaft, Plane stress, Plane strain.

Books Recommended:

1. Mathematical Theory of Elasticity, I. S. Sokolnikoff, Tata McGraw-Hill Publishing Co. Ltd.
2. Theory of Elasticity, S. Timoshenko and N. Goodier, Theory of Elasticity, McGraw-Hill.

MATH-CC- 425 (NUMBER THEORY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Congruencies, Number System

Course Objectives: This course is designed to provide students an introduction to classical number theory and enable them to study higher courses in number theory, and to apply the learnt concepts of number theory using public-key cryptography.

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

- Apply the knowledge of Number theory and Cryptography to attain a good mathematical maturity and enables to build mathematical thinking and skill.
- Utilize the congruencies, Chinese remainder theorem, indices, residue classes, Legendre symbols to solve different related problems.
- Identify and analyze different types of divisibility tests, Euler's theorem, Wilson theorem, Mobius inversion formula to formulate and solve various related problems.
- Design, analyze and implement the concepts of Diophantine equations for solving different types of problems, for example, sum of two and four squares.
- Create, select and apply appropriate number theoretic techniques such as primes, greatest integer functions in Cryptography to use in real life problems.
- Identify the challenging problems in modern mathematics and find their appropriate solutions.

Module I

Divisibility and Congruence Theory

The division algorithm, The greatest common divisor, The Euclidean algorithm, The Diophantine equation, Fundamental theorem of arithmetic, The Sieve of Eratosthenes, The Goldbach conjecture, Basic properties of congruence, Special divisibility tests and linear congruencies.

Module II

Fermat's and Euler's Theorem

Fermat's factorization method, The Little theorem and Wilson's theorem, Euler's generalization of Fermat's theorem, Euler's Phi-function, Euler's theorem and some properties of the Phi-Function, An application to cryptography.

Module III

Number-Theoretic Functions

The Functions τ and σ, The Mobius inversion formula, The greatest integer function and an application to the calendar.

Module IV

Primitive Roots and Indices

The order of an integer modulo *n*, Primitive roots for primes, Composite numbers having primitive roots and the theory of indices.

Module V

The Quadratic Reciprocity Law

Euler's criterion, The Legendre symbol and its properties, Quadratic reciprocity, Quadratic congruencies with composite moduli.

Books Recommended:

1. Elementary Number Theory, David M. Burton, McGraw Hill.

MATH-CC- 426 (P) (BASIC INTRODUCTION OF MATLAB)

L	T	P	Credit
0	0	2	2

Pre-requisite: Basic knowledge of programming through MATLAB..
Course Objectives: This course is designed to understand some basic concepts of MATLAB and its applications. This course will promote new teaching model that will help to develop programming skills and technique to solve mathematical problems. They will understand MATLAB graphic feature and its applications and will use MATLAB as a simulation tool.

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

- To understand about the basic of Matlab environment.
- To create the function in Matlab.
- To solve the differential equations through numerical techniques.
- Understand the 2D, 3D graphical picture of distinct kinds of differential equations.
- Know about the symbolic calculations.

Module I

Introduction to MATLAB
The MATLAB Environment, MATLAB Basics – Variables, Numbers, Operators, Expressions, Input and Output, Vectors, Arrays – Matrices.

Module II

MATLAB Functions
Basics of MATLAB function, Create function, Built-in Functions, User defined Functions .

Module III

Graphics with MATLAB
Files and File Management – Import/Export, Basic 2D, 3D plots , Graphic handling

Module IV

Programming with MATLAB
Conditional Statements, Loops, MATLAB Programs – Programming and Debugging, Applications of MATLAB Programming.

Module V

Mathematical Computing with MATLAB
Algebraic equations, Basic Symbolic Calculus and Differential equations, Numerical Techniques and Transforms.

References:
1. "A Guide to MATLAB - for Beginners and Experienced Users", 2nd Ed., Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg, Cambridge University Press, (2006).
2. "Essentials of MATLAB Programming", 2nd Ed., Stephen J. Chapman, Cengage Learning, (2009).
3. "MATLAB Demystified", David McMahon, The McGraw-Hill Companies, (2007).
4. "MATLAB for Engineers", 3rd Ed., Holly Moore, Pearson Education, Inc., (2012).
5. "Engineering computation with MATLAB", 2nd Ed., David M. Smith, Pearson Education, Inc., (2010).

MATH-OE- 001 (Foundation Course Of Mathematics)

L	T	P	Credit
2	0	0	2

Pre-requisite: Set theory, Relations, Functions.

Course Objectives: Prepare students to develop mathematical foundations to understand and create mathematical arguments require in learning many mathematics concept to be used in Chemistry specially in Physical Chemistry. To motivate students how to solve practical problems using Mathematical Concepts.

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

- Solve the problems based upon Matrices addition, Subtraction and multiplications and to evaluate determinants.
- Solve problems based upon limit and continuity.
- Solve the problems based upon differentiation and integration.

Module I

Matrix and Determinants

Definition and types of Matrices, Addition, Subtraction, Scalar multiplication and multiplication of matrices, Adjoint and inverse of matrix, Cramer's rule, Determinant, Minors, Cofactors, Properties of determinants, Rank of matrix, Dependence of vectors, Eigen values and vectors of a matrix, Cayley-Hamilton theorem (without proof).

Module II

Limits

Limit at a point, Properties of limit, Computation of limits of various types of functions

Module III

Continuity

Continuity at a point, Continuity over an interval, Intermediate value theorem, Type of Discontinuities.

Module IV

Differentiation

Derivative, Derivatives of sum, differences, product & quotients rule, Chain rule, Derivatives of composite functions, Logarithmic differentiation, Differentiation of function of several independent variables, Change of variables, Relations between partial derivatives, Total differentials, Chain rules for partial differentiation, Euler's theorem.

Module V

Integration

Integral as limit of sum, Riemann sum, Fundamental theorem of calculus, Indefinite integrals, Methods of integration: substitution, By parts, Partial fractions, Integration of algebraic and transcendental functions.

Books Recommended:

1. Elementary Engineering Mathematics, B.S. Grewal, Khanna Publishers.
2. Advanced Engineering Mathematics, H.K. Dass, S. Chand and Company.
3. Mathematics I and Mathematics II, R. D. Sharma, Dhanpat Rai Publication.

SEMESTER-III
RM-CC- 022 (RESEARCH METHODOLOGY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Idea about Research.

Course Objectives: This course will help to: Develops Better Insight Into Topic; Provides Systematic Structure; Enhance The Research Quality; Derive Better Solutions; Aids In Decision Making; Inculcates Logical And Systematic Thinking.

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

- understand some basic concepts of research and its methodologies
- identify appropriate research topics
- select and define appropriate research problem and parameters
- prepare a project proposal (to undertake a project)
- organize and conduct research (advanced project) in a more appropriate manner
- write a research report and thesis
- write a research proposal (grants)

Module I

Foundations of Research

Meaning, Objectives, Motivation, Utility. Concept of Theory, Empiricism, deductive and inductive theory. Characteristics of scientific method – Understanding the language of research – Concept, Construct, Definition, Variable. Research Process. **Problem Identification & Formulation –** Research Question – Investigation Question –Measurement Issues – Hypothesis – Qualities of a good Hypothesis –Null Hypothesis & Alternative Hypothesis. Hypothesis Testing – Logic & Importance

Module II

Research Design

Concept and Importance in Research – Features of a good research design Exploratory Research Design – concept, types and uses, Descriptive Research Designs – concept, types and uses. Experimental Design: Concept of Independent & Dependent variables.

Qualitative and Quantitative Research: Qualitative research – Quantitative research – Concept of measurement, causality, generalization, replication. Merging the two approaches.

Module III

Measurement

Concept of measurement– what is measured? Problems in measurement in research – Validity and Reliability. Levels of measurement – Nominal, Ordinal, Interval, Ratio. **Sampling:** Concepts of Statistical Population, Sample, Sampling Frame, Sampling Error, Sample Size, Non Response. Characteristics of a good sample. Probability Sample – Simple Random Sample, Systematic Sample, Stratified Random Sample & Multi-stage sampling. Determining size of the sample – Practical considerations in sampling and sample size.

Module IV

Data Analysis

Data Preparation – Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis – Cross tabulations and Chi-square test including testing hypothesis of association. **Interpretation of Data and Paper Writing** – Layout of a Research Paper, Journals in Chemical Sciences, Impact factor of Journals, When and where to publish ? Ethical issues related to publishing, Plagiarism and Self-Plagiarism. Use of Encyclopedias, Research Guides, Handbook etc., Academic Databases for Computer Science Discipline.

Module V

Use of tools / techniques for Research

Methods to search required information effectively, Reference Management Software like Zotero/ Mendeley, Software for paper formatting like LaTeX/MS Office, Software for detection of Plagiarism

Books recommended:

1. Business Research Methods – Donald Cooper & Pamela Schindler, TMGH, 9th edition
2. Business Research Methods – Alan Bryman & Emma Bell, Oxford University Press.
3. Research Methodology – C.R.Kothari

MATH-CC- 431 (COMPLEX ANALYSIS-I)

L	T	P	Credit
4	0	0	4

Pre-requisite: Calculus of several variables and complex number system.

Course Objectives: The objective of this course is to introduce and develop a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, Cauchy-Riemann relations and harmonic functions and to make students equipped with the understanding of the fundamental concepts of complex variable theory. In particular, to enable students to acquire skill of contour integration to evaluate complicated real integrals via residue calculus.

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

- Know the fundamental concepts of complex analysis.
- Evaluate complex integrals and apply Cauchy integral theorem and formula.
- Evaluate limits and checking the continuity of complex function & apply the concept of analyticity and the Cauchy-Riemann equations.
- Solve the problems using complex analysis techniques applied to different situations in engineering and other mathematical contexts.
- Establish the capacity for mathematical reasoning through analyzing, proving and explaining concepts from complex analysis.
- Extend their knowledge to pursue research in this field.

Module I

Complex Numbers and Function

The algebra and geometric representation of complex numbers, Limits and continuity, Analytic functions, Polynomials and rational functions, Exponential and trigonometric functions, Periodicity, Logarithm, Sets and elements, Arcs and closed curves, Analytic functions in region.

Module II

Conformal Mapping

Conformal mapping, Length and area, Linear group, Cross ratio, Symmetry, Oriented circles, Family of circles, Use of level curves, Survey of elementary mappings, Elementary Riemann surfaces.

Module III

Complex Integration

Line integrals, Rectifiable arcs, Line integral as function of arcs, Cauchy's theorem for a rectangle, Cauchy's theorem in a disk, The index of a point with respect to a closed curve, Cauchy's integral formula, Higher derivatives.

Module IV

Series of Complex Function

Sequences, Series, Uniform convergence, Power series and Abel's limit theorem, Weierstrass's theorem, Taylor's series and Laurent series, Removable singularities, Taylor's theorem, Zeros and poles, The local mapping and the maximum principle.

Module V

Calculus of Residue and General Cauchy's Theorem

Chains and Cycles, Simple connectivity, Homology, Cauchy's theorem, Locally exact differentials and multiply connected regions, Residue theorem, Argument principle, Evaluation of definite integral.

Books Recommended:

1. Complex Analysis, Lars V. Ahlfors, McGraw Hill Int. Ed.
2. Function of Complex Variable, John B. Conway, Narosa Publishers.
3. Theory of Functions of Complex Variables, Shanti Narayan, S. Chand and Co.

MATH-CC- 432 (TOPOLOGY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Real Analysis-I.

Course Objectives: The objective of the course on Topology is to provide the knowledge of Topological Spaces and their importance. To acquaint students with the concept of Homeomorphism and the topological properties and important mathematical concepts which can be generalized in topological spaces, so that students may learn and appreciate the nature of abstract Mathematics.

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

- Understand the concepts of topological spaces and the basic definitions of open sets, neighbourhood, interior, exterior, closure and their axioms for defining topological space.
- Understand the concept of Bases and Sub bases, create new topological spaces by using subspace.
- Understand continuity, compactness, connectedness, homeomorphism and topological properties
- Understand how points of space are separated by open sets, Housdroff spaces and their importance.
- Understand regular and normal spaces and some important theorems in these spaces

Module I

Metric Spaces

Open sets, Closed sets, Convergence, Completeness, Baire's category theorem, Continuity.

Module II

Topological Spaces

The definition and some examples, Elementary concepts, Open bases and open sub bases, Weak topologies, Function algebras C (X, R) and C (X, C).

Module III

Compactness

Compact spaces, Products of spaces, Tychonoff's theorem, Locally compact spaces, Compactness for metric spaces, Ascoli's theorem.

Module IV

Spaces

T_1-spaces and Hausdorff spaces, Completely regular spaces, Normal spaces, Urysohn's lemma and Tietze's extension theorem, Urysohn imbedding theorem, Stone-Cechcompactification.

Module V

Connectedness

Connected spaces, Components of a space, Totally disconnected spaces, Locally connected spaces.

Books Recommended:

1. Introduction to Topology and Modern Analysis, G.F. Simmons, McGraw Hill.

MATH-CC- 433 (FUNCTIONAL ANALYSIS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Real analysis and Linear Algebra

Course Objectives: This course will develop a deeper and rigorous understanding of fundamental concepts of functional analysis, their properties and related theorems.

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

- Explain the fundamental concepts of functional analysis and their role in modern mathematics.
- Utilize the concepts of functional analysis, for example continuous and bounded operators, normed spaces, Hilbert spaces and to study the behavior of different mathematical expressions arising in science and engineering.
- Understand and apply fundamental theorems from the theory of normed and Banach spaces including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem and uniform boundedness theorem.
- Understand the nature of abstract mathematics and explore the concepts in further details.
- Explain the concept of projection on Hilbert and Banach Spaces.

Module I

Normed Spaces

Definition of normed linear spaces, Convergent sequence in normed linear space, Cauchy sequence in normed linear space, Complete normed linear space, Theorems on normed linear space, Zeroth norm.

Module II

Banach Spaces

Definition and some examples of Banach Space, Continuous linear transformation, The Hann-Banach theorem, The open mapping theorem, The closed graph theorem, The uniform boundedness theorem, The natural imbedding of N in N**, Reflexivity.

Module III

Hilbert Spaces

Definition and some simple properties of Hilbert space, Orthogonal complements, Orthonormal sets, Conjugate space H*, adjoint of an operator, Self- adjoint, normal and unitary operators, Projections.

Module IV

Spectral Theory of Linear Operators in Normed Spaces

Spectral Theory in finite dimensional normed spaces, Basic concepts, Spectral properties of bounded Linear operators.

Module V

Resolvent and Spectrum

Properties of resolvent and spectrum, Use of Complex analysis in spectral theory, Banach algebra, Further properties of Banach algebra.

Books Recommended:

1. Introduction to Topology and Modern Analysis, G.F. Simmons, McGraw Hill.
2. Introductory Functional Analysis with Applications, E. Kreyszig , John, Wiley and Sons.

MATH-CC- 500 (SEMINAR)

L	T	P	Credit
2	0	0	2

Pre-requisite: communication Skills

Course Objectives: The objectives of the seminar are to develop the skill of communication in presentation, skill of identify the topic with the consideration feasibility and also of searching literature on selected research oriented project work.

C**ourse Outcomes**: At the end of the course, the students will be able to

- Demonstrate capacity to lead and manage change through collaboration with others
- Report research findings in written and verbal forms.

Every student will have to deliver a seminar of 15-30 minutes duration on the topic related to his/her project work which will be chosen by him/her in consultation with the teacher of the department. The seminar will be delivered before the students and faculty of the department. A three member committee (one coordinator and two teachers of the department) will be constituted to evaluate the seminar. The following factors will be taken into consideration while evaluating the candidate.

(i). Depth of the subject matter
(ii). Expressions
(iii). Presentation
(iv). Answers to the questions asked.

MATH-CC- 434 (P) (MATHEMATICA AND ITS APPLICATIONS)

L	T	P	Credit
0	0	2	2

Pre-requisite: Basics of Mathematica.

Course Objectives: This course is designed to understand some basic concepts of Mathematica and its applications

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

- To learn the features of Mathematica as a programming tool.
- To promote new teaching model that will help to develop programming skills and technique to solve mathematical problems.
- To understand Mathematica graphic feature and its applications.
- To use Mathematica as a simulation tool.

Module I

Introduction of Mathematica

Definition of functions, Mathematica basics: Operators, Expressions, Matrices and operations on matrices.

Module II

Numerical Calculations

Differentiation and Integration, Running calculation in Mathematica, Numerical calculation.

Module III

Solutions of differential equations

Building up different kind of calculation, Solutions of PDEs and ODEs, Algebraic calculations.

Module IV

Symbolic calculations and graphics

Symbolic Mathematica, Numerical methods, 2D and 3D graphs.

Module V

File management

Create tables for the solution of any kind of differential equations, Import and export.

Books Recommended:

1. S. Wolfram. The Mathematica (1999).
2. David McMahon , Daniel M. Topa. A Beginner's Guide to Mathematica (2006).

ELECTIVE COURSES
MATH-EC- 435 (MATHEMATICAL STATISTICS-I)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Statistics

Course Objectives: The aim of the course is to enable the students with understanding of various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.

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

- Organize, manage and present data.
- Use the basic probability rules, including additive and multiplicativelaws, using the terms, independent and mutually exclusive events.
- Translate real-world problems into probability models.
- Derive the probability density function of transformation of randomvariables.
- Calculate probabilities, and derive the marginal and conditionaldistributions of bivariate random variables.
- Analyze Statistical data using MS-Excel.
- Use discrete and continuous probability distributions, includingrequirements, mean and variance, and making decisions.
- Appropriately interpret results of analysis of variance tests.

Module I

Introduction to Statistics and Probability

Definition, Types of variables, Organizing data, Descriptive measures, Basic definitions and rules for probability, Conditional probability, Independence of events, Bayes theorem, Random variables, Probability distributions: Binomial, Poisson, Uniform and normal distributions.

Module II

Mathematical Expectation

The probability set Function, Random variables, The probability density function, The distribution function, Certain probability models, Mathematical expectation, Some special mathematical expectations.

Module III

Distributions

Chebyshev's inequality, Conditional probability, Marginal and conditional distributions, stochastic independence, The binomial, trinomial, and multinomial distributions, The Poisson distribution.

Module IV

Distributions of Various Variable

The Gamma and Chi-square distributions, the normal distribution and the bivariate normal distribution, Sampling theory, Transformations of variables of the discrete type, Transformations of the variables of the continuous type, The T and F distributions.

Module V

Testing of Hypothesis

Hypothesis testing: One sample and two sample tests for means and proportions of large samples (z-test), One sample and two sample tests for means of small samples (T-test), F-test for two sample standard deviations, ANOVA one and two way-design of experiments.

Books Recommended :

1. Statistical Method, S.P. Gupta, S. Chand Publication.
2. Statistics for Management, T. N. Srivatsava, TMH.
3. Introduction to Probability and its Applications, W. Feller, Wiley Eastem Private Limted.

ELECTIVE COURSE
MATH-EC- 436 (OPERATIONS RESEARCH-I)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Calculus, analysis and linear algebra**.**

Course Objectives: This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems, game theory, dynamic programming and queuing models etc. The major focus will be on formulation of real world phenomena from its physical considerations and implementation of optimization algorithms for solving these problems.

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

- Apply the knowledge of basic optimization techniques in order to get best possible results from a set of several possible solution of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc.
- Formulate an optimization problem from its physical consideration.
- Select and implement an appropriate optimization technique keeping in mind its limitations in order to solve a particular optimization problem.
- Extend their knowledge of basic optimization techniques to do interesting research work on these types of optimization techniques.

Module I

Linear Programming Problem (LPP)

Formulation and examples of LPP, Feasible solution, Basic feasible and optimal solutions, Extreme points, Graphical Methods to solve LPP, Simplex method, Big M method, Two phase method, Degeneracy, Unrestricted variables, Unbounded solutions.

Module II

Dual Programming Problems

Duality theory, Dual LPP, Fundamental properties of Dual problems, Dual simplex algorithm.

Module III

Transportation Problem (TP)

Mathematical formulation of TP, Basic feasible solutions of TPs by North–West Corner method, Least Cost method, Vogel's approximation method, Unbalanced TP, U-V method.

Module IV

Assignment Problem (AP)

Mathematical formulation of AP, Assignment methods, Hungarian method, Unbalanced AP.

Module V

Game theory

Two-person, Zero-sum games, The maximin–minimax principle, Pure strategies, Mixed strategies, Graphical solution of $(2 \times n)$ and $(m \times 2)$ games, Dominance property.

Books Recommended:

1. Operations Research, S.D. Sharma, Kedar Nath Ram Nath and Co.
2. Operations Research, Kanti Swarup, P.K. Gupta and Manmohan, Sultan Chand and Sons.

ELECTIVE COURSE
MATH-EC- 437 (GRAPH THEORY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Discrete Mathematics.

Course Objectives:

Graph Theory is an integral part of Discrete Mathematics and has applications in diversified areas such as Electrical Engineering, Computer science, Linguistics. In this course basic concepts of Graph theory such as Trees, Eulerian Graphs, Matching, Vertex colorings, Edge colorings, Planarity, are introduced.

Course Outcomes:

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

- Understand the definitions namely, cut vertex, bridge, blocks and Automorphism group of a graph.
- Study the properties of trees and connectivity.
- Idetify Eulerian graphs and apply results to identify Hamiltonian graphs.
- Understand the concepts Planarity including Euler identity.
- Discuss and understand the importance of the concepts Matchings and Colorings.

Module I

Paths and Circuits

Isomorphism, Sub Graphs, Puzzle with Multi Colored Cubes, Walks, Paths and Circuits, Connected Graphs, Disconnected Graphs, Components, Euler Graphs, Operations on Graphs, More on Euler Graphs, Hamiltonian Paths and Circuits, Traveling Salesman Problem.

Module II

Trees and Fundamental Circuits

Trees, Some Properties of Trees, Pendant Vertices in a Tree, Distances and Centers in a Tree, Rooted and Binary Trees, Spanning Trees, Fundamental Circuits, Finding all Spanning Trees of a Graph, Spanning Trees in a Weighted Graphs.

Module III

Cut sets and Cut Vertices

Cut Sets, All Cut Sets in a Graph, Fundamental Circuits and Cut Sets, Connectivity and Separability, Network Flows, One -Isomorphism, Two-Isomorphisms.

Module IV

Planar and Dual Graphs

Combinatorial Vs Geometric Graphs, Planar Graphs, Kuratowski's Two Graphs, Different Representations of a Planar Graph, Detection of Planarity, Geometric Dual.

Module V

Vector Spaces of a Graph

Set with One Operation, Sets with Two Operations, Modular Arithmetic and Galois Field, Vectors and Vector Spaces, Vector Space associated with a Graph, Basis vectors of a Graph.

Books Recommended:

1. Graph Theory with Applications to Engineering and Computer Science, Narsingh Deo Prentice Hall of India, Pvt. Ltd., New Delhi.

OPEN ELECTIVE COURSE
MATH-OE- 002 (Basics Of Probability and Statistics)

L	T	P	Credit
2	0	0	2

Pre-requisite: Knowledge of basic Mathematical operations.

Course Objectives: The aim of the course is to enable the students with understanding of various types of probability distributions. It aims to equip the students with standard concepts of statistical techniques and their utilization

Course Outcomes:

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

- Explore the basic ideas about measures of central tendency, dispersion and their applications in other statistical problems.
- Tackle with data and draw inferences form it by applying appropriate statistical techniques.
- Explain the different types of discrete and continuous distributions and their utilization.
- Understand the various practical concepts of regression and co-relation.
- Demonstrate understanding of the concepts of time series and acquire knowledge on vital statistical, index no's and calculate and indices from given data

Module I

Introduction to Statistics & Probability

Statistics–Definition, Types of Variables, Organizing Data, Descriptive Measures, Basic definitions and rules for Probability, Conditional Probability Independence of Events, Baye's Theorem, Random Variables.

Module II

Probability Distributions

Probability Distributions: Binomial, Poisson, Uniform and Normal Distributions.

Module III

Correlation

Meaning of Correlation, Types of Correlation, Coefficient of Correlation, Measurement of Correlation, Probable error of Coefficient of Correlation, Standard error of Coefficient of Correlation, Coefficient of Determination, Correlation Ratio.

Module IV

Regression

Meaning of Regression, Types of Regression, Regression lines, Regression Equations, Regression Coefficient, Standard error of Estimates, Ratio of Variation, Limitation of Regression Analysis, Difference between Correlation and Regression.

Module V

Index Numbers and Time Series Analysis

Meaning of Index Number and its Classification, Weighted Index Numbers, Meaning of Time Series, Components of Time Series, Measurement of Trend, Measurement of Seasonal Variations, Ratio-to-moving Average Method, Line Relative Method.

Books Recommended:

1. Statistics for Management, R. I. Levin and D. S. Rubin, PHI.
2. Statistics for Management, T. N. Srivatsava, TMH.
3. Statistics, E. Narayanan Nadar, PHI Learning Private Limited.

SEMESTER-IV
MATH-CC- 441 (COMPLEX ANALYSIS -II)

L	T	P	Credit
4	0	0	4

Pre-requisite: Complex Analysis I.

Course Objectives: This course is designed to enable the readers to understand further deeper topics of Complex Analysis and will provide basic topics needed for students to pursue research in pure Mathematics

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

- Equip with necessary knowledge and skills to enable them handle mathematical operations, analyses and problem solving involving complex numbers.
- Understanding of topological and geometric properties of the complex plane.
- Analyze how complex numbers provide a satisfying extension of the real numbers.
- Learn techniques of complex analysis that make practical problems easy (e.g. graphical rotation and scaling as an example of complex multiplication).

Module I

Harmonic Functions

Definition and basic properties of harmonic function, The mean value property, Hadamard's three circle theorem, Poisson's formula, Schwarz's theorem, The reflection principle, Functions with the mean value property, Harnack's principle, The Dirichlet's problem; Subharmonic functions, Solution of Dirichlet's problem.

Module II

Partial Fractions and Factorization

Partial fractions, Infinite products, Canonical products, Gamma functions, Stirling's formula,

Module III

Entire Functions and The Riemann Zeta Functions

Entire functions, Jensen's formula, Hadmard's Theorem, The Riemann Zeta functions, The product development, Extension of z (*s*) to the whole plane, The functional equation, The zeros of the Zeta function.

Module IV

Simply Periodic Functions

Representation by exponentials, The Fourier development, Functions of finite order, Doubly periodic functions, The period module, Unimodular transformations, The canonical basis, General properties of elliptical functions, Analytic continuations, The Weierstrass theory, Germs and sheaves, Sections and Riemann surfaces.

Module V

Algebraic Functions

Analytic continuations along arcs, Homotopic curves, The Monodromy theorem, Branch points, Algebraic functions, The resultant of two polynomials, Definition and properties of algebraic functions, Behaviour at the critical points, Picard's theorem.

Books Recommended:

1. Complex Analysis, Lars V. Ahlfors, Int. Ed. McGraw-Hill Book Co.
2. Function of One Complex Variable, John B. Conway, Narosa Publishers.

MATH-CC- 501 (PROJECT)

Credit
8

Pre-requisite: Basic knowledge of the subject chosen.

Course Objectives:

The objectives of project work will be to enrich the students to design research oriented project on particular context; to identify the topic with the consideration feasibility; to search literature on selected research oriented project work; to identify/search the advances in current research; to prepare a dissertation report with complete follow up of research methodology; to develop the skill of communication in presentation; to demonstrate the utility of various software such as Origin, MS-Office., other used in applied mathematics etc; and to employ/use the techniques used in typing of dissertation such as Foot Note, End Note etc.

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

- Carry out a substantial research-based project.
- Demonstrate capacity to improve student achievement, engagement and retention.
- Demonstrate capacity to lead and manage change through collaboration with others
- Demonstrate an understanding of the ethical issues associated with practitioner research.
- Report research findings in written and verbal forms.
- Use research findings to advance education theory and practice.

All students of 4th semester will have to work on project on different topics related to their project work which will be chosen by them in consultation with the teachers of the department. The project will be delivered before the students and faculty of the department. A three member committee (one coordinator and two teachers of the department) will be constituted to evaluate the seminar. The following factors will be taken into consideration while evaluating the candidate.

(i) Project Report
(ii) Presentation
(iii) Viva-voce.

ELECTIVE
MATH-EC- 442 (MATHEMATICAL STATLSTICS-II)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Statistics and Calculus of several variables.

Course Objectives: The aim of the course is to enable the students with understanding of various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.

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

- Deal with formulation of hypotheses as per situations and their testing.
- Calculate and interpret the correlation between two variables.
- Calculate the simple linear regression equation for a set of data.
- Employee the principles of linear regression and correlation, including least square method, predicting a particular value of Y for a given value of X and significance of the correlation coefficient
- Demonstrate understanding of the concepts of time series and its applications in different areas.
- Acquire knowledge on vital statistics, Index numbers and calculate anindices from given data.
- Analyze statistical data using MS-Excel.
- Know the practical issues arising in sampling studies.

Module I

Non-Parametric Methods

Chi-square test for single sample standard deviation, Chi square tests for independence of attributes and goodness of fit, Sign test for paired data, Rank sum test, Kolmogorov-Smirnov test for goodness of fit, Comparing two populations, Mann-Whitney U test and Kruskal Wallis test, One sample run test.

Module II

Correlation, Regression, Index Numbers and Time Series Analysis

Correlation analysis, Estimation of regression line, Time series analysis: Variations in time series, Trend analysis, Cyclical variations, Seasonal variations and irregular variations, Index Numbers-Laspeyre's, Paasche's and Fisher's ideal index.

Module III

Sampling Distribution and Estimation

Definition, Sampling distribution of mean and proportion, Application of central limit theorem, Sampling techniques, Estimation: Point and interval estimates for population parameters of large sample and small samples, determining the sample size.

Module IV

Classification of Distributions

Extensions of the change of variable Technique, Distributions of order statistics, The moment generating function technique, The distribution of χ and ns^2/σ^2, Expectations of functions of random variables, Limiting distributions.

Module V

Central Limit Theorem

Stochastic convergence, Limiting moment generating functions, The central limit theorem, Some theorems on limiting distributions.

Books Recommended:

1. Introduction to Mathematical Statistics, Robert V. Hogg and Allen T. Craig, Macmillan Publishing Co., Inc., New York.
2. Statistics for Management, Anand Sharma, Himalaya Publishing House.

ELECTIVE
MATH-EC-443 (OPERATIONS RESEARCH-II)

L	T	P	Credit
4	0	0	4

Pre-requisite: Operational Research-I

Course Objectives: This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems, game theory, dynamic programming and queuing models etc. The major focus will be on formulation of real world phenomena from its physical considerations and implementation of optimization algorithms for solving these problems.

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

- Apply the knowledge of basic optimization techniques in order to get best possible results from a set of several possible solutions of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc.
- Formulate an optimization problem from its physical consideration.
- Select and implement an appropriate optimization technique keeping in mind its limitations in order to solve a particular optimization problem.
- Extend their knowledge of basic optimization techniques to do interesting research work on these types of optimization techniques.

Module I

Queuing Theory

Queueing systems, Queuing problem, Transient and steady states, Probability distributions in queuing systems. Poisson process (Pure birth process), Properties of passions arrivals, Exponential process, Markovian property, Pure death process, Service time distribution, Erlang service time distribution, Solution of queueing models.

Module II

Dynamic Programming

Decision tree and Bellman's principle of optimality, Concept of dynamic programming, Minimum path problem, Backward and forward recursive approach.

Module III

Non-Linear Programming Problems (NLPP)

Formulation of a NLPP, General non-linear NLPP, Constrained optimization with equality constraint, Necessary and sufficient condition for a general NLPP with one constraint, with $m<n$ constraints, Constrained optimization with inequality constraints (Kuhn-Tucker conditions), Graphical solution of NLPP, Verification of Kuhn-Tucker conditions.

Module IV

Quadratic Programming

Quadratic programming, Wolfe's modified Simplex method, Beale's method.

Module V

Separable Programming

Separable programming, Piecewise linear approximation, Separable programming algorithm.

Books Recommended:

1. Operations Research, S.D. Sharma, KedarNath Ram Nath and Co.
2. Operations Research, KantiSwarup, P.K. Gupta and Manmohan, Sultan Chand and Sons.

ELECTIVE

MATH-EC- 444 (DIFFERENTIAL GEOMETRY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic calculus and vector calculus.

Course Objectives: The objective of this course is to make students familiar with basic concepts of differential geometry so as to deal with geometry of curves and spaces using the methods of differential calculus

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

- Understand the basic concepts and results related to space curves, tangents, normals and surfaces.
- Explain the geometry of different types of curves and spaces.
- Explain the physical properties of different curves and spaces.
- Understand principal directions and curvatures, asymptotic lines and then apply their important theorems and results to study various properties of curves and surfaces.
- Utilize Geodesics, it's all related terms, properties and theorems.

Module I

Fundamental Forms

Tangent, Principal normal, Curvature, Binormal, Torsion, Serret-Frenet formulae, Locus of center of curvature, Spherical curvature, Locus of center of spherical curvature. Theorem: Curve determined by its intrinsic equations, Helices, Involutes & Evolutes.

Module II

Fundamental Magnitudes

Surfaces, Tangent plane, Normal, Curvilinear coordinates First order magnitudes, Directions on a surface, The normal, Second order magnitudes, Derivatives.

Module III

Fundamental Curvatures

Curvature of normal section.Meunier's theorem, Principal directions and curvatures, First and Second curvatures, Euler's theorem, Surface of revolution.

Module IV

Gauss's Formulae

Isometric lines and theorems of implict and inverse function, Gauss's formulae for r_{11}, r_{12}, r_{22} Gauss characteristic equation, Mainardi-Codazzi relations, Derivatives of angle w.

Module V

Geodesic

Geodesic property, Equations of geodesics, Surface of revolution, Torsion of Geodesic, Bonnet's theorem, Vector curvature, Geodesic curvature.

Books Recommended:

1. Differential Geometry of Three Dimension, C.E. Weatherburn, Khosla Publishing House.
2. Introduction to Differential Geometry, T.J. Willmore, Oxford University.

ELECTIVE

MATH-EC- 445 (LINEAR ALGEBRA AND MATRIX ANALYSIS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basics of Matrices and Determinants, Jorden Blocks and operators

Course Objectives: The primary course objective is to deal with different operators. They will also able to solve the problems based upon Diagonalisibility of Matrices.

Course Outcomes:

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

- Understand the inner product space.
- Understand the Diagonalisibility.
- Understand the Operators and their types.
- Understand the different inequalities.

Module I

Inner Product Space

Inner product, Inner product spaces, Linear functional and adjoints, orthogonal projections, self-adjoint operators. Unitary operators, Normal operators, Spectral theory, functions of operators. Polar decomposition.

Module II

Operations on Matrices

Simultaneously Diagonalisable Matrices, Unitary equivalence, some implication of Schur's theorem, the eigenvalues of sum and product of commuting matrices.

Module III

Spectral Theory

Normal matrices, Spectral theorem for normal matrices, Simultaneously unitarily diagonalisable commuting normal matrices.Matrix norms.

Module IV

Operators on Matrices

Operator norms, Matrix norms induced by vector norms, The spectral norm, Frobenius norm, Unitary invariant norm, The maximum column sum matrix norms, the maximum row sum matrix norm.

Module V

Inequalities in Matrices

Positive definite matrices, Definitions and properties, Characterizations, The positive semi-definite ordering, Loewner partial order, Inequalities for the positive definite matrices, Hadamard's inequality, Fischer's inequality, Minkowski's inequality.

Books Recommended:

1. Matrix Analysis, Rajendra Bhatia, Springer Verlag, (1997)
2. Positive Definite Matrix, Rajendra Bhatia, Hindustan Book Agency, (2007)

ELECTIVE

MATH-EC- 446 (CALCULUS OF SEVERAL VARIABLES)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basics knowledge of Vector Space.

Course Objectives: This course is designed to enable the student a rigorous study of the multivariate calculus. The inverse function theorem, the implicit function theorem will be central. The target would be to prove the Classical Stokes theorem for differential forms on chains.

Course Outcomes:

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

- Understand the concept of limit, integral and derivative from 1-dimensional to higher dimensional settings.
- Set up and solve optimization problems involving several variables, with or without constraints.
- Change variables in multiple integrals.
- Compute derivatives using the chain rule and product rule.
- Understand major theorems of the course and of some physical applications of these theorems.

Module I

Functions and Continuity

Vector space structure of R_n over R, norm and inner product, linear transformations, dual spaces; topology of R_n, limit points, continuity, compactness, connectedness, vector valued functions ($f: R_n \rightarrow R_m$), oscillation of functions and continuity.

Module II

Differentiability on Euclidean Space R_n:

Frechet derivatives, Results on chain rule, Differentiability, Partial Derivatives and Continuity of Frechet derivatives; The inverse function theorem, Implicit function theorem.

Module III

Integration On R_n

Partition of a closed rectangle, lower and upper sums, Integral of a function ($f: R_n \rightarrow R$) on a closed rectangle, measure zero and content zero, integrable functions, characteristic function, Fubini's theorem; real-analytic functions, partitions of unity, change of variable.

Module IV

Differential Forms On R_n**:**

Multilinear functions over a finite dimensional vector space V, k tensors, Tensor product, Alternating k-tensors, Wedge product, Vector spaces of k-tensors over R, determinant, Orientation and volume element; Tangent spaces in R_n, Vector fields, Differential forms, Linear maps between vector spaces of alternating k-tensors, Closed differential forms, Exact differential forms, Poincare lemma.

Module V

Integration On Chains In R_n

Singular n-cubes and singular n-chains in R_n, Results on boundary of a chain, Definitions of integral of a function ($f: R_n \rightarrow R$) over a singular n-cube and n-chain, Stokes' theorem on chains.

Books Recommended:

1. M. Spivak, Calculus on Manifolds, Addison Wesley, 1965.
2. S. Lang, Introduction to Differentiable Manifolds, Springer, 2002.
3. S. Axler, K.A. Ribet, An Introduction to Manifolds, Springer, 2008.

ELECTIVE

MATH-EC- 447 (METHODS OF APPLIED MATHEMATICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basics of Matrices and Determinants, Jorden Blocks and operators.

Course Objectives: The primary course objective is to deal with different operators. They will also able to solve the problems based upon Diagonalisibility of Matrices

Course Outcomes:

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

- Understand the inner product space.
- Understand the Diagonalisibility.
- Understand the Operators and their types.
- Understand the different inequalities.

Module I

Matrix Analysis-I

A review characteristic & minimal equations of a matrix, Caley-Hamilton theorem, trace of a matrix, orthogonal and unitary matrices, Eigen values and eigen vectors of a matrix and their determination. Similarity of matrices. Two similar matrices have the same eigen values, algebraic and geometric multiplicity of a characteristic root, mutual relation between eigen vectors corresponding to different eigen values, the necessary and sufficient condition for a square matrix of order n to be similar to a diagonal matrix, orthogonal reduction of real symmetric matrices.

Module II

Matrix Analysis-II

Normal matrices, Schur's theorem, The necessary and sufficient condition for a square matrix to be a unitarily similar to a diagonal Matrix, Quadratic forms , The Kroneckers and Lagranges reduction, reduction by orthogonal transformation of real quadratic matrices, necessary and sufficient condition for quadratic form to be a positive definite, rank , index and signature of a quadratic form.

Module III

Fourier Series

Euler – Fourier Formula, piecewise montonic and piecewise continuous functions, periodic functions. Fourier series expansions, Fourier series for even and odd functions, Fourier sine series expansion and Fourier cosine series expansion of f(x), Riemann-Lebesgue theorem, Dirchlet's criterion for a set of exact conditions on convergence in the theory of Fourier series.

Module IV

Numerical Analysis

Numerical Solution for algebraic equations, method of iteration and Newton-Raphson method, Rate of Convergence, Solution of Systems of linear algebraic equations using Gauss elimination and Gauss-Seidel methods, finite differences, Lagrange, Hermite and spline interpolation.

Module V

Numerical Differentiation and Integration

Numerical differentiation and integration with different methods.

Recommended Books:

1. Elementary Matrix Algebra, Franz E. Hohn, American Publishing Company, Pvt. Ltd.
2. A Text Book of Matrices, Shanti Narayan, S. Chand Co. Ltd.
3. Fourier Series & Boundary Value Problems, Churchill.
4. Introductory Methods of Numerical Analysis, S.S. Sastry, Prentice Hall of India, 2005

ELECTIVE
MATH-EC-448 (CLASSICAL MECHANICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic Mechanics and Calculus of several variables

Course Objectives: To demonstrate knowledge of functional and extremum path and the application of the knowledge in solving some fundamental problems. To demonstrate the knowledge and understanding of the fundamental concepts in the dynamics of system of particles and Lagrangian and Hamiltonian formulation of mechanics. To represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.

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

- Understand the concept of functional and determine stationary paths of a functional to deduce the differential equation for stationary paths.
- Use Euler-Lagrange equation to find stationary paths and its applications in some classical fundamental problems.
- Define and understand basic mechanical concepts related to discrete and continuous mechanical systems.
- Describe and understand the motion of a mechanical system using Lagrange- Hamilton formalism.
- Connect concepts and mathematical rigor in order to enhance understanding.

Module I

Basic Definitions

Generalized Coordinates, Constraints, Work and potential energy, Generalized forces, Principle of virtual work, Classification of dynamical Systems.

Module II

Lagrange's Equations

Lagrange's Equations for a particle in a plane, Lagrange's equations for any simple dynamical system, Lagrange's equations for non holonomic systems with moving constraints, Lagrange's equations for impulsive motion.

Module III

Stationary Values

Stationary Values of a function, Constrained stationary values, Stationary value of a definite integral, The Brachistochrone problem, Hamilton's equations, Derivation of Hamilton's equations, Ignorable coordinates, The Routhian function.

Module IV

Hamiltonian Function

The form of Hamiltonian function, Modified Hamilton's principle, Principle of least action, The Hamiton-Jacobi equation, Jacobi theorem.

Module V

Lagrange and Poission Brackets

Lagrange and Poission brackets and their properties, Invariance of Lagrange and Poission brackets under canonical transformation, Jacobi identity.

Books Recommended:

1. Principle of Mechanics, John L. Synge and Byron A. Griffith, McGraw Hill.
2. Classical Dynamics, Donald. T. Green Wood, Prentic-Hall of India.
3. Classical Mechanics, K. SankaraRao, Prentice-Hall of India.

MATH-EC- 449 (MAGNETO FLUID DYNAMICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Continuum Mechanics, Fluid Mechanics, Tensor analysis, Basics of Magnetism.
Course Objectives: The primary course objective is to solve Magneto Fluid Dynamics problems and equip the students with the tools necessary to solve Magneto Fluid Dynamics.
Course Outcomes: At the end of the course, the students will be able to

- Understand the theory of magnetic field and its basic equations.
- Understand the theory of Magneto hydrodynamic waves.
- Understand the theory of Terbulence.

Module I

Fundamental Equations
Maxwell's electromagnetic field equations, Magnetic induction equation and magnetic Reynold's number. Alfven's Theorem and its consequences. Magnetic energy equation and effects.

Module II

Magneto hydrostatics
Magneto hydrostatics, Force Free magnetic fluids (Basic equations, boundary conditions & magnetic energy, general solution when α is constant).

Module III

Steady States
Pressure balanced Magneto hydrostatics configurations. Toroidal magnetic field, Steady laminar motion. General solution of a vector wave equation.

Module IV

Magneto hydrodynamic Waves
Aflven waves, Magneto hydrodynamic waves in compressible fluid, Reflection and refraction of Alfven waves, Dissipative effects.

Module V

Turbulence
Introduction, Spectral analysis, Homogeneity and Isotropy. Kolmogorff's principle, Hydromagnetic turbulence, Inhibition of turbulence by a magnetic field.

Books Recommended:

1. An Introduction to Magneto Fluid Dynamics, V.C.A. Ferraro & C. Plumpton, Clarendon Press, Oxford 2nd Edition.

MATH-EC- 450 (THEORY OF SAMPLE SURVEY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic knowledge of Statistics.

Course Objectives: The primary course objective of this course is to obtain the maximum information about the population without examining each and every unit of the population and to find the reliability of the estimates derived from the sample, which can be done by computing the standard error of the statistic.

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

- Understand the concept of population
- Understand the concept of probability
- Understand the concept of estimators, estimation and variance.

Module I

Basics of population

Concepts of population, population unit, sample, sample size, parameter, statistics estimator, biased and unbiased estimator, mean square error, standard error. Census and Sample surveys, Sampling and Non sampling errors.

Module II

Basics of probability

Concepts of Probability and non-probability sampling, sampling scheme and sampling strategy, Introduction of Simple Random Sampling (Use of Lottery Method, Random numbers and Pseudo random numbers)

Module III

Estimators

Simple Random sampling (with or without replacement); Estimation of population Mean and Total, Expectation and Variance of these Estimators, unbiased estimators of the variance of these Estimators

Module IV

Estimation

Estimation of Population proportion and Variance of these estimators, estimation of sample size based on desired accuracy, Confidence interval for population Mean and Proportion Concepts of Stratified population and stratified sample, estimation of population mean and Total based on stratified sample.

Module V

Variance

Expectation and variance of estimator of population mean and total assuming SRSWOR within strata. Unbiased estimator of the variances of these estimators, Proportional Allocation, Optimum allocation (Neyman allocation) with and without varying costs, Comparison of simple random sampling and stratified random sampling with proportional and optimum allocations.

Books Recommended:

1. Sampling Theory of Surveys and Applications, P.V.Sukhatme, P.V.Sukkhatme, S. Sukhatme & C.Ashok (1997), Piyush Publications.
2. Sample Survey Theory. Des Raj and P.Chandok (1998), Narosa Publishing House.
3. Sampling Techniques, Wiliam G. Cochran (1977), 3rd Edition-John Wiely & Sons.
4. Theory and Methods of Survey Sampling, Parimal Mukhopadhyay (1988), Prentice Hall of India Pvt. Ltd.
5. Sampling Theory of Methods, Murthy M.N. (1977), Statistical Publishing Society, Culcutta.