MASTER OF SCIENCE IN MATHEMATICS
M.Sc. (Mathematics)

SYLLABUS & SCHEME

(From the Academic Year 2024-25 Onwards)

BOARD OF STUDY

DEPARTMENT OF MATHEMATICS
SANT LONGOWAL INSTITUTE OF ENGINEERING & TECHNOLOGY
(Deemed to be University under Ministry of Education, Govt. of India)
Longowal – 148106 (Punjab) INDIA

DEPARTMENT OF MATHEMATICS

VISION

The Department of Mathematics, SLIET, has always strived to be among the best Mathematics Departments in the country and has worked towards becoming a centre for advanced research in various areas of mathematics so that it can contribute to the development of the nation.

MISSION

- To work towards transformation of young people to competent and motivated professionals with sound theoretical and practical knowledge.
- To make students aware of technology to explore mathematical concepts through activities and experimentation.
- To produce post-graduate students with strong foundation to join research or to serve in industry.
- To create an atmosphere conducive to high class research and to produce researchers with clear thinking and determination who can, in future, become experts in relevant areas of mathematics.
- To inculcate in students the ability to apply mathematical and computational skills to model, formulate and solve real life applications.
- To make the students capable of discharging professional, social and economic responsibilities ethically.

M.Sc. (MATHEMATICS) 2 YEAR PROGRAMME
(SEMESTER SYSTEM)

Mathematics is the backbone of science and engineering. Its utility in the emerging areas of science, engineering and technology is increasing day by day. Considering its importance, the Department of Mathematics feels encouraged to propose the scheme and syllabi of M.Sc. (Mathematics). After thorough deliberations and discussions and keeping syllabi of Indian universities in mind, the proposed syllabi contain various topics on pure, applied and computational mathematics. The course would be beneficial to student community for their academic growth and employment.

NUMBER OF SEATS: 25

ELEGIBILITY: B.Sc. / B.A. with Mathematics as one of the subjects.

PROGRAMME EDUCATIONAL OBJECTIVES:

- To provide students with knowledge and insight in mathematics so that they are able to work as mathematical professionals.
- To prepare them to pursue higher studies and conduct research.
- To train students to deal with the problems faced by industry through knowledge of mathematics and scientific computational techniques.
- To provide students with knowledge and capability in formulation and analysis of mathematical models in real life applications.
- To introduce the fundamentals of mathematics to students and strengthen their logical and analytical ability.
- To provide a holistic approach in learning through well designed courses involving fundamental concepts and state-of-the-art techniques in the respective fields.

PROGRAMME OUTCOMES:

The successful completion of this program will enable the students to:

1. Apply knowledge of mathematics to solve complex problems.
2. Identify the problems and formulate mathematical models.
3. Design the solutions for real life problems.
4. Analyse and interpret data to provide valid inferences.
5. Apply modern techniques to obtain solutions of mathematical problems.
6. Take the responsibility for mathematics practice.
7. Demonstrate the mathematics knowledge for sustainable development.
8. Apply ethical principles and commit to professional ethics.
9. Function effectively as an individual and as a member/leader in multidisciplinary groups.
10. Communicate mathematics effectively and make effective presentations.
11. Handle projects in mathematics independently or in multidisciplinary environments.
12. Recognise the need for society and engage in lifelong preparedness for technological advancement of the nation.

The board of studies for Master of Science in Mathematics of Department of Mathematics included the following members:

Chairman

- Dr. J.R. Sharma, Professor & Head, Department of Mathematics, SLIET Longowal

External Members

- Dr. Vinay Kanwar, Professor, Department of Applied Sciences, UIET, Panjab University
- Dr. Mahesh Kumar Sharma, Professor, School of Mathematics, Thapar University, Patiala

Members

- Dr. S.S. Dhaliwal, Professor
- Dr. Mandeep Singh, Professor
- Dr. Vinod Mishra, Professor
- Dr Sushma Gupta, Professor
- Dr. V.K. Kukreja, Professor
- Dr. R.K. Mishra, Professor
- Dr. R.K. Guha, Professor
- Dr. Yogesh Kapil, Assistant Professor
- Dr. Sudhir Kumar, Assistant Professor

Alumni Member

- Dr. Chinu Singla, Guest Faculty, Department of Mathematics, SLIET, Longowal

Parent Member

- Shri Jaspal Singh F/O Ms. Jatinder Kaur (M.Sc. Reg. No. 2262015)

STUDY SCHEME

M.Sc. (MATHEMATICS) (2 YEARS; 4 SEMESTERS)

SEMESTER - I

SN	SUB CODE	SUBJECT TITLE	L	T	P	CREDITS
1	MA – 811	REAL ANALYSIS	4	1	0	5
2	MA – 812	ABSTRACT ALGEBRA	4	1	0	5
3	MA – 813	NUMBER THEORY & CRYPTOGRAPHY	4	1	0	5
4	MA – 814	CLASSICAL MECHANICS	4	1	0	5
5	MA – 815	DIFFERENTIAL EQUATIONS	4	1	0	5
		TOTAL				**25**

SEMESTER - II

SN	SUB CODE	SUBJECT TITLE	L	T	P	CREDITS
1	MA – 821	MEASURE THEORY	4	1	0	5
2	MA – 822	LINEAR ALGEBRA	4	1	0	5
3	MA – 823	OPERATIONS RESEARCH	4	1	0	5
4	MA – 824	COMPLEX ANALYSIS	4	1	0	5
5	MA – 825	MATHEMATICAL STATISTICS	4	1	0	5
6	MA – 826	INTRODUCTION TO PYTHON	-	-	4	2
		TOTAL				**27**

SEMESTER – III

SN	SUB CODE	SUBJECT TITLE	L	T	P	CREDITS
1	MA – 911	TOPOLOGY	4	1	0	5
2	MA – 912	MATHEMATICAL METHODS	4	1	0	5
3	MA – 913	NUMERICAL ANALYSIS	3	1	2	5
4	MA – 914	TENSORS AND DIFFERENTIAL GEOMETRY	4	1	0	5
5	MAE – 91*	ELECTIVE – I	4	1	0	5
		TOTAL				**25**

***ELECTIVE SUBJECTS FOR SEMESTER – III (SELECT ONE SUBJECT)**

SN	SUB CODE	SUBJECT TITLE	L	T	P	CREDITS
1	MAE – 911	NUMERICAL LINEAR ALGEBRA	3	1	2	5
2	MAE – 912	ADVANCED COMPLEX ANALYSIS	4	1	0	5
3	MAE – 913	COMPUTATIONAL ASTROPHYSICS	4	1	0	5
4	MAE – 914	DISCRETE MATHEMATICS	4	1	0	5
5	MAE – 915	FLUID DYNAMICS	4	1	0	5

SEMESTER – IV

SN	SUB CODE	SUBJECT TITLE	L	T	P	CREDITS
1	MA – 921	FUNCTIONAL ANALYSIS	4	1	0	5
2	MA – 922	DATA ANALYTICS	3	1	2	5
3	MA – 923	ALGEBRAIC CODING THEORY	4	1	0	5
4	MAP – 924	PROJECT	0	0	12	6
5	MAE – 92**	ELECTIVE – II	4	1	0	5
		TOTAL				**26**

****ELECTIVE SUBJECTS FOR SEMESTER - IV (SELECT ONE SUBJECTS)**

SN	SUB CODE	SUBJECT TITLE	L	T	P	CREDITS
1	MAE – 921	ADVANCED NUMERICAL ANALYSIS	4	1	0	5
2	MAE – 922	GRAPH THEORY	4	1	0	5
3	MAE – 923	MATHEMATICAL MODELLING	4	1	0	5
4	MAE – 924	THEORY OF LINEAR OPERATORS	4	1	0	5
5	MAE – 925	APPROXIMATION THEORY	4	1	0	5
6	MAE – 926	WAVELET ANALYSIS	4	1	0	5
7	MAE – 927	THEORY OF SEISMOLOGY	4	1	0	5

NOTE: *Elective courses shall be offered depending upon the availability of the faculty in the Department, as well as sufficient number of students in one course.*

SEMESTER- I

MA-811 REAL ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives: This course introduces to students the fundamentals of mathematical analysis, reading and writing mathematical proofs. The aim is to understand the axiomatic foundation of the real number system, in particular concepts of completeness, limits, continuity, differentiability and integrability. Students will attain a basic level of competency in developing their own mathematical arguments and communicate it to others in writing.

UNIT- I

Elementary set theory, finite, countable and uncountable sets. Metric spaces: definition and examples, open and closed sets, Compact sets, elementary properties of compact sets, compact subsets of Euclidean spaceR^k, Heine Borel theorem, Perfect sets, Cantor set, Separated sets, connected sets in a metric space, connected subsets of real line.

UNIT- II

Convergent sequences (in Metric spaces), Cauchy sequences, sub sequences, Complete metric space, Cantor's intersection theorem, category of a set and Baire's category theorem. Examples of complete metric space.

UNIT- III

Limits of functions (in Metric spaces), Continuous functions, continuity and compactness, Continuity and connectedness, Discontinuities, Monotonic functions, Uniform continuity.

UNIT- IV

Riemann Stieltje's Integral: Definition and existence of Riemann Stieltjes Integral, Properties of integral, integration and differentiation, Fundamental theorem of Calculus, 1st and 2nd mean value theorems for Riemann Stieltje's integral, Integration of vector valued functions, Rectifiable curves.

Course Outcomes (CO): Upon completion of this course, the student will
1) get equipped with basic properties of countable and uncountable set, metric spaces and various examples of standard metric spaces.
2) be able to classify open and closed sets, limit points, convergent and Cauchy convergent sequences,
3) get the skill to work in complete, compact and connected spaces.
4) be able to appreciate how completeness, continuity, and uniform continuity etc. are generalized from the real line to metric spaces.
5) determine the Riemann-Stieltjes integrability of a bonded function and prove theorems concerning integration.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. Walter Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill (2013).
2. H.L. Royden, P.M. Fitzpatrick, Real Analysis, 4rd edition, Prentice Hall of India2010.
3. Tom M. Apostol, Mathematical Analysis, Pearson (1974).
4. G.F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw-Hill (2008).

MA-812 ABSTRACT ALGEBRA

L	T	P	C
4	1	0	5

Course Objectives: Study of algebra is a tool for understanding algebraic manipulations rigorously. The objective of the course is to introduce basic structures of algebra like groups, rings and fields. The course gives the students, a good mathematical maturity and enables them to build mathematical thinking and skills. Hence, the main pillar to tackle real life problems.

UNIT - I

Review of basic concepts of groups with emphasis on exercises, order of group, subgroup, some counting principles, coset and Lagrange's theorem, cyclic groups, normal subgroups and quotient groups, homomorphisms, fundamental theorem of homomorphism and isomorphism. Group of automorphism.

UNIT - II

Review of permutation groups, alternating group and simplicity of A_n ($n \geq 5$), Structure theory of groups, Direct products, fundamental theorem of finitely generated abelian groups, invariants of finite abelian groups, Sylow's theorems, groups of order p^2, pq .

UNIT - III

Rings, rings of fractions (Integral domains and their fields of fractions), division rings. Factorization in Integral domain, Euclidean and principle ideal domains, ring homomorphism, Ideals, algebra of ideals, sum and direct sum of ideals, maximal and prime ideals, nilpotent and nil ideals.

UNIT - IV

Basics of Fields and their examples, characteristic of a field, some basic field extensions, algebraic and transcendental elements.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Explore the properties of groups, sub-groups, including symmetric groups, cyclic groups, normal sub-groups and quotient groups.
2) Apply class equation and Sylow's theorems to solve different problems.
3) Explore the properties of rings, sub-rings, ideals including integral domain, principle ideal domain, Euclidean ring and Euclidean domain.
4) Utilize the concepts of homomorphism and isomorphism between groups and rings.
5) Apply the concept of field and their properties.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. Surjeet Singh & Qazi Zameeruddin, Modern Algebra, Vikas Publishing House (2006).
2. I.N. Herstein, Topics in Algebra, Wiley Eastern (1975).
3. I.N. Herstein, Abstract Algebra, PHI (1995).
4. Vivek Sahai & Vikas Bist, Algebra, Narosa Publishing House (2018).
5. Joseph A. Gallian, Contemporary Abstract Algebra, CRC press (2020).
6. I.S. Luthar & I.B.S. Passi, Algebra Volume 1 & 2, Narosa Publishing House (2013).

MA-813 NUMBER THEORY & CRYPTOGRAPHY

L	T	P	C
4	1	0	5

Course Objectives: This course will introduce some of the fundamental theorems and results of number theory. Students will have a knowledge of congruences, arithmetic functions and cryptography.

UNIT - I

Divisibility, Euclidean algorithm, Diophantine equation ax + by=c, Primes, fundamental theorem of arithmetic, basic properties of congruences, residue classes, linear congruences, Chinese Remainder theorem, theorems of Euler, Fermat and Wilson.

UNIT - II

Arithmetical functions, sum and number of divisors, Moebius inversion formula, greatest integer function, Euler's phi function, Euler's theorem, Some properties of phi function, congruences of higher degree, congruences of prime power moduli and prime modulus, power residue.

UNIT - III

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, theory of indices, introduction to public key cryptography, The Knapsack cryptosystem, application of primitive roots to cryptography.

UNIT - IV

Quadratic residue, Euler's criterion, Legendre symbols, Gauss's lemma and reciprocity law. Jacobi symbol. Perfect numbers, Fermat numbers, Finite continued fractions, infinite simple continued fractions, periodic continued fractions, Farey fractions, rational approximation, Hurwitz theorem, irrational numbers.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Learn about linear congruences and Chinese Remainder Theorem to obtain simultaneous solution of finite number of congruences.
2) Learn the properties of arithmetic functions and also solve congruences of higher degree.
3) Have a knowledge of primitive roots for prime numbers.
4) Have a knowledge of cryptography and various methods of cryptography.
5) Determine the existence of solution of quadratic congruence by computation of Legendre symbol, understand the concept of continued fractions, Farey fractions.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. G.H. Hardy and E.M. Wright, Theory of Numbers, Oxford Science Publications (2003).
2. I. Niven and H.S. Zuckerman, Introduction to the Theory of Numbers, John Wiley &Sons (1960).
3. D.M. Burton, Elementary Number Theory, Tata McGraw-Hill (2006).
4. H. Davenport, Higher Arithmetic, Cambridge University Press (1999).
5. D. Redmond, Number Theory: An introduction, Marcel Dekker, Inc. (1996).

MA-814 CLASSICAL MECHANICS

L	T	P	C
4	1	0	5

Course Objectives: The aim of this course is to understand the principle of classical mechanics influenced by legends as Langrage, Hamilton, Kepler, Euler and Legendre and to enable students to formulate mathematical models leading to solutions in physical world.

UNIT - I

Motion under central force: Planetary motion under inverse square law. Satellite orbits. Laplace-Runge-Nenz vector. Principle of Variations: Functional, variation and extremal. Euler equation of motion. Applications to shortest distance problem, maximum surface of revolution and brachistochrone. Geodesics on sphere.

UNIT - II

Lagrangian mechanics: Generalized coordinates. Degree of freedom. Holonomic and nonholonomic systems. Scleronomic and rhenomic systems. Lagrangian, Lagrange equation of motion.
Lagrange mechanics on manifolds: Lagrange dynamical systems. Symmetry, invariance and Noether's theorem.

UNIT - III

Hamiltonian mechanics: Cyclic coordinates, Hamiltonian. Hamiltonian canonical equations of motion. Legendre transformation, geometrical interpretation and Hamiltonian equation from principle of stationary action.
Phase space structure: Phase space. Liouville theorem. Poincare recurrence theorem.

UNIT - IV

Canonical transformation: Hamiltonian canonical equation of motion. Hamilton-Jacobi equation. Jacobi's theorem. Condition for a transformation to be canonical.
Perturbation theory: Action-angle variables. Adiabatic invariants.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) To understand the basic importance of classical mechanics
2) To understand motion under central force.
3) To understand variational principles.
4) To understand Lanrangian and Hamiltonian mechanics.
5) Applications in mathematical and physical domain

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. J.R. Taylor, Classical Mechanics, University Science Books, 2005.
2. V.I. Arnold, Mathematical Methods of Classical Mechanics, Springer, 1989.
3. H. Goldstein, Charles Poole and John Safko, Classical Mechanics, Addision-Wisely, 2000.
4. V. Mishra, Theory of Transforms with Applications, Ane Books, 2017 (Chapter 8: Legendre Transform).

MA-815 DIFFERENTIAL EQUATIONS

L	T	P	C
4	1	0	5

Course Objectives: The main aim of this course is to understand various analytical methods to find exact solution of ordinary and partial differential equations and their implementation to solve real life problems.

UNIT - I

Initial value problem, Existence of solutions of ordinary differential equations of first order, Existence and Uniqueness theorem, Picard-Lindelof theorem, Peano's existence theorem, Existence of independent solutions, Wronskian. Boundary value problems for second order differential equations, Green's function and its applications.

UNIT - II

Eigen value problems, self adjoint form, Sturm-Liouville problem and its applications. Linear systems, Autonomous systems, Phase plane and its phenomena, Existence and uniqueness of solution (statement only), Critical points and their nature, Stability analysis for linear systems.

UNIT - III

Classification of First order PDE, Charpit's method, Monge's method, Well-posed and Ill-posed problems, Classification of second order PDE, Reduction to canonical form.

UNIT - IV

Solution of parabolic, hyperbolic and elliptic equations by various suitable methods.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Check the existence and uniqueness of the solution of initial value problems.
2) Solve ODEs by Peano's theorem, Wronskian method and Green's function.
3) Check stability analysis for linear system.
4) Classify first order PDEs and learn to solve such equations by various methods.
5) Classification of second order PDEs and solution of BVPs using different method.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. E.A. Coddington & N. Levinson, Theory of Differential Equations, McGraw-Hill (1955).
2. G.F. Simmons, Differential Equation with Applications and Historical Notes, Tata McGraw-Hill (2003).
3. S.G. Deo & V. Raghavendra, Ordinary Differential Equations and Stability Theory, Tata McGraw-Hill (1997).
4. I.N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill (1957).
5. S.L. Ross, Differential Equations, Wiley (2004).

SEMESTER – II

MA-821 MEASURE THEORY

L	T	P	C
4	1	0	5

Course Objectives: This course has numerous applications in different branches of mathematics, e.g., in the theory of differential equations, functional analysis, probability etc. The objective of this course is to give fundamental knowledge of various families of subsets of a nonempty set - algebra, sigma algebra, monotone classes, Borel sets etc. Another objective is to study Lebesgue integral of measurable functions defined on the real line for better understanding of the relations between differentiation and integration and study of L^p spaces.

UNIT - I

Preliminaries- Algebra and sigma algebra of subsets of a set, set function, measure defined on sigma algebras. Lebesgue outer measure. Lebesgue measurable sets, Borel sigma algebra and Lebesgue sigma algebra, Regularity, Lebesgue measure, Non-measurable sets.

UNIT - II

Measurable functions, its characterizations and properties like sum, product and composition , Sequential pointwise Limits and simple approximation of measurable functions Borel and Lebesgue measurability, Littlewoods three principles, Lebesgue Integral of bounded functions over a set of finite measure, Bounded convergence theorem, Integration of non-negative functions, Fatou's Lemma, Monotone Convergence Theorem, The general Lebesgue Integral, Lebesgue Dominant Convergence Theorem, Integration of series, Riemann and Lebesgue integrals.

UNIT - III

Vitali Covers, Differentiation of Monotone functions, The Four derivates, continuous non differentiable functions. Functions of bounded variation. Lebesgue Differentiation theorem. Differentiation of an integral. The Lebesgue points and Lebesgue set.

UNIT - IV

Convex functions, Jensen's inequality, The L^p-spaces, Holder and Minkowski inequalities. Completeness of L^p, Convergence in Measure. Almost uniform convergence.

Course Outcomes (CO): Upon completion of this course, the student will :
1) get equipped with knowledge of various classes of sets like algebra and sigma algebra and will be able to generate examples of such families of sets and will be able to classify measurable, non-measurable and Borel sets in R.
2) be able to explain Lebesgue measurability/ Borel measurability of real valued functions and to define Lebesgue integrals of such functions.
3) be able to apply various theorems connecting integrals of sequences of functions and that of their limit.
4) understand the relation between differentiation and Lebesgue integration.
5) Understand the concept of normed spaces/L^p-spaces and convergence in L^p-spaces.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. H.L. Royden, P.M. Fitzpatrick, Real Analysis, 4rd edition, Prentice Hall of India2010.
2. G.de Barra, Measure Theory and Integration, Wiley Eastern Ltd. (2012).
3. P.K. Jain and V. P. Gupta, Lebesgue Measure and Integration, Narosa Publishing House (2010).

MA-822 LINEAR ALGEBRA

L	T	P	C
4	1	0	5

Course Objectives: The main objective of this course is to understand multidimensional geometry. This encourages students to develop a working knowledge in Linear Algebra like linear transformations, eigenvalues, eigenvectors, canonical forms , Inner product spaces, Gram Schmidt orthogonalization process.

UNIT - I

Vector space of linear transformations, algebra of linear transformations, singular and non-singular transformations, Rank and Nullity theorem. Properties, representation of linear transformations as a matrix and change of basis formula. Dual spaces, dual basis, annihilator space of a subspace of a vector space.

UNIT - II

Eigenvalues and eigenvectors of a linear transformation, relation between characteristic roots of linear transformation and the roots of its minimal polynomial, Cayley Hamilton theorem.

UNIT - III

Canonical forms: similarities of linear transformation, diagonalization, Invariant Subspaces, Reduction to triangular forms, Nilpotent transformation, index of nilpotency, Invariants of a Nilpotent transformation, Jordan blocks and Jordan forms

UNIT - IV

Inner product spaces, properties, Cauchy Schwarz inequality, orthogonal vectors. Orthogonal complements, orthonormal sets and bases, Gram Schmidt orthogonalization process. Bilinear forms, symmetric and Hermitian forms, Quadratic forms and their classification.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Utilize the concepts of vector spaces, basis, dimension and linear transformations.
2) Find the matrices corresponding to linear transformation and their properties.
3) Use different canonical forms like triangular and Jordan canonical forms etc.
4) Find eigenvalues and eigenvectors of a linear transformation.
5) Use the concepts of Inner product spaces and their properties, Gram Schmidt orthogonalization process and measurement of the angle between two vectors along with their lengths.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. K. Hoffmann & R. Kunze, Linear algebra, Pearson (2015).
2. I.N Herstein, Topics in Abstract Algebra, Wiley Eastern Ltd (1995).
3. J. Gilbert and L. Gilbert, Linear Algebra and Matrix Theory, Academic Press (1995).
   Vivek Sahai and Vikas Bist, Linear Algebra, Narosa Publishing House (2019).

MA-823 OPERATIONS RESEARCH

L	T	P	C
4	1	0	5

Course Objectives: Operations research helps in solving real life problems in different environments that need decisions. This module aims to introduce students to use quantitative methods and techniques for effective model formulation, like LPP, TP, AP Network Problem and their applications.

UNIT-I

Basic concepts and notations of LPP. Mathematical formulation of LPP, Graphical solution. Spanning set, basis, replacing a vector in a basis, Basic solution and Basic Feasible Solutions (BFS) of system of linear equations, BFS by using Gauss-Jordan elimination process and using rank method. Hyperplane, hypersurfaces, convex set and their properties. Extreme points, adjacent point of a convex set. Standard form of an LPP.

UNIT - II

Simplex method, two phase method. Big M method. Degeneracy. Primal and Dual problem. Complimentary Slackness Conditions (CSC), Solution of primal and Dual and vice versa. Dual Simplex method. Post Optimality analysis (Changes in cost vector and right-hand side vector) Goal Programming.

UNIT - III

Basic concepts and notations of transportation problem, Balanced and unbalanced transportation problems. Initial BFS of TP using north-west corner rule, Matrix Minima method and Vogel's approximation method. Optimal solutions. Special type of transportation problems. Assignment problem. Hungarian method to solve assignment problem.

UNIT - IV

Basic network for CPM and PERT, Time estimates, PERT, PERT calculations, Critical Path Method (CPM), Calculations for Slack, various float, Project Cost Analysis, Crashing. [10 hours]
Introduction to game theory. The maximin & Minimax Criterion. Existence of saddle point. Game without saddle point. Mixed strategy. Solution of 2X2 game. Dominance & its use to solve 2X2 game. 2XN & NX2 game. Graphical method, Solution of Game by LPP method and iterative method.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Formulate some real-life problems into LPP and obtain their solution by Simplex, Big M and two-phase methods.
2) Construction and solution of Dual Problem and using Duality theory can check the optimality of primal and Dual pair. Learn, how to tackle a changed problem by post optimality analysis. Apply Goal programming to find the optimum solution to a single or multi-dimensional linear objective function.
3) Formulate and find the optimal solution of transportation and assignment problem.
4) Learn applications of game theory in real life problem and their solution by various methods.
5) Use CPM and PERT to learn how to manage and complete a project within stipulated time and money.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. J.G. Chakravorty & P.R. Ghosh, Linear Programming and game Theory, Moulik Library (2009).
2. S.K. Gupta, Linear Programming & Network Models, Affiliated East-West Private Ltd. (1985).
3. Kanti Swarup, P.K. Gupta & Man Mohan, Operations Research, S. Chand & Sons (1994).
4. H.A. Taha, Operations Research, PHI (2007).

MA-824 COMPLEX ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives: This course will introduce some of the fundamental theorems and results of number theory. Students will have a knowledge of congruences, arithmetic functions and cryptography.

UNIT - I

Divisibility, Euclidean algorithm, Diophantine equation ax + by=c, Primes, fundamental theorem of arithmetic, basic properties of congruences, residue classes, linear congruences, Chinese Remainder theorem, theorems of Euler, Fermat and Wilson.

UNIT - II

Arithmetical functions, sum and number of divisors, Moebius inversion formula, greatest integer function, Euler's phi function, Euler's theorem, Some properties of phi function, congruences of higher degree, congruences of prime power moduli and prime modulus, power residue.

UNIT - III

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, theory of indices, introduction to public key cryptography, The Knapsack cryptosystem, application of primitive roots to cryptography.

UNIT - IV

Quadratic residue, Euler's criterion, Legendre symbols, Gauss's lemma and reciprocity law. Jacobi symbol. Perfect numbers, Fermat numbers, Finite continued fractions, infinite simple continued fractions, periodic continued fractions, Farey fractions, rational approximation, Hurwitz theorem, irrational numbers.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Learn about linear congruences and Chinese Remainder Theorem to obtain simultaneous solution of finite number of congruences.
2) Learn the properties of arithmetic functions and also solve congruences of higher degree.
3) Have a knowledge of primitive roots for prime numbers.
4) Have a knowledge of cryptography and various methods of cryptography.
5) Determine the existence of solution of quadratic congruence by computation of Legendre symbol, understand the concept of continued fractions, Farey fractions.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. G.H. Hardy and E.M. Wright, Theory of Numbers, Oxford Science Publications (2003).
2. I. Niven and H.S. Zuckerman, Introduction to the Theory of Numbers, John Wiley &Sons (1960).
3. D.M. Burton, Elementary Number Theory, Tata McGraw-Hill (2006).
4. H. Davenport, Higher Arithmetic, Cambridge University Press (1999).
5. D. Redmond, Number Theory: An introduction, Marcel Dekker, Inc. (1996).

MA-825 MATHEMATICAL STATISTICS

L	T	P	C
4	1	0	5

Course Objectives: The course aims to shape the attitudes of learners regarding the field of statistics. Specifically, the course aims to motivate in students an intrinsic interest in statistical thinking and instil the belief that statistics is important for scientific research.

UNIT – I

Review of probability, Moments, Skewness and Kurtosis. Discrete and continuous random variables. Distribution function. Joint and marginal distribution function. Mathematical expectations of a random variable. Variance and Covariance. Moment generating functions. Characteristic function.

UNIT – II

Discrete and continuous univariate distributions - Binomial, Poisson, Normal, Exponential, Gamma distributions. Their properties and fitting of distributions.

UNIT – III

Review of correlation. Partial and multiple correlation upto three variables. Regression analysis upto three variables. Types of sampling. Standard error. Hypothesis. Critical values. Tests of significance for large samples. Sampling of attributes and variables.

UNIT – IV

Exact sampling distributions: Chi-square, Student's '*t*' and F distributions. Properties and applications.
Analysis of variance: One-way and two-way classification.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Compute the probability, skewness, kurtosis, expectation, moments, distribution function of random variables.
2) Fit the discrete and continuous univariate distributions of the random variables.
3) Carryout the correlation and regression analysis upto three variables.
4) Perform significance tests of large samples characterized based on attributes and variables.
5) Perform significance tests of exact sampling distributions and carryout ANOVA.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. P.L. Meyer, Introduction to Probability and Statistical Applications, Oxford & IBH (2007).
2. R.V. Hogg, J.W. Mckean & A.T. Craig, Introduction of Mathematical Statistics, PHI (2004)
3. T.W. Anderson, An Introduction to Multivariate Statistical Analysis, John Wiley (2003).
4. S.P. Gupta, Statistical Methods, Sultan Chand & Sons (2017).
5. S.C. Gupta & V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons (2014).

MA-826 **INTRODUCTION TO PYTHON**

L	T	P	C
0	0	4	2

Course Objectives: The course is designed to introduce the Python programming language. The focus of the course is to provide students with an introduction to programming, I/O, and visualization using the Python programming language.

UNIT - I

Basics: comments, character set, tokens, core data types, inbuilt functions.
Operators: Arithmetic operators and their properties, Bitwise operators, compound assignment operator.
Decision statements: Boolean operators and their uses, if, if-else, nested if statements, conditional expressions.

UNIT - II

Loop control statements: The while, for and nested loops, break and continue statement.
Functions: Syntax and basics, parameters and arguments, The local and global scope of a variable.
Strings: The str class, inbuilt string functions, the string operators.

UNIT - III

Lists and List processing: Creating lists and accessing them, slicing, inbuilt list functions, comprehensions, searching techniques, sorting.
Object-Oriented Programming: Defining class, the self-parameter and adding methods, class attributes, overloading, inheritance, overriding.

UNIT - IV

Tuples, sets and dictionaries.
Graphic programming: Turtle module and uses, drawing with colors and iterations, Bar charts.
File handling: Need of file handling, text input and output, the seek () function and Binary files.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Explain basic principles of Python programming language.
2) Implement object-oriented concepts.
3) Design and implement a program to solve a real-world problem.
4) Implement conditions and loops for Python programs.
5) Use functions and represent compound data using Lists, tuples and dictionaries.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. A.N. Kamthane & A.A. Kamthane, Programming and Problem Solving with Python, McGraw Hill (2020).
2. M. Lutz, Programming Python, O`Reilly Media (2013).
3. M. Lutz, Learning Python - Powerful Object Oriented Programming, O'Reilly Media (2013).
4. M. Urban & J. Murach, Python Programming - Beginner to Pro, Murach & Associates (2016).
5. R. Gupta, Making Use of Python, Wiley Publishing House (2002).
6. Jaan Kiusalaas, Numerical Methods in Engineering with Python, Cambridge University Press (2013).

SEMESTER – III

MA-911 TOPOLOGY

L	T	P	C
4	1	0	5

Course Objectives: This course aims to teach the fundamentals of point set topology and constitute an awareness of need for the topology in Mathematics.

UNIT - I

Definition and examples of topological spaces, Bases and sub bases, Order topology, Product topology, Subspaces and relative topology closed sets, Closure, Dense subsets, Neighbourhoods, Interior, exterior and boundary. Accumulation points and derived sets. Alternative methods of defining a topology in terms of Kuratowski closure operator and neighbourhood systems.

UNIT - II

Continuous functions and homomorphism, Open Mappings, Closed Mappings, Compactness and local compactness. One –point compactification. Connected and arc wise connected spaces. Components. Locally connected spaces.

UNIT - III

T_0 , T_1 , T_2 spaces and sequences. Hausdorffness of one-point compactification. Axioms of Countability and Separability. Equivalence of separable, second countable and Lindelof spaces in metric spaces. Equivalence of Compact and countably compact sets in metric spaces.

UNIT - IV

Regular, completely regular, normal and completely normal spaces. Metric spaces as T_2, completely normal and first axiom spaces. Urysohn Lemma, Tietze Extension Theorem, Urysohan Metrization Theorem.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Construct topological spaces from metric spaces and using general properties of neighbourhoods, open sets, close sets, basis and sub-basis.
2) Apply the concepts of compact spaces, connected spaces and continuous functions on topological spaces.
3) Use the concepts of separation axioms, axioms of countability, separable, countable compact spaces etc.
4) Apply the concepts and properties of regular, completely regular, normal, completely normal spaces etc.
5) Use the concept of extension of continuous mappings, metrization and compactification of topological spaces.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. K.D. Joshi, Introduction to General Topology, New Age International Publishers (2006).
2. J.R. Munkres, Topology: a first course, PHI (2007).
3. G.F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw-Hill (1963).
4. W.J. Pervin, Foundation of General Topology, Academic Press (1964).
5. J.L. Kelley, General Topology, Springer- Verlag, New York.

MA-912 MATHEMATICAL METHODS

L	T	P	C
4	1	0	5

Course Objectives: This course is intended to prepare the students with mathematical tools and techniques that are required in advanced applied mathematics. The objective of this course is to enable the students to apply mathematical methods for solving integral equations, differential equations, initial and boundary value problems.

UNIT - I

Fredholm integral equations of the first and second kind, Resolvent kernel, Eigenvalues, Eigen functions, conversion of a boundary value problem into Fredholm integral equation, Fredholm alternative, Fredholm theorem, Solution by methods of successive substitutions and successive approximations.

UNIT - II

Volterra integral equations of the first and second kind, conversion of an initial value problem into Volterra integral equation, Solution by methods of successive substitutions and successive approximations.

UNIT – III

Introduction to Fourier transform and its properties, Fourier sine and cosine transforms and theorems, convolution theorem, finite Fourier transform, applications of Fourier transforms in solving boundary value problems like heat equation and wave equation.

UNIT - IV

Rayleigh-Ritz, Collocation and Galerkin methods for solution of initial and boundary value problems.

Course Outcomes (CO): Upon completion of this course, the student will
1) learn comprehensively about the theory of Fredholm linear integral equations of first and second type.
2) learn comprehensively about the theory of Volterra linear integral equations of first and second type.
3) be able to know about various Fourier transformations and their properties.
4) be able to apply the Fourier transforms to solve initial and boundary value problems.
5) have the ability to solve initial and boundary value problems using weighted residual methods.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. J.W. Brown & R. Churchill, Fourier Series and Boundary Value Problems, McGraw-Hill (2011).
2. P.V. O'Neil, Advanced Engineering Mathematics, CENGAGE Learning (2011).
3. I.N. Sneddon, The Use of Integral Transforms, Tata McGraw-Hill (1985).
4. R.S. Gupta, Elements of Numerical Analysis, Macmillan India Ltd. (2008).
5. M.D. Raisinghania, Integral Equations and Boundary Value Problems, S. Chand (2012).

MA-913 NUMERICAL ANALYSIS

L	T	P	C
3	1	2	5

Course Objectives: The aim of this course is to familiarize the students about numerical techniques required for solving algebraic, transcendental equations, linear system of equations, differential equations etc. This course provides adequate knowledge of writing modular and efficient programs of fundamental problems using C.

UNIT - I

Types of errors, General error formula, Error in series approximation, Iterative methods for solving transcendental equations viz. Bisection method, Regula-falsi method, Secant method, Successive approximation method, Aitken's Δ^2 -method and Newton-Raphson method, Convergence analysis, convergence order, computational efficiency.

UNIT - II

Systems of linear equations, Gauss elimination method, Gauss-Jordan method, Factorization method, Jacobi's method, Gauss-Seidal method, Conditions of convergence, Ill-conditioned linear systems, Eigen value problem, Rayleigh's power method for finding largest and smallest eigen values and eigen vectors.

UNIT - III

Finite differences, Difference operators and their relations, Fundamental theorem of finite difference calculus, Interpolation with equal intervals: Newton's forward, Newton's backward, Stirling's and Bessel's interpolation formulae, Error in interpolation. Interpolation with unequal intervals: Lagrange's and Newton's divided difference formulae. Numerical differentiation by Newton's forward and backward formulae, Error analysis.

UNIT - IV

Numerical integration by Trapezoidal, Simpson's one-third and Simpson's three-eighth rules, Error in numerical integration, Solution of Initial value problem: Taylor's series method, Picard's method, Euler's and modified Euler's methods, Runge-Kutta methods up to fourth order, Solution of simultaneous I^{st} order ODE by Runge-Kutta method, Stability and convergence analysis of the methods.

Course Outcomes (CO): Upon successful completion of this course, students will be able to:

1) Identify and apply various numerical methods to solve problems involving error analysis, and master the use of numerical techniques to find roots of equations.
2) Apply finite difference methods for numerical differentiation and interpolation, and utilize Newton's divided difference and Lagrange's formulas effectively.
3) Execute numerical integration techniques and perform numerical differentiation, and solve ODEs using initial and boundary value techniques.
4) Implement least squares regression for fitting linear and polynomial equations to data sets and compute correlation coefficients to analyse.
5) Develop a deep understanding of probability laws, random variables, and their distributions, and apply these concepts to real-world data analysis and decision-making scenarios.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. C. F. Gerald & P. O. Wheatley, Applied Numerical Analysis, Addison-Wesley (2004)
2. M.K. Jain, S.R.K. Iyengar & R.K. Jain, Numerical Methods for Scientific & Engg. Computation, New Age International (2007).
3. S.D. Conte & De Boor, Numerical Analysis - An Algorithmic Approach, Tata McGraw- Hill (1972).
4. R.S. Gupta, Elements of Numerical Analysis, Macmillan India Ltd. (2008).
5. K.E. Atkinson, An introduction to Numerical Analysis, John Wiley & Sons (1988).

NUMERICAL ANALYSIS LAB

Programming in PYTHON based on the following problems:

1. Finding roots of the equation $f(x) = 0$ using
   i) Bisection Method ii) Secant Method iii) Method of false position

2. Finding roots of the equation $f(x) = 0$ using
   i) Iterative Method ii) Newton - Raphson's Method

3. To check consistency and finding Solution of a system of linear algebraic equations using
   i) Gauss elimination Method ii) Gauss - Seidal Method iii) Jacobi Method

4. Solution of a system of linear equations by triangularization method.

5. Finding dominating Eigen value and Eigen vector using Rayleigh's power Method.

6. Interpolation using
   i) Newton's forward difference formula ii) Newton's backward difference formula

7. Interpolation using
   i) Newton's divided difference formula ii) Lagrange's interpolation formula

8. Interpolation using
   i) Gauss's forward formula ii) Gauss's backward difference formula

9. Interpolation using Splines
   i) Linear ii) Quadratic iii) Cubic

10. Numerical differentiation using
    i) Newton's forward interpolation formula ii) Newton's backward interpolation formula

11. Numerical Integration using
    i) Trapezoidal rule ii) Simpson's $1/3^{rd}$ rule
    iii) Simpson's $3/8^{th}$ rule iv) Romberg's rule

12. Solution of I^{st} order ordinary differential equations using
    i) Taylor's series method ii) Picard's method
    iii) Euler's method iv) Euler's modified method

13. Solution of I^{st} order ordinary differential equations using
    i) Runge-Kutta method of III^{rd} order ii) Runge-Kutta method of IV^{th} order

MA-914 TENSORS AND DIFFERENTIAL GEOMETRY

L	T	P	C
4	1	0	5

Course Objectives: The aim of the course is to introduce the fundamental concepts and techniques of differential geometry, with a strong emphasis on tensors and their applications. The course is designed to equip students with the necessary skills to solve problems in diverse fields such as physics, engineering, and advanced mathematics.

UNIT-I

Introduction and Basics : Scalars, Vectors, and Tensors, Coordinate Systems and Transformations, Contravariant and Covariant Tensors, Mixed Tensors, Tensor Addition, Scalar Multiplication, and Inner Product. Tensor Algebra, Tensor Product, Symmetric and Skew-Symmetric Tensors, Tensor Contraction and Quotient Law. Applications of Contraction in Physics and Engineering. Transformations and Reciprocal Tensors: Examples, Reciprocal Tensors and Kronecker Delta. Metric Tensor and Riemannian Space. Applications in Differential Geometry and Relativity. Riemannian Space. Christoffel Symbols and Covariant Differentiation: Christoffel Symbols, Transformation Laws for Christoffel Symbols, Covariant Derivative of Tensors. Riemannian Curvature Tensor. Bianchi Identities, Ricci Tensor and Scalar Curvature. General Relativity: Einstein Field Equations

UNIT-II

Theory of space curves introduction, Representation of space curves, Arc length, Tangent, Curvature and Torsion, Contact between curves and surfaces, Betrand curves, Spherical indicatrix, Fundamental existence theorem for space curves.

UNIT-III

The first fundamental form and local intrinsic properties of surfaces, Definitions, Nature and representation of surface, Curves on a surface, Tangent plane and Surface normal. The general surface of revolution, Helicoids, Metric on a surface, Direction coefficients on a surface.

UNIT-IV

First fundamental form. Families of curves, Orthogonal trajectories, Intrinsic properties, Double family of curves. Differential equation of geodesics, Nature of Geodesics, Canonical geodesics equations. Fundamental of cosmology and Cosmological models.

Course Outcomes (CO): Upon successful completion of this course, students will be able to:

1) Apply tensor analysis to solve problems in elasticity, stresses, and tensions within deformed bodies.
2) Explain and use the concepts and language of differential geometry. Problem associated with space curve.
3) Employ differential geometry techniques to address problems associated with surface.
4) Solve complex problems associated with family of curves and Geodesics.
5) Process and analyze the fundamental of cosmology and cosmological models.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. I.S. Sokolnikoff, Tensor Analysis: Theory and Application to Geometry and Mechanics of continua, Wiley Publication (1964).
2. T.J. Willmore, An Introduction to Differential Geometry, Dover Publications (2012).
3. D. Somasundaram, Differential Geometry: A first course, Alpha Science International (2004).
4. R.B. Mishra, Tensors, Hardwari Publications (2002).
5. C.E.Weatherburn, An Introduction to Riemannian Geometry and Tensor Calculus, Radha Publication House Calcutta (2010).

ELECTIVE PAPERS FOR SEMESTER – III (Select any one subject)

MAE-911 NUMERICAL LINEAR ALGEBRA

L	T	P	C
3	1	2	5

Course Objectives: The student will learn the concepts of conditioning and stability of a numerical method. He will also learn various matrix factorizations used for different purposes and numerical methods of eigenvalues.

UNIT - I

Floating point computations and laws of floating point arithmetic, vector norms, 2- norm and its properties, matrix norms, sub-multiplicative norms convergent matrices, concept of stability, conditioning of the problem and ill-conditioning, condition number of a matrix and its properties.

UNIT - II

Gaussian elimination (with and without partial/complete pivoting) and LU factorization, numerical solution of linear systems, scaling, effect of conditioning number.
Special systems: Banded systems, positive definite systems, Cholesky decomposition.
Iterative methods for linear systems: Jacobi's, Gauss-Seidel, Successive over-relaxation and Conjugate gradient method.

UNIT - III

Gram-Schmidt orthonormal process, Householder matrices and their applications, QR factorization, stability of QR factorization, Given's matrices and QR factorization.
Singular value decomposition (SVD), geometric interpretation, properties of SVD, practical applications.

UNIT - IV

Least square solutions to linear systems, properties and applications, pseudoinverse and least square problem. Numerical matrix eigenvalue problem: cases of practical applications, localization of eigenvalues, computing selected eigenvalues and eigenvectors.

Software Support: MATLAB/PYTHON.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Use floating point arithmetic and conditioning of a problem and stability analysis.
2) Utilize concepts such as vector and matrix norms, eigen and singular values.
3) Estimate stability of the solutions to linear algebraic equations and eigenvalue problems.
4) Utilize various factorizations and canonical forms of matrices for different purposes.
5) Use the underlying principles of iterative algorithms.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. B.N. Datta, Numerical Linear Algebra and Applications, 2nd Edn., SIAM (2010).
2. F. Bornemann, Numerical Linear Algebra, A Concise Introduction with MATLAB and Julia, Springer (2018).
3. W. Ford, Numerical Linear Algebra with Applications Using MATLAB, Elsevier, Academic Press (2014).
4. L.N. Trefethen & D. Bau III, Numerical Linear Algebra, SIAM (1997).
5. R. Butt, An introduction to Applied Numerical Linear Algebra using MATLAB, Narosa (2015).

MAE-912 ADVANCED COMPLEX ANALYSIS

L	T	P	C
4	1	0	5

Course Objective: This course will provide a strong foundation of complex analysis and its techniques. Moreover, it will motivate students to pursue Complex analysis at advanced level, too.

UNIT - I

Normal and compact families of analytic functions, Montel's theorem, Hurwitz's theorem, Schwarz's Lemma. Analytic continuation, Analytic continuation by power series method, Natural boundary, Schwarz reflection principle, Monodromy theorem.

UNIT - II

Harmonic functions, Basic properties, mean value theorem, maximum and minimum modulus principles, Poisson integral formula, Harmonic functions on a disc, Harnack's inequality and theorem, Green's function.

UNIT - III

Univalent function, the area theorem, Bieberbach theorem, Koebe ¼ theorem, Distortion and Growth theorem for the class S of normalized univalent functions, Coefficient estimates for members of class S, Littlewood's inequality for the class S.

UNIT - IV

Convex and starlike functions, necessary and sufficient condition for starlike and convex functions, Alexander's theorem, growth and distortion theorems for the classes of normalized convex and starlike functions, close-to-convex functions, Noshiro-Warchawski theorem, Riemann mapping theorem, Convolution by convex functions.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Study normal families and their properties. Understand the concept of analytic continuation and its applications.
2) Have a thorough knowledge of harmonic functions, Harnack's inequality and Green's function.
3) Have a knowledge of univalent functions and coefficient estimates of various classes.
4) Study subclasses of the class of univalent functions, their growth and distortion theorems, geometric properties.
5) Have a knowledge of Riemann mapping theorem.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. Z. Nihari, Conformal Mapping, Dover Publications (1975).
2. J.B. Conway, Functions of One Complex Variable, Springer (1978).
3. A.W. Goodman, Univalent functions, Vol. I, Mariner Tampa (1983).
4. P.L. Duren, Univalent Functions, Springer-Verlag (1983).
5. D.K. Thomas, N. Tuneski & A. Vasudevarao, Univalent functions- A Primer, De Gruyter, Berlin (2018).

MAE-913 COMPUTATIONAL ASTROPHYSICS

L	T	P	C
4	1	0	5

Course Objectives: This course is intended to provide the background needed to read the current research literature in computational astrophysics, and to get the essential knowledge of the subject. This may help the students to intend their research interest in the area of astrophysics and space science.

UNIT - I

Space, time and gravitation, Vector and tensors, Laws of tensors. Sky coordinates and motion, seasons, phases of the Moon, the Moon's orbit, and eclipses. Planetary motions: Kepler's law, Gravity, Light & Energy. Galaxies: our Milky Way, Galaxy types & formation.

UNIT - II

Relativity to cosmology: Historical background, Einstein universe, Expanding universe, Redshift, Supernovae, The Big Bang, History of Universe. Apparent magnitude, Hubble's law, The Schwarzschild solution.

UNIT - III

Einstein field equations in cosmology, Energy tensors of the universe, Solution of the Friedmann's equations, Einstein-de Sitter model, Angular size, Radiation backgrounds.

UNIT - IV

Cosmological models, Cosmological model with cosmological constant, Universe at the large scales, Homogeneity and isotropy of the universe, Cosmological principle, Cosmological metrics and dynamic nature of the universe.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Apply their knowledge to describe various aspects of computational astrophysics.
2) Understand the physical concepts associated with universe.
3) Understand the physical concepts associated with galaxies.
4) Understand laws of cosmology like big bang, Hubble's law, Einstein field equations etc.
5) Apply the knowledge to construct the suitable cosmological models of the universe.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. J.V. Narlikar, Introduction to Cosmology, Cambridge University Press.
2. F. Hoyle, G. Burbidge & J.V. Narlikar, A Different Approach to Cosmology, Cambridge University Press (2005).
3. J.N. Islam, An Introduction to Mathematical Cosmology, Cambridge University Press.

MAE-914 DISCRETE MATHEMATICS

L	T	P	C
4	1	0	5

Course Objectives: Prepare students to develop mathematical logic and mathematical arguments which are required in many courses involving mathematics & computer sciences and to solve such problems using discrete mathematics.

UNIT - I

Mathematical Logic: Statement, notations, proposition, logic operations, connectives (conjunction, disjunction, negation), Statement formulas and truth tables, propositions generated by set, Equivalence of formulas, Tautological implications law of logic, validity using truth table, Rules of inference, consistency of premises and Direct and indirect method of proof. Predicates, Statement function, Variables, Quantifiers, Universe of discourse, Inference of the predicate calculus.

UNIT - II

Relation and Function: Binary relations, functions, equivalence relations, Composition of binary relations, Partial order relation and Partial Order set, Representation of relation: Matrix, Di-graph, Hasse diagram. Pigeonhole Principle. Principle of mathematical induction, Numeric and generating function. Recursive relation: definition, Introduction to primitive function. Polynomials and their recursion, iteration, degree and order of recurrence relations and their solutions.

UNIT - III

Lattice Theory: Lattice and Algebraic systems, Principle of duality, Basic properties of Algebraic systems, Distributive, Complemented and bounded Lattices and their properties.

Boolean Lattices and Boolean Algebra, Uniqueness of finite Boolean Algebra, Boolean functions and Boolean expressions, Normal forms of Boolean expression and simplifications of Boolean expressions, Method to find Truth table of a Boolean function. Logical gates and circuits relations of Boolean function.

UNIT - IV

Basic terminology of graph theory, paths, circuits, degree, adjacency and their properties. Trees, Spanning trees, Properties of tree, binary trees, rooted trees, planer graphs, Euler's theorem for planer graph. Eulerian graphs, Hamiltonian graphs and their properties, Kruskal's and Prim's algorithm for finding minimum spanning tree, Dijkstra's algorithm for shortest path problem..

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Construct mathematical arguments using logical connectives and quantifiers.
2) Validate the correctness of an argument using statement and predicate calculus.
3) Work with some of the discrete structures which include sets, relations, functions and recurrence relations.
4) Understand how lattices and Boolean algebra can be used as tools in the study of computer networks.
5) Understand various fundamental concepts of graph theory, its properties and applications in real life problems.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. J.P. Trembley & R. Manohar, A First Course in Discrete Structure with applications to Computer Science, Tata McGraw-Hill (1999).
2. M.K. Das, Discrete Mathematical Structures, Narosa Publishing House (2007).
3. Babu Ram, Discrete Mathematics, Vinayak Publications (2004).
4. C.L. Liu, Elements of Discrete Mathematics, Tata McGraw-Hill (1978).
5. K.H. Rosen, Discrete Mathematics and Its Applications, Tata Mc-Graw Hill (2017).

MAE-915 FLUID DYNAMICS

L	T	P	C
4	1	0	5

Course Objectives: To introduce basic characteristics of fluid, fluid kinematics, conservative principles, equation of motion, fluid flow through various systems and water wave propagation.

UNIT - I

Fundamental of Fluid Dynamics: Fluid properties. Dimensions and units. Stream lines and path lines. Compressible and incompressible flow. Dimensionless numbers. Conservation of mass. Energy equation. Linear momentum equation. Continuity equation. Navier-Stokes equation. Bernoulli's equation.

UNIT - II

Laminar Flow: Steady flow between parallel plates. Flow through circular tubes and circular annuli. Flow through simple pipes. Flow losses in conduits. Euler's equation of motion. Integration of Euler's equation, Kelvin circulation theorem. Irrotational flow. Stream functions and boundary conditions.

UNIT - III

Water Waves: Introduction. Travelling and standing waves. Gravity waves. Gravity waves in deep and shallow water. Energy of gravity waves. Wave drag on ships. Ship wakes. Gravity waves in flowing fluid and at interface. Steady flow over a corrugated bottom. Wind driven waves in deep water.

UNIT - IV

Incompressible Aerodynamics: Introduction. Theorem of Kutta and Zhukovskii. Cylindrical airfoils. Zhukoviskii's hypothesis. Vortex sheets. Induced flow. Three dimensional airfoils. Aerodynamic forces. Ellipsoidal airfoils.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) To understand the important Fluid dynamics.
2) To introduce the basic aspects of fluid flow**.**
3) To understand laminar flow**.**
4) To understand water wave propagation.
5) Applications in mathematical and physical domain.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. R. Fitzpatrick, Theoretical Fluid Mechanics, IOP Publishing (2017).
2. B.R. Munson, D.F. Young & T.H. Okiishi, Fundamental of Fluid Mechanics, John Wiley and Sons (2002).
3. D.E. Rutherford, Fluid Dynamics, Oliver and Boyd (1959).
4. M.E. O'Neil & F. Charlton, Ideal and Incompressible Fluid Dynamics, John Wiley &Sons (1986).

SEMESTER – IV

MA-921 FUNCTIONAL ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives: The main aim of this course is to provide the students basic concepts of functional analysis, to facilitate the study of advanced mathematical structures arising in the natural sciences and the engineering sciences and to make them grasp the newest technical and mathematical techniques/literature.

UNIT-I

Normed linear spaces, Banach spaces. Examples of Banach spaces and subspaces, Finite dimensional normed spaces, Equivalent norms, Bounded and Continuous linear maps. Normed spaces of bounded linear maps and Bounded linear functionals, Dual spaces, Dual spaces of l^p and C [a, b], Reflexivity.

UNIT-II

Hahn-Banach theorem and its applications, Uniform boundedness principle, Open mapping theorem Closed graph theorem, Projections on Banach spaces.

UNIT-III

Hilbert spaces, examples, Orthogonality, Orthonormal sets and sequences, Bessel's inequality, Parseval's theorem. The conjugate space of a Hilbert space.

UNIT-IV

Hilbert-adjoint operators, Self-adjoint operators, Normal and Unitary operators. Projection operators. Weak convergence. Completely continuous or compact operators, properties of compact operators.

Course Outcomes (CO): Upon completion of this course, the student will :

1) get equipped with understanding of normed linear spaces, Banach space and Dual spaces.
2) Be able to prove and apply various properties of operators and functionals on normed and Banach spaces.
3) Get the knowledge of fundamental theorems like Hahn Banach theorem, open mapping theorem, closed graph theorem and principle of uniform boundedness.
4) get the skill to work in inner product spaces, Hilbert spaces and orthogonal spaces.
5) Get the skill to prove and apply various properties operators on Hilbert spaces.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. E. Kreyszig, Introductory Functional Analysis with Applications, Wiley (1978).
2. Balmohan V Limaye, Functional Analysis, New Age International Publishers(2014).
3. G.F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw-Hill (1963).
4. C. Goffman & G. Pedrick, First Course in Functional Analysis, PHI, New Delhi (1987).
5. S. Ponnusamy, Foundation of Functional Analysis, Alpha Science International (2002).
6. G. Bachman & L. Narici, Functional Analysis, Courier Corporation (1966).

MA-922 DATA ANALYTICS

L	T	P	C
3	1	2	5

Course Objectives: The main aim of this course is to introduce the students different statistical concepts of data handling and the latest computational software. The students will learn about estimation, process control techniques, parametric / non-parametric sampling distributions and design of experiment.

UNIT – I

Python fundamentals: Introduction, syntax, variables type, data types, data types conversion, operators, decision making statements, loops, break and continue statements.

UNIT – II

Estimation: Parametric space, sample space, point and interval estimation. Requirements of good estimator: consistency, unbiasedness, efficiency, sufficiency, and completeness. Maximum likelihood Estimator.
Process control: Concept, its applications and importance. Causes of variations in quality. Control limits: natural tolerance, specification and modified. Control charts for variables and attributes: $\bar{x}$, R, p and C.

UNIT – III

Sampling distribution: critical and acceptance regions, level of significance, critical and p-values.
Nonparametric tests: Sign test, Wilcoxon signed rank test, Mann-Whitney test, Kolmogorov-Smirnov test, Kruskal Wallis test, Friedman test.

UNIT – IV

Experimental designs: Completely randomized design, randomized block design, Factorial design.
Multivariate techniques: Discriminant analysis, Factor analysis, Principal component analysis, Cluster analysis.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Perform all the statistical calculation using Python software.
2) Select a good estimator and control the quality of a product using control charts.
3) Test the validity of a hypothesis using non-parametric tests.
4) Check the variation between different factors using design of experiment.
5) Analyse the joint behaviour of more than one random variable using multivariate techniques.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. A.N. Kamthane & A.A. Kamthane, Programming and Problem Solving with Python, McGraw Hill (2020).
2. T.W. Anderson, An Introduction to Multivariate Statistical Analysis, John Wiley (2003).
3. S.P. Gupta, Statistical Methods, Sultan Chand & Sons (2017).
4. S.C. Gupta & V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons (2014).
5. R.A. Johnson & D.W. Wichern, Applied Multivariate Statistical Analysis, PHI (2012).
6. D.F. Morrison, Multivariate Statistical Analysis, McGraw Hill (1990).

MA-923 ALGEBRAIC CODING THEORY

L	T	P	C
4	1	0	5

Course Objectives: The objective of this course is to introduce basic topics of algebraic coding theory like error correction and detection, linear codes and their parameters, various bounds on parameters and Cyclic codes. Students will learn how codes in mathematics are used for error correction and data transmission.

UNIT - I

Error detecting and error correcting codes, Decoding principle of maximum likelihood, Hamming distance, Distance of a code, Finite Fields, Construction of finite fields, Irreducible polynomials over finite fields, Vector spaces over finite fields.

UNIT - II

Linear codes, Hamming weight, Generator matrix and parity-check matrix of linear codes, Equivalence of linear codes, Encoding with a linear code, Decoding of linear codes, MacWilliams identity.

UNIT - III

Syndrome decoding, Bounds in coding theory: Sphere-covering bounds, Gilbert-Varshamov bound, Hamming bound and perfect codes (Hamming codes and Golay codes), Singleton bound and MDS codes, Plotkin bound.

UNIT - IV

Construction of linear codes using propagation rules, Reed-Muller codes, ISBN codes, Cyclic codes, generator polynomial, parity check polynomial, BCH codes.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Use basic concepts such as encoding, decoding, error detection and correction and Hamming distance.
2) Construct linear codes, their generator and parity-check matrices, decoding of linear codes.
3) Use different types of codes like MDS codes, Golay codes, Perfect codes, ISBN codes and Reed-Muller codes.
4) Find various upper and lower bounds on the parameters of codes.
5) Construct cyclic code and their generator polynomials.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. S. Ling & C. Xing, Coding Theory, Cambridge University Press (2004).
2. L.R. Vermani, Elements of Algebraic Coding Theory, Chapman and Hall (1996).
3. S. Roman, Coding and Information Theory, Springer Verlag (1992).
4. R. Hill, A First Course in Coding theory, Clarendon Press Oxford (1990).

MAP-924 **PROJECT**

L	T	P	C
0	0	12	6

The project work has 6 credits. The duration of the project work is one semester and it will be allotted at the end of 3rd semester. Candidates can do the project work on recent research problem or latest research articles published in reputed international journals. The work can be done in the department itself or in collaboration with other departments, reputed institutions or industry (through proper MOU).

ELECTIVE PAPERS FOR SEMESTER – IV (Select any two subjects)

MAE-921 ADVANCED NUMERICAL ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives: This course is intended to teach the students numerical techniques that are required in advanced applied mathematics. Through this course students will learn numerical methods for: systems of linear and nonlinear equations; spline interpolation; Eigen value problem; physically important BVP like Laplace, Poisson, Heat and Wave equations.

UNIT - I

Iterative methods for solution of system of linear equations: Relaxation and successive over-relaxation methods. Necessary and sufficient conditions for convergence. Jacobi and Givens methods for finding eigenvalue and corresponding eigenvector. Cubic Spline interpolation. Error in interpolating polynomial.

UNIT - II

General Newton's method. Existence of roots. Stability and convergence under variation of initial approximations. General iterative method for the system: $x = g(x)$ and its sufficient condition for convergence. Romberg's integration. Gaussian integration. Error analysis in integration.

UNIT - III

Predictor Corrector methods: Milne's and Adam Bashforth methods. Finite difference method for solving initial value problem. Classification of PDE. Solutions of parabolic equations by Crank-Nicolson, DuFort methods. Solution of elliptic equation by diagonal five point and standard five point formulae. Solution of hyperbolic equations. Stability and convergence analysis.

UNIT - IV

Solution of boundary value problems by weighted residual methods Galerkin method. Variational formulation of a given boundary value problem. Ritz method and orthogonal collocation method. Introduction to finite element method. Solution of boundary value problems by finite element method.

Course Outcomes (CO): Upon completion of this course, the student will be able to

1) solve the linear systems by relaxation methods and find their eigenvalues and eigenvectors.
2) solve the systems of nonlinear equations and evaluate the integrals by Romberg's and Gaussian quadrature rules.
3) solve BVP viz. Heat conduction equation, Laplace equation and Poisson equation by finite difference method.
4) Solve BVP by Galerkin, Ritz, Orthogonal Collocation and finite element methods.
5) learn the convergence analysis, stability analysis and applications of the numerical methods.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. Isacson and Keller, Analysis of Numerical methods, John Wiley and Sons (1966).
2. M.K. Jain, Numerical Solution of Differential Equations, New Age International (2014).
3. Prem K. Kytbe, An Introduction to Boundary Element Methods, CRC Press (2006).
4. B.P. Demidovich and J.A.Maron, Computational Mathematics, Mir Publishers (1981).
5. M.K. Jain, S.R.K. Iyengar & R.K. Jain, Numerical Methods for Scientific & Engg. Computation, New Age International (2012).

MAE-922 GRAPH THEORY

L	T	P	C
4	1	0	5

Course Objectives: The aim of this course is to provide the basic concepts in Graph Theory and apply them as a tool in the various real life problems.

UNIT - I

Basic terminology of graph theory, Graph, simple and multiple graphs, paths, circuits, degree, and their properties. Isomorphism, Subgraphs, Operations on Graphs. Eulerian graphs, Hamiltonian graphs and their properties. Travelling salesman problem.

UNIT - II

Trees, Spanning trees, Properties of tree, binary trees, rooted trees. Planer graphs, Euler's theorem for planer graph. minimum spanning tree, Kruskal's and Prim's algorithm for finding minimum spanning tree. matchings and coverings in bipartite graphs perfect matchings, applications - the personnel assignment problem.

UNIT - III

Weighted graphs. shortest path problem: Belman-Ford, Dijkastra and Floyd-Marshall algorithm.
Cut sets and their properties. Fundamental circuits and Cut sets. Connectivity & separability. Network Flows. Max-Flow Problem.

UNIT - IV

Vector spaces of a graph, Sets with one and two operations, basis vectors of a graph, circuit and cut set subspaces. Matrix representation of graph, submatrix, circuit matrix, Fundamental circuit matrix and rank. Incidence and adjacency matrices and their properties.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Understand various type of graphs and their properties on paths, circuits, degree, adjacency etc.
2) Understand and apply the fundamental concepts of tree and fundamental circuit in graph theory.
3) Apply graphs in real life problems, like shortest path, max-flow problem.
4) Apply graphs as a vector space and used its properties in graph theory.
5) Represent graphs as a matrix.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. N. Deo, Graph Theory with Applications to Engineering and Computer Science, PHI Private Limited.
2. F. Harary, Graph Theory, Narosa Publishing House (2001).
3. J.A. Bondy & U.S.R. Murty, Graph Theory with Applications, Springer (2008).
4. R. Diestel, Graph Theory. New York, NY: Springer-Verlag (1997).
5. B. Bollobas, Modern Graph Theory, New York (1998).

MAE-923 **MATHEMATICAL MODELLING**

L	T	P	C
4	1	0	5

Course Objectives: The aim of this course is to formulate the mathematical models of real life situations and their analysis.

UNIT - I

Introduction to mathematical modelling, its scope and role in real life, different types of models, how to develop a model through ODE, PDE, difference equation and solution of these models.

UNIT - II

Continuous population models for single species, insect outbreak model, delay models, linear analysis, models in physiology, harvesting models.
Discrete population models for single species, cobwebbing, chaos, fishery management models.

UNIT - III

Two-species population models: simple predator-prey model, predator-prey models with time delays, models for competition.
Multi-species population models: Lotka-Volterra model.

UNIT - IV

Epidemic models: Deterministic models without removal and with removal.
Diffusion models: Diffusion equation, diffusion in artificial kidney, Longitudinal diffusion in a packed bed.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Basic concepts related to formulation of mathematical models related to practical situations.
2) Formulate continuous and discrete models related to single species population.
3) Formulate continuous and discrete models related to two and multi species population.
4) Formulate models related to epidemics.
5) Formulate models related to diffusion phenomenon

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. J.N. Kapur, Mathematical Modelling, New Age International (P) Ltd. New Delhi 2nd Edition (2016).
2. J.N. Kapur, Mathematical Models in Biology and Medicine, Affiliated East-West Press (P) Ltd. (2010).
3. R. Aris, Mathematical Modelling Techniques, Dover Publications Inc., New York (1994).
4. J.D. Murray, Mathematical Biology – An Introduction, Springer, New York (2002).

MAE-924 THEORY OF LINEAR OPERATORS

L	T	P	C
4	1	0	5

Course Objectives: The aim of this course is to provide the basic concepts of bounded linear operators, compact operators and their spectral properties.

UNIT - I

Spectral theory in normed linear spaces, resolvent sets and spectrum, spectral properties of bounded linear operators, properties of resolvent and spectrum. Spectral mapping theorem for polynomials, spectral radius of a bounded linear operator on a complex Banach space.

UNIT - II

Elementary theory of Banach algebras, Resolvent set and spectrum, Invertible elements, Resolvent equation, general properties of compact linear operator.

UNIT - III

Spectral properties of compact linear operators on normed space, Behaviour of compact linear operators with respect to solvability of operator equations. Fredholm type theorems.

UNIT - IV

Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space, Positive operators, Monotone sequence theorem for bounded self-adjoint operators on a complex Hilbert space, square root of positive operators.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Use the spectral theory of operators on normed linear spaces.
2) Use Banach algebra and properties of its elements.
3) Utilize the concept of compact linear operators on normed space and their spectral properties.
4) Use the concept of bounded self-adjoint linear operators on a complex Hilbert space.
5) Use the concept of monotone sequences of operators and Positive operators, their square root.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1) E. Kreyszig, Functional Analysis with applications, John Wiley & Sons (1989).
2) P.R. Halmos, Introduction to Hilbert Space and Theory of Spectral Multiplicity, Dover Publications (2017).
3) N.I. Akhiezer & J.T. Glazman, Theory of Linear operators in Hilbert space, Dover Publications (1993).
4) R. Bhatia, Notes on functional analysis, Hindustan Book Agency (2015).

MAE-925 APPROXIMATION THEORY

L	T	P	C
4	1	0	5

Course Objectives: The objective of this course is to introduce the basic topics of approximation theory, which is strongly influenced by our need to solve practical problems of computations.

UNIT - I

Best approximation in normed spaces, existence of the best approximation, uniqueness problem.
Convexity conditions: uniform and strict convexity and their relations, The continuity of best approximation operator.

UNIT - II

The Tchebycheff solution of inconsistent linear equations: system of equations with one unknown, the special case m=n+1 and various algorithms to solve it.
Polynomial interpolation: the Largrange's formula and its error, Hermite interpolation and the Vandermonde's matrix. The Tchebycheff polynomials, norm of the Lagrange interpolation operator

UNIT - III

The Weierstrass theorem, Monotone operators, The Bernstein polynomials, Fejer theorem.
General linear families: characterization theorem, Haar conditions, alternation theorem.
The unicity problem: strong unicity theorem, Haar's theorem and Freud's theorem.
Discretization: The inequalities of Markoff and Bernstein

UNIT - IV

Least square approximation: the general form, orthogonal system of polynomials, the recurrence relation, Gaussian integration, Stieltje's theorem, , uniform and least square convergence of orthogonal expansion, approximation to periodic functions, Bessel inequality, convergence of Fourier series.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) Explain fundamental concepts in approximation theory.
2) Use the basic methods for polynomial approximations.
3) Use the theory of convergence (Weierstrass) and best approximations.
4) Construct orthogonal polynomials and apply Gauss quadrature methods.
5) Use Tchebycheff solution and Tchebycheff polynomials.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. M.J.D. Powell, Approximation Theory and Methods, Cambridge University press (1981).
2. E.W. Cheney, Introduction to Approximation Theory, AMS Chelsea Publishing Co. (1981).
3. G.G. Lorentz, Bernstein Polynomials, Chelsea Publishing Co. (1986).
4. A.F. Timan, Theory of Approximation of Functions of a Real Variable, Dover Publication Inc. (1994).
5. A. Iske, Approximation Theory and Algorithms for Data Analysis, Springer (2018).

MAE-926 WAVELET ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives: The principle objective is to provide an introduction to the basic concepts and methodologies of theory of wavelets. The wavelet analysis has an advantage over Fourier analysis and therefore, to prepare the students to understand and analysis the application oriented problems in frontier areas of science.

UNIT-I

Review of vector spaces. Inner products, Orthonormal bases. Reiz systems and frames. Continuous Fourier transform. Continuous time-frequency representation of signals. Uncertainty Principle.

UNIT-II

Wavelet: origin and history. Examples of wavelets. Support of a wavelet system. L^2 (R) and approximate identities. Continuous wavelets transform (CWT). Interpretation and time frequency resolution. CWT as an operator. Inverse CWT. Relationship Between Wavelet and Fourier Transforms.

UNIT-III

Discrete wavelets transform. Haar scaling function. Wavelet bases of multiresolution analysis (MRA). Daubechies wavelets. Refinement relation with respect to normalized bases. General Theorems.

UNIT-IV

Evaluation of Scaling and wavelet functions. Designing wavelets (direct approach): Restriction on filter coefficients. Decomposition filters and reconstructing the signal. Frequency domain characterization of filter coefficients. B-spline wavelets.

Course Outcomes (CO): Upon completion of this course, the student will be able to:

1) Review the vector space and Fourier transform.
2) To introduce the basic aspects of wavelet theory.
3) To understand multiresolution analysis and the refinement relation.
4) Daubechies wavelets and evaluation of filter coefficients and scaling function.
5) To develop frequency domain characterization relation and B-spline wavelets.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. M.W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer (1999).
2. R.M. Rao & A.S. Bopardikar, Wavelet Transforms: Theory and Applications, Pearson (1998).
3. M.A. Pinsky, Introduction to Fourier Analysis and Wavelets, Thomson (2002).
4. J.C. Goswami & AK Chan, Fundamental of Wavelets: Theory Algorithm and Applications, John Wiley & Sons (2011).
5. L. Debnath & F.A. Shah, Wavelet Transforms and Their Applications, Birkhauser (2002).

MAE-927 MATHEMATICAL THEORY OF SEISMOLOGY

L	T	P	C
4	1	0	5

Course Objectives: To understand earthquake dynamics, its cause and detection mechanism.

UNIT - I

Earth Composition and Structure: Core, mantle and crest. Lithosphere. Asthenosphere. Basic plate kinematics: plate velocity and plate driving forces. Geodynamo and magnetic field.

UNIT - II

Stress and Strain Analysis: Stress tensor, Stain tensor. Stress-strain relationship, Generalized Hooke's law, Poisson ratio, Shear ratio.

UNIT - III

Seismic Waves: Elastic plane waves: Harmonic wave. Wave equation and solution. Snell's law. Momentum equation. Polarization of P and S waves. Spherical waves. Ray paths for laterally homogeneous models. Ray tracing through velocity gradients. Travel time curves. Spherical earth ray tracing. 3-dimensional ray tracing. Seismic phases. Travel time. Seismic wave energy. SH and SV waves, Surface waves: Love and Rayleigh waves.

UNIT - IV

Seismograph, intensity and Scale: Horizontal and vertical components seismograph. Indicator equation. Theory of undamped and damped seismometer. Seismographs for near and distant earthquakes. Elements of earthquake motion. Intensity of earthquake motion. Scales of Seismic intensity. Duration of earthquake.

Course Outcomes (CO): Upon completion of this course, the student will be able to:
1) To understand the importance of seismology.
2) To introduce the basic aspects of earth structure and earthquake theory
3) To understand stress-stain relationship and its application to seismic waves.
4) To understand seismograph and earthquake intensity measurement.
5) Applications in mathematical domain.

CO/PO Mapping (S/M/W indicates strength of correlation) S – Strong, M – Medium, W – Weak												
Cos	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	S	W	M	M	W	W	S	S
CO2	S	S	M	S	S	W	M	M	W	W	S	S
CO3	S	S	M	S	S	W	M	M	W	W	S	S
CO4	S	S	M	S	S	W	M	M	W	W	S	S
CO5	S	S	M	S	S	W	M	M	W	W	S	S

RECOMMENDED BOOKS:

1. A. Bedford and D. Drumheller, Introduction to Elastic Wave Propagation, John Wiley & Sons (1994).
2. P.M. Shearer, Introduction to Seismology, Cambridge University Press (2009).
3. W.M. Ewing, W.S. Jardetzky & F. Press, Elastic Waves in Layered Media, McGraw-Hill Book Company (1957).
4. C. Davison, A Manual of Seismology, Cambridge University Press (1921).