VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM&SYLLABUS (DRAFT) OF

B.Sc. (HONOURS / HONOURS WITH RESEARCH)

MAJOR IN MATHEMATICS

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes

(CCFUP), 2023& NEP, 2020

VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS/ HONOURS WITH RESEARCH) MAJOR IN MATHEMATICS
(under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks CA	Marks ESE	Marks TOTAL
B.Sc. (Hons./ Hons. with Research)	4th	VII			**SEMESTER-VII**					
			Major-14	MATHMJ14	T: Measure Theory and Complex Analysis	4	3-1-0	15	60	75
			Major-15	MATHMJ15	T: Classical Mechanics and Abstract Algebra	4	3-1-0	15	60	75
			CRM	MATHCRM	T: Research Methodology and Ethics	4	3-1-0	15	60	75
			Major Elective-03	MATHDSE03	T: Ordinary Differential Equations OR Data Science and Graph Theory	4	3-1-0	15	60	75
			Minor-07 (Disc.-I)	MATMIN07	T: Probability and Statistics *(To be taken by the other Discipline)*	4	3-1-0	15	60	75
					Semester-VII Total	20				375
		VIII			**SEMESTER-VIII**					
			Major-16	MATHMJ16	T: Continuum Mechanics and Linear Algebra	4	3-1-0	15	60	75
			Major Elective-04	MATHDSE04	T: Fluid Mechanics and MHD OR Calculus on R^n and Operator Theory	4	3-1-0	15	60	75
			Major Elective-05	MATHDSE05	Partial Differential Equations and Generalized Functions OR Fuzzy Mathematics and Soft Computing OR Integral Transforms and Topology — For Honours Students only	4	3-1-0	15	60	75
			Major Elective-06	MATHDSE06	Advanced Complex Analysis and Machine Learning OR Stochastic Process and Statistical Methods OR Differential Geometry and Manifold Theory — For Honours Students only	4	3-1-0	15	60	75
			Research	MATHRD	DISSERTATION: *For Honours With Research Students only*	*8*	*0-0-8*	*-*	*150*	*150*
			Minor-8 (Disc.-II)	MATMIN08	T: Probability and Statistics *(To be taken by the other Discipline)*	4	3-1-0	15	60	75
					Semester-VIII Total	20				375
					YEAR-4	40				750
					To be awarded *Bachelor of Science (Honours / Honours with Research) Major in Mathematics*	166	Marks (Year: I+II+III+IV)			3075

MJ = Major, MI = Minor Course, DSE = Discipline Specific Elective Course, CRM= Compulsory Research Methodology, CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical

SEMESTER-VII

MAJOR (MJ)

Major – 14
Measure Theory and Complex Analysis
[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

MEASURE THEORY

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts of measurable sets, measurable functions, and Lebesgue measure, and develop an understanding of their role in modern analysis.
2. To provide a rigorous foundation of the Lebesgue integral, its properties, and its relationship with the Riemann integral.
3. To equip students with convergence theorems and integration techniques essential for applications in pure and applied mathematics, particularly in analysis, probability, and functional spaces.

Course Outcomes (COs):

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

CO1: Understand the concepts of measurable sets, measurable functions, and Lebesgue measure, and analyze their properties including sets of measure zero and Borel sets.

CO2: Apply the theory of Lebesgue integration, including simple functions, convergence theorems, and comparison with the Riemann integral, to evaluate and study integrals of measurable functions.

Syllabus:

Course content	No. of Lectures
Measurable sets, Measure, simple properties	4
Set of measure zero, Cantor set	3
Borel sets and their measurability, Measurable functions, continuity and measurability, Borel measurable functions, sequence of measurable functions	3
Simple functions and it's properties, Integral of nonnegative measurable functions	6
Lebesgue integral on a measurable set: Definition, Basic properties	3
Lebesgue integral of a bounded function over a set of finite measure. Simple Properties	3
Comparison of Lebesgue and Riemann integral, Lebesgue criterion of Riemann Integrability	2
General Lebesgue integral	3
Bounded convergence theorem for a sequence of Lebesgue integrable functions, Fatou's lemma, Classical Lebesgue dominated convergence theorem. Monotone convergence theorem (Statement only)	3
Total Lecture:	**30 hours**

Further Readings:

Text Books:

1. W. Rudin, Real and Complex Analysis, International Student Edition, McGraw-Hill.
2. Inder K. Rana, An Introduction to Measure and Integration (2nd ed.), Narosa Publishing House, New Delhi.

Reference Books:

1. P.R. Halmos, Measure Theory, Graduate Text in Mathematics, Springer-Verlag.
2. H.L. Royden, Real Analysis, 3rd ed., Macmillan.

GROUP-B

COMPLEX ANALYSIS

Course Objectives:

The main objectives of this course are:

1. To develop a deep understanding of the foundational results in complex analysis, including Cauchy's theorem, integral formulas, series expansions, and maximum modulus principles.
2. To introduce the concepts of singularities, residues, poles, and multivalued functions, and to study their theoretical properties and implications.
3. To equip students with analytical tools such as residue calculus, argument principle, and Rouche's theorem, enabling applications in evaluating integrals, infinite sums, and problems in applied mathematics.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the concepts of Cauchy's Theorem and Multiple valued function.

CO2: Understand the concepts of Residues and Poles with associated Riemann's theorem, Schwarz's lemma, Casorati-Weierstrass's theorem.

CO3: They will learn the application of residues

Syllabus:

Course content	No. of Lectures
Review of basic complex analysis: Cauchy's theorem, primitives of analytic functions, Fundamental Theorem of Algebra, Cauchy's integral formula. Morer's theorem. Liouville's theorem. Taylor's series, Laurent's series. Maximum modulus principle.	6
Definition of Homotopy, Homotopy version of Cauchy's theorem, Extension of Cauchy's Theorem to Multiply-Connected Regions	4
Multiple valued function: Definition, Branch point and branch cut	2
Residues and Poles: Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points, Residues at Poles, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular, Riemann's theorem, Schwarz's lemma, Casorati-Weierstrass's theorem,	6
Application of Residues: Evaluation of Improper Integrals, Improper Integrals from Fourier Analysis, Jordan's Lemma, Indented Paths, An Indentation Around a Branch Point, Integration along a Branch Cut, Definite Integrals Involving Sines and Cosines, other type of contour Integrations, Estimation of Infinite Sums	8
Winding number, Counting zeros Argument Principle, Rouche's Theorem.	4
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. Complex Variable and Applications, J. W. Brown and R. V. Churchill, 8th Edition, McGraw-Hill.

Reference Books:

1. Foundations of Complex Analysis, S. Ponnusamy, Narosa, 1995.
2. Functions of one Complex Variable, J. B. Conway, 2nd edition, Narosa, 1997.

A Text Book of Complex Analysis, P.K.Nayek and M.R.Seikh, Universities Press, 2018

Major – 15
Classical Mechanics and Abstract Algebra

[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

CLASSICAL MECHANICS

Course Objectives:

The main objectives of this course are:

1. To provide a rigorous foundation of classical mechanics through generalized coordinates, constraints, and variational principles, leading to Lagrangian and Hamiltonian formulations.
2. To introduce invariance transformations, conservation laws, canonical transformations, and Poisson brackets as essential tools in analytical dynamics.
3. To develop a clear understanding of the postulates and mathematical framework of the Special Theory of Relativity, including Lorentz transformations and relativistic dynamics.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the principles of motion of a system of particles, constraints, Lagrange's and Hamilton's equations, variational principles, and the derivation of equations of motion for holonomic and non-holonomic systems.

CO2: Apply the concepts of invariance transformations, conservation laws, Poisson brackets, and the special theory of relativity, including Lorentz transformations and relativistic force and energy equations, to solve physical problems.

Syllabus:

Course content	No. of Lectures
Motion of a system of particles. Constraints. Generalized coordinates. Holonomic and non-holonomic systems. Principle of virtual work. D'Alembart's Principle.	6
Lagrange's equations, Hamiltonian. Hamilton's equations. Cyclic coordinates. Routhian equation.	6
Principle of stationary action, Principle of least action, Hamilton's principle. Variational principle, Brachistochrone problem. Lagrange's equations from Hamilton's principle.	6
Invariance transformations. Conservation laws. Space-time transformations. Canonical transformations. Liouville's theorem.	4
Poisson bracket.	4
The special theory of relativity: Postulates of special relativity. Lorentz transformation. Consequences of Lorentz transformation. Force and energy equations	4
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. Goldstein, H. (1950) Classical Mechanics, Addison-Wesley, Cambridge.
2. Pal, M. (2009) A Course on Classical Mechanics, Narosa, New Delhi, & Alpha Science, Oxford, London.

Reference Books:

1. Gupta, A.S. (2005) Calculus of Variations with Applications, Prentice-Hall of India, New Delhi.
2. Gupta, B.D. and Prakash, S. (1985) Classical Mechanics, Kedar Nath Ram Nath, Meerut.
3. Kibble, T.W.B. (1985) Classical Mechanics, Orient Longman, London.
4. Rana, N.C. and Joag, P.S. (2004) Classical Mechanics, Tata McGraw-Hill Publishing Company Limited, New Delhi.
5. Symon, K.R. (1971) Mechanics, Addison-Wesley Publ. Co., Inc., Massachusetts.
6. Takwale, R.G. and Puranik, S. (1980) Introduction to Classical Mechanics, Tata McGraw-Hill Publ. Co. Ltd., New Delhi.

GROUP-B

ABSTRACT ALGEBRA

Course Objectives:

The main objectives of this course are:

1. To study the structure and properties of polynomial rings, integral domains, and factorization concepts, with emphasis on unique factorization, Euclidean domains, and principal ideal domains.
2. To develop an understanding of group-theoretic concepts such as normal and subnormal series, solvability, and their role in algebraic structures.
3. To explore field extensions, both finite and algebraic, and their applications to classical problems such as ruler and compass constructions.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the structure of polynomial rings, divisibility in integral domains, and concepts of unique factorization, Euclidean domains, and principal ideal domains.

CO2: Analyze advanced algebraic structures through solvable groups and field extensions, and apply these concepts to classical problems such as ruler and compass constructions.

Syllabus:

Course content	No. of Lectures
Polynomial rings over commutative rings, division algorithm and consequences, Eisenstein criterion, and unique factorization in Z [x]	8
Divisibility in integral domains, Unique factorisation domain, Euclidean domain.	5
Principal ideal domain	4
Normal series, subnormal series, solvable series, and solvable groups.	5
Field extensions: finite, algebraic, and finitely generated extensions; Classical ruler and compass constructions.	8
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, John Wiley, 1999.
2. J.A. Gallian, Contemporary Abstract Algebra, 9th Edition, Narosa, 2017.

Reference Books:

1. M. Artin, Algebra, 2nd Edition, Prentice Hall of India, 2011.
2. N. Jacobson, Basic Algebra, 2nd Edition, Hindustan Publishing Co., 2009.

COMPULSORY RESEARCH METHODOLOGY (CRM)

[for both Hons. and Hons. with Research students]

CRM: Research Methodology and Ethics

[THEORY; CREDITS: 04; FM- 75; 60L]

RESEARCH METHODOLOGY AND ETHICS

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts, characteristics, and types of research, and to distinguish between research methods and methodology.
2. To develop the ability to identify and formulate research problems, review literature critically, and frame appropriate research questions and hypotheses.
3. To equip students with knowledge of research design, data collection methods, sampling techniques, and proposal writing skills.
4. To cultivate ethical awareness in research by emphasizing research integrity, academic honesty, and responsible conduct in data handling and publication.
5. To familiarize students with research metrics, publication ethics, and modern tools for evaluating the quality and impact of research.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of research, including types of research, research problems, hypothesis formulation, and the research process.

CO2: Apply research design principles, data collection methods, and sampling techniques to conduct effective and systematic research.

CO3: Develop skills to review literature, write research proposals, and integrate research findings into coherent reports or projects.

CO4: Demonstrate knowledge of research ethics, publication ethics, privacy and confidentiality, and evaluate research impact using appropriate metrics.

Syllabus:

Course content	No. of Lectures
Basics of Research Definition, importance, and characteristics of research; distinction between method and methodology; types of research – basic, applied, qualitative, quantitative, descriptive, analytical, experimental.	5
Research Problem and Literature Review Identification and formulation of research problem; research questions and objectives; survey of literature – importance, sources, and research gaps.	4
Hypothesis and Research Process Hypothesis – meaning, role, and types (null, alternative, simple, complex, directional, causal); research process – steps from problem identification to report writing.	4

Research Design and Plan Research design – meaning, significance, and types (exploratory, descriptive, analytical, experimental); developing a research plan – statement of problem, objectives, methodology, data plan, timeline, budget. S	5
Data and Data Collection Types of data – primary and secondary; sources of data; methods of data collection – observation, interview, questionnaire, case study, experiment, content analysis.	4
Sampling Methods Concept of sampling; probability sampling – simple random, stratified, cluster, systematic; non-probability sampling – purposive, convenience, quota, snowball.	4
Reviewing and Proposal Writing Reviewing articles – analysis of objectives, methodology, findings; writing a research proposal – title, abstract, problem statement, literature review, methodology, outcomes, references.	4
Integration and Wrap-up Case discussions and practice on research problems, article reviews, and proposals; recap and integration of the research process.	3
Research Ethics	
Introduction to Ethics Definition, nature, and scope of ethics; different branches of ethics; importance of ethics in research and academic life.	4
Research Ethics Meaning and significance; responsibilities of researchers towards fellow researchers, public, and academic community; concept of academic integrity.	4
Ethical Judgments and Scientific Misconduct Ethical judgments in research: scientific misconduct – falsification, fabrication, plagiarism; redundant, duplicate, and overlapping publications; salami slicing; selective reporting; misrepresentation of data.	6
Privacy and Confidentiality Concepts of privacy, autonomy, confidentiality, and anonymity in research; ethical handling of sensitive data.	3
Publication Ethics Definition and importance of publication ethics; publication misconduct; conflict of interest; authorship issues; responsibilities of editors, reviewers, and publishers.	5
Research Metrics Overview of research metrics; impact factor, h-index, g-index, i10-index; altmetrics and their role in evaluating research impact.	5
Total Lecture	**60 hours**

Further Readings:

Research methodology

1. Kothari, C. R., & Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
2. Kumar, R. (2019). *Research Methodology: A Step-by-Step Guide for Beginners* (5th ed.). Sage Publications.
3. Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (5th ed.). Sage Publications.

4. Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research Methods for Business Students* (8th ed.). Pearson Education.
5. Bougie, R. & Sekaran, U., (2019). *Research Methods for Business: A Skill-Building Approach* (8th ed.). Wiley.
6. Walliman, N. (2017). *Research Methods: The Basics* (2nd ed.). Routledge.
7. Punch, K. F. (2014). *Introduction to Social Research: Quantitative and Qualitative Approaches* (3rd ed.). Sage Publications.

Research ethics

1. Academic Integrity and Research Quality, University Grants Commission Bahadur Shah Zafar Marg New Delhi, December 2021.
2. Resnik, D. B. (2020). *The Ethics of Research with Human Subjects: Protecting People, Advancing Science, Promoting Trust*. Springer.
3. Shamoo, A. E., & Resnik, D. B. (2015). *Responsible Conduct of Research* (3rd ed.). Oxford University Press.
4. COPE (Committee on Publication Ethics). (2017). *Code of Conduct and Best Practice Guidelines for Journal Editors*. https://publicationethics.org/membership/code-of-conduct
5. American Psychological Association. (2020). *Publication Manual of the American Psychological Association* (7th ed.). APA.
6. Steneck, N. H. (2007). *ORI Introduction to the Responsible Conduct of Research*. Office of Research Integrity, U.S. Department of Health & Human Services.
7. Wager, E., & Kleinert, S. (2011). *Responsible Research Publication: International Standards for Authors*. In Mayer, T., & Steneck, N. (Eds.), *Promoting Research Integrity in a Global Environment* (pp. 309–316). World Scientific.

MAJOR ELECTIVE (DSE)

Major Elective – 03: Ordinary Differential Equations

[THEORY; CREDITS: 04; FM- 75; 60L]

ORDINARY DIFFERENTIAL EQUATIONS

Course Objectives:

The main objectives of this course are:

1. To develop a deep understanding of eigenvalue problems and Sturm–Liouville theory, including their properties, applications to boundary value problems, and expansion theorems.
2. To introduce the concept of Green's functions and their role in solving ordinary differential equations and boundary value problems.
3. To study systems of linear differential equations, their matrix representation, existence and uniqueness of solutions, and the use of the Wronskian.
4. To explore series solutions of differential equations, including Frobenius method, hypergeometric and confluent hypergeometric functions, with emphasis on their analytical properties and applications.
5. To understand special functions such as Legendre and Bessel functions, their generating functions, orthogonality properties, recurrence relations, and integral representations in mathematical physics.

Course Outcomes (COs)

Upon successful completion of this course, students will be able to:

CO1: Understand the theory of Sturm–Liouville problems, eigenvalues and eigenfunctions, and apply orthogonality and expansion theorems to boundary value problems.

CO2: Comprehend Green's functions, their properties, and utilize them to solve ordinary differential equations and boundary value problems.

CO3: Analyze systems of linear differential equations, homogeneous linear differential equations, and solutions near singularities, including the use of the Frobenius method.

CO4: Understand and apply special functions, including hypergeometric, Legendre, and Bessel functions, their series and integral representations, generating functions, and recurrence relations for solving physical and engineering problems.

Syllabus:

Course content	No. of Lectures
Eigen Value Problem: Ordinary differential equations of the Strum-Liouville type, Properties of Strum Liouville type, Application to Boundary Value Problems, Eigen values and Eigen functions, Orthogonality theorem, Expansion theorem.	8
Green's Function: Green's Function and its properties, Green's function for ordinary differential equations, Application to Boundary Value Problems.	6
System of Linear Differential Equations: Systems of First order equations and the Matrix form, Representation of nth order equations as a system, Existence and uniqueness of solutions of system of equations, Wronskian of vector functions.	10

Differential Equation: Homogeneous linear differential equations, Fundamental system of integrals, Singularity of a linear differential equation, Solution in the neighborhood of a singularity, Regular integral, Equation of Fuchsian type, Series solution by Frobenius method.	8
Hypergeometric Equation. Hypergeometric functions, Series solution near zero, one and infinity, Integral formula for the hypergeometric function, Differentiation of hypergeometric function, The confluent hypergeometric function, Integral representation of confluent hypergeometric function.	10
Legendre Equation: Legendre functions, Generating function, Legendre functions of first kind and second kind, Laplace integral, Orthogonal properties of Legendre polynomials, Rodrigue's formula, Schlaefli's integral.	10
Bessel Equation: Bessel function, Series solution of Bessel equation, Generating function, Integrals representations of Bessel's functions, Hankel functions, Recurrence relations, Asymptotic expansion of Bessel functions.	8
Total Lecture	**60 hours**

Further Readings:

Text Books:

1. G.F. Simmons: Differential Equations, TMH Edition, New Delhi, 1974.
2. S.L. Ross: Differential Equations (3rd edition), John Wiley & Sons, New York, 1984.

Reference Books:

1. M.S.P. Eastham: Theory of Ordinary Differential Equations, Van Nostrand, London, 1970.
2. M. Braun: Differential Equations and Their Applications; An Introduction to Applied Mathematics, 3rd Edition, Springer-Verlag.
3. E.D. Rainville and P.E. Bedient: Elementary Differential Equations, McGraw Hill, NewYork, 1969.
4. E.A. Coddington and N. Levinson: Theory of ordinary differential equations, McGraw Hill, 1955.

OR

Major Elective – 03:
Data Science and Graph Theory

[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

DATA SCIENCE

Course Objectives:

The main objectives of this course are:

1. To provide a foundational understanding of data science concepts, life cycle, and mathematical tools including topology of data, distance functions, and dimension reduction techniques.
2. To develop knowledge of probability, statistical methods, and hypothesis testing essential for data analysis and interpretation.
3. To introduce classification methods, data visualization techniques, and modern data science tools (Python, R, Pandas, NumPy) for practical applications.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of Data Science, including data representation, probability, statistics, visualization, and basic classification methods.

CO2: Apply essential tools such as Python, R, Pandas, and NumPy to analyze data, perform visualization, and implement classification and dimensionality reduction techniques.

Syllabus:

Course content	No. of Lectures
Data Science – Introduction, Brief history of data science, Data science life cycle, Topology of data, Distance function, Euclidean space, Euclidean Norm, Distance between two points in 2D, 3D, and extension to n dimensions.	4
Quadratic function, Maxima, minima, Saddle points, vertex, slope, Principal Component Analysis and Dimension Reduction.	3
Basic concept of probability, Bayes' theorem, Distributions: Uniform, Gaussian, Student's t, Chi–square.	4
Sample statistics such as mean, median, mode, variance, standard deviations, correlation, regression, parametric and non-parametric tests.	3
Frequency plot, box plots, concepts of quartile, whisker, outlier, parity plot, normal probability plot.	3
Classification: Metrics, Bayes' Rule, Linear and Quadratic Discriminant Analysis, K-Nearest Neighbours, Classification with Scikit–learn.	4
Data visualization techniques: Plotting Qualitative and Quantitative Variables, Data visualization in a Bivariate Setting.	5
Data Science Tools: Python, R, Pandas, NumPy	4
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. James, G., Witten, D., Hastie, T., & Tibshirani, R. *An Introduction to Statistical Learning with Applications in R*. Springer.

2. Rajaraman, A., & Ullman, J. D. *Mining of Massive Datasets*. Cambridge University Press.

Reference Books:

1. Hastie, T., Tibshirani, R., & Friedman, J. *The Elements of Statistical Learning*. Springer.
2. McKinney, W. *Python for Data Analysis*. O'Reilly Media.

GROUP-B

GRAPH THEORY

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts of graph theory including paths, cycles, connectivity, trees, and special classes of graphs.
2. To study graph properties such as colouring, planarity, matching, and matrix representations, along with their theoretical significance.
3. To develop problem-solving skills through graph algorithms and explore applications of graphs in optimization problems such as shortest path, spanning trees, and the traveling salesman problem.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of graph theory, including paths, cycles, connectivity, trees, planar and directed graphs, and graph coloring.

CO2: Apply graph algorithms, matrix representations, and graph-theoretic techniques to solve problems such as shortest path, spanning trees, traveling salesman problem, and intersection graphs.

Syllabus:

Course content	No. of Lectures
Basic graph theoretical concepts.	3
Paths and cycles.	2
Connectivity, trees, spanning subgraphs, bipartite graphs, Hamiltonian and Euler cycles.	3
Distance and centre.	3
Cut sets and cut vertices.	3
Colouring and matching. Four colour theorem (statement only). Chromatic Polynomial.	4
Planar graphs, Dual graph. Directed graphs and weighted graphs.	3
Matrix representation of graphs	3
Algorithms for shortest path and spanning trees, Applications of graphs in traveling salesman problem	3
Intersection graph	3
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. Deo, N. (2017). Graph theory with applications to engineering and computer science. PHI Limited, New Delhi, 1979.
2. West, D. B. (2001). Introduction to graph theory, Upper Saddle River: Prentice hall.

Reference Books:

1. Chartrand, G. (2006). Introduction to graph theory. Tata McGraw-Hill Education.
3. Gross, J. L., & Yellen, J. (2005). Graph theory and its applications. CRC Press.

Minor-07
Probability and Statistics

[THEORY; CREDITS: 04; FM- 75; 60L]

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand fundamental probability concepts, including probability axioms, random variables, and probability distributions.
b) Analyze discrete and continuous probability distributions, including binomial, Poisson, normal, and exponential distributions.
c) Evaluate joint distributions, conditional expectations, and correlation coefficients, and apply regression analysis for two variables.
d) Apply statistical theorems such as **Chebyshev's inequality, laws of large numbers, and the central limit theorem** in real-world scenarios.
e) Understand the fundamentals of Markov chains, including **state classification and Chapman-Kolmogorov equations**.
f) Perform statistical inference through **sampling distributions, parameter estimation, and hypothesis testing**.

Course contents:

Unit 1: Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential.

Unit 2: Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.

Unit 3: Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central limit theorem for independent and identically distributed random variables with finite variance, Markov chains, Chapman-Kolmogorov equations, classification of states.

Unit 4: Random Samples, Sampling Diatributions, Estimation of parameters, Testing of hypothesis.

Reference Books

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
2. Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
4. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007
5. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

SEMESTER-VIII

MAJOR (MJ)

Major – 16
Continuum Mechanics and Linear Algebra
[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

CONTINUUM MECHANICS

Course Objectives:

The main objectives of this course are:

1. To develop a fundamental understanding of the concepts of stress, strain, and deformation in continuous media, and to establish the mathematical relationships between forces, stresses, and displacements.
2. To equip students with analytical and tensorial tools necessary for formulating and solving problems related to equilibrium, compatibility, and constitutive behavior in isotropic and elastic materials.
3. To apply the principles of linear elasticity and continuum theory to model and analyze real-world problems in solid mechanics, material science, and applied mathematics using formulations such as Airy's stress function and Navier's equations.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of stress, strain, stress–strain relations, and apply transformation laws, principal stresses/strains, Mohr's circle, and compatibility equations to analyze deformable bodies under different loading conditions.

CO2: Apply the theory of linear elasticity, including Hooke's law, isotropic material properties, Navier's equations, and Airy's stress function, to solve engineering and mathematical problems involving elastic solids.

Syllabus:

Course content	No. of Lectures
Stress: Body force, Surface forces, Cauchy's stress principle	2
Stress vector, State of stress at a point, Stress tensor, The stress vector –stress tensor relationship	3
Force and moment equilibrium. Stress tensor symmetry stress quadric of Cauchy	4
Stress transformation laws, Principal stress, Stress invariant, Stress ellipsoid, maximum and minimum shear stress, Mohr's Circles for stresses	3
Strain: Deformation Gradients, Displacement Gradient Deformation tensor, Finite strain tensors	2
Small deformation theory-infinitesimal strain tensor, Relative displacement, Linear rotation tensor, Interpretation of the linear strain tensors	3
Strength ratio, Finite strain interpretation, Principal strains, Strain invariant	3
Cubical dilatation, Compatibility equation for linear strain, Strain energy function	3

Linear Elastic Solid: Hook's law. Saint –Venant's principal. Isotropic media. Elastic constrains. Moduli of elasticity of isotropic bodies and their relation. Beltrami-Michell compatibility equations for stress components. Plain state of stress and strain, Airy's stress function. Navier's equations. (The concept of elasticity in terms of strain and stress.)	6
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. R.N.Chatterjee, Mathematical Theory of Continuum Mechanics, Narosa Publishing House.
2. A.J.M. Spencer, Continuum Mechanics, Longman, 1980.

Reference Books:

1. T.J.Chung, Continuum Mechanics, Prentice – Hall.
2. Gedrge R. Mase, Continuum Mechanics: Schaum's Outline of Theory and Problem of Continuum Mechanics, McGraw Hill.

GROUP-B

LINEAR ALGEBRA

Course Objectives:

The main objectives of this course are:

1. To provide an in-depth understanding of advanced concepts of linear algebra including dual spaces, linear operators, and canonical forms.
2. To develop the ability to analyze and apply inner product spaces, orthogonality, and spectral theorem to solve mathematical and applied problems.
3. To enhance problem-solving and analytical skills through the study of bilinear and quadratic forms and their geometric and computational interpretations.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the concepts of dual spaces, eigenvalues and eigenvectors, diagonalization, canonical forms, inner product spaces, and bilinear and quadratic forms, along with their properties and theoretical foundations.

CO2: Apply the principles of linear transformations, spectral theorem, Gram–Schmidt process, and reduction of quadratic forms to solve problems in linear algebra and related mathematical applications.

Syllabus:

Course content	No. of Lectures
Dual Space: The dual Space, Dual Basis, Double Dual, Transpose of a Linear Transformation and its matrix w. r. t. dual basis	6
Diagonalization and Canonical Forms: Eigen spaces of a linear operator, diagonalizability, invariant subspaces, Projection operator and its relation with the eigen values of a linear operator, the minimal polynomial for a linear operator, primary decomposition theorem, Nilpotent operator, Invariant factors and elementary divisors, Rational and Jordan canonical forms of a linear operator.	10

Inner Product Spaces: Inner product spaces, orthogonal and orthonormal inner product spaces, Gram-Schmidt orthogonalization process, the adjoint of linear operator, normal and self-adjoint operators, Hermitian, unitary and normal transformations, spectral theorem.	7
Bilinear Forms: Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic form, rank, signature and index of a quadratic form, reduction of a quadratic form to its normal form, Sylvester's law of inertia.	7
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. Prentice-Hall of India, 1991.
2. S. Freidberg. A. Insel, and L Spence, Linear Algebra, Fourth Edition, Pearson, 2015.

Reference Books:

1. I. N. Herstein, Topics in Algebra, 2nd Ed., John Wiley & Sons, 2006.
2. Ramachandra Rao and P. Bhimasankaram, Linear Algebra, Hindustan, 2000.
3. S. Lang, Linear Algebra, Springer-Verlag, New York, 1989.
4. M. Artin, Algebra, Prentice Hall of India, 1994.
5. G. Strang, Linear Algebra and its Applications, Brooks/Cole Ltd., New Delhi, Third Edition, 2003.
6. K. B. Datta, Matrix and Linear Algebra, Prentice Hall India Pvt.

MAJOR ELECTIVE (DSE)

Major Elective – 04
Fluid Mechanics and MHD
[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

FLUID MECHANICS

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental principles and governing equations of fluid mechanics and their physical significance.
2. To develop analytical and mathematical skills to model, derive, and solve fluid flow problems under different physical conditions.
3. To familiarize students with real and ideal fluids, Navier–Stokes equations, boundary conditions, and applications in engineering and applied sciences.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of fluid mechanics, including types of fluids and flows, continuum hypothesis, coordinate systems, and the derivation and physical interpretation of governing equations such as continuity, momentum, and energy equations.

CO2: Apply non-dimensionalization techniques, Reynolds number analysis, and exact solutions of the Navier-Stokes equations to solve practical fluid flow problems in engineering applications.

Syllabus:

Course content	No. of Lectures
Basics: The concept of a fluid mechanics, fluid as continuum, Units of Measurements, Viscosity, classification of fluid (real/ideal fluid, nanofluid, ferrofluid, compressible/ incompressible, Newtonian/Non-Newtonian), types of fluid flow (rotational/irrotational flows, steady/unsteady flow, uniform/non uniform Flow, 1D/2D/3D flow, laminar or turbulent flow). **Flow Visualization**: stream functions, streamlines, streamtubes, Pathlines, vorticity, iso-vorticity line.	7
Preliminaries for the derivation of governing equation: Coordinate systems (Lagrangian description and Eulerian description), Models of the flow (Finite Control Volume and Infinitesimal Fluid Element), Substantial Derivative, Source of Forces, Examples	5

Derivation of Governing Equations along with Initial and Boundary Conditions: Derivation of Continuity Equation, Four Forms (non-conservation/conservation, partial differential /integral) of Continuity Equations, Derivation of Momentum (Navier-Stokes) Equation for a compressible viscous flow in non-conservation and conservation forms, Special case (Incompressible Newtonian Fluid), Physical interpretation of each term, Equivalent forms of Navier-Stokes in Spherical and Cylindrical Coordinate system, Derivation of Energy Equation, Similarity/dissimilarity between Navier-Stokes and Energy equations, Associated typical Initial and Boundary Conditions for velocity and thermal fields.	9
Inviscid fluid Flows: Euler's equation of motion, Bernoulli's equation and its applications	5
Non-dimensionalization: Non-dimensionalization, Reynolds number, Importance of Reynolds number to Navier-Stokes Equation, Exact Solution of Navier-Stokes Equation (Couette-Poisseuille flow)	4
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. Fluid Mechanics. P. K. Kundu & I. M. Cohen, 4th edition (Academic Press, 2008)
2. Computational Fluid Dynamics (The Basics with Applications), John D. Anderson Jr., McGraw-Hill Series in Mechanical Engineering.

Reference Books:

1. An Introduction to Fluid Dynamics , G. K. Batchelor, Cambridge University Press.
2. Fluid Mechanics (4th Edition), Frank M. White, WCB McGraw-Hill.

GROUP-B

MAGNETO HYDRODYNAMICS (MHD)

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts and governing equations of magneto hydrodynamics (MHD) combining fluid dynamics and electromagnetism.
2. To develop the ability to model and analyze MHD flow problems under various physical and boundary conditions.
3. To provide understanding of magnetic effects such as Lorentz force, Alfven waves, Hall currents, and their implications in engineering and astrophysical contexts

Syllabus:

Course content	No. of Lectures
Maxwell's electromagnetic field equations when medium in motion.	3
Lorentz's force. The equations of motion of a conducting fluid. Basic equations.	3
Simplification of the electromagnetic field equation.	3

Magnetic Reynolds number. Alfven theorem.	3
Magnetic body force. Ferraro's law of isorotation.	3
Laminar Flow of a viscous conducting liquid between parallel walls in transverse magnetic fields.	3
M.H.D. Flow Past a porous flat plate without induced magnetic field.	3
MHD Couelte Flow under diff4th Editionerent boundary conditions	3
Magneto hydro dynamics waves. Hall currents.	3
MHD flow past a porous flat plate without induced magnetic field.	3
Total lectures	**30**

Further Readings:

Text Book:

1. P. A. Davidson, An Introduction to Magneto-hydrodynamics, 2001, Cambridge University Press

Reference Book:

1. Hosking, Roger J., Dewar, Robert, 2016, Fundamental Fluid Mechanics and Magneto-hydrodynamics, Springer

OR

Major Elective – 04

Calculus on R^n and Operator Theory

[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

CALCULUS ON R^n

Course Objectives:

The main objectives of this course are:

1. To develop a strong understanding of scalar and vector fields, differentiability, and the geometric interpretation of multivariable functions.
2. To enable students to apply derivative-based theorems, such as the mean value, Taylor's, inverse, and implicit function theorems, to analyze functions of several variables.
3. To build analytical and problem-solving skills in multivariable calculus with applications to higher mathematics and applied sciences.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the concepts of scalar and vector fields, continuity, directional and total derivatives, Jacobian matrix, and the chain rule in multivariable functions.

CO2: Apply the mean value theorem, Taylor's formula, inverse and implicit function theorems to solve problems and analyze functions of several variables.

Syllabus:

Course content	No. of Lectures
Scalar and vector fields; continuity of multivariable functions; directional derivative.	3
Total derivative; total derivative in terms of partial derivatives; Jacobian matrix; chain rule; matrix form of chain rule.	4
Mean value theorem for differentiable functions; sufficient condition for differentiability; equality of mixed partial derivatives.	4
Taylor's formula for functions from $\mathbb{R}^n \to \mathbb{R}^1$; applications.	3
Inverse function theorem; implicit function theorem; applications.	6
Total Lecture	**20 Hrs**

Further Readings:

Text Books:

1. T. M. Apostol, Mathematical Analysis, Narosa Publishing House, New Delhi.
2. T. Marsden, Basic Multivariate Calculus, Springer, 2013.

Reference Books:

1. C. Goffman, Calculus of Several Variables, A Harper International Student reprint, 1965.
2. Tom M. Apostol, Calculus, Volume II, Wiley India Pvt. Limited, 2002.
3. Michael Spivak, Calculus on Manifolds, Westview Press, 1965.
4. James R. Munkres, Analysis on Manifolds, Westview Press, 1990.

GROUP-B

OPERATOR THEORY

Course Objectives:

The main objectives of this course are:

1. To introduce the concepts of resolvent set, spectrum, spectral radius, and numerical range associated with bounded linear operators.
2. To develop analytical understanding of spectral properties, Banach algebras, and their applications in functional analysis.
3. To enable students to apply spectral theorems, numerical radius relations, and algebraic structures to solve advanced operator theory problems.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the concepts of resolvent set, spectrum, spectral radius, numerical range, and the properties of bounded linear operators in normed and Banach spaces.

CO2: Apply the spectral mapping theorem, numerical radius relations, and properties of normed and Banach algebras to analyze and solve problems in functional analysis.

Syllabus:

Course content	No. of Lectures
Resolvent set of a bounded linear operator; examples and basic properties.	**3**
Spectrum of a bounded linear operator; point spectrum (eigenvalues); continuous spectrum; residual spectrum; approximate point spectrum; illustrative examples.	**4**
Spectral radius of a bounded linear operator; Gelfand's formula; examples and applications.	**4**
Spectral properties of bounded linear operators; spectral mapping theorem for polynomials; problem-solving and examples.	**4**
Numerical range; convexity of numerical range (Toeplitz–Hausdorff theorem); closure of numerical range contains the spectrum; examples.	**4**
Numerical radius; relation between numerical radius and norm of a bounded linear operator; applications.	**3**
Normed algebra; Banach algebra; examples; singular and non-singular elements.	**4**
Spectrum of an element in a Banach algebra; spectral radius of an element; illustrative examples.	**3**
Total Lecture	**30**

Further Readings:

Text Books:

1. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons.
2. G. Bachman and L. Narici, Functional Analysis, Dover Publications.

Reference Books:

1. Kadison and Ringrose, Fundamentals of operator theory, Vol. I and II, Academic press.
2. A Taylor and D. Lay, Introduction to Functional Analysis, John Wiley and Sons.
3. N. Dunford and J.T. Schwarts, Linear Operators – 3, John Wiley and Sons.
4. P.R. Halmos, Introduction to Hilbert space and the theory of Spectral Multiplicity, Chelsea Publishing Co., N.Y.

MAJOR ELECTIVE- 05

[to be studied by Honours students only]

Major Elective – 05

Partial Differential Equations and Generalized Functions

[THEORY; CREDITS: 04; FM- 75; 60L]

PARTIAL DIFFERENTIAL EQUATIONS AND GENERALIZED FUNCTIONS

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts, formation, and classification of partial differential equations (PDEs) of various types.
2. To develop analytical and problem-solving skills for solving first-order and higher-order PDEs with different initial and boundary conditions.
3. To familiarize students with classical solution techniques such as separation of variables, D'Alembert's solution, and Fourier series methods.
4. To study Dirichlet and Neumann boundary value problems, Poisson's integral formula, and Green's functions for Laplace's equation.
5. To understand the concept of generalized functions, including Dirac delta function, and apply Fourier transforms to solve PDEs arising in applied sciences.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand and classify first-order and higher-order partial differential equations, including semi-linear, quasi-linear, and constant coefficient equations.

CO2: Apply analytical methods such as separation of variables and D'Alembert's solution to solve classical PDEs, including Laplace, wave, and heat equations.

CO3: Solve Dirichlet and Neumann boundary value problems, utilize Poisson's integral formula, and apply Green's functions to two-dimensional Laplace equations.

CO4: Understand the theory and operations of generalized functions, including Dirac delta function, and apply Fourier transforms to solve problems in PDEs.

Syllabus:

Course content	No. of Lectures
First order PDE in two independent variables and the Cauchy problem. Semi-linear and quasilinear equations in two-independent variables	5
Higher order PDE with constant coefficient	6
Adjoint and self-adjoint equations	4
Laplace, Wave and Heat equations	5
Equation of vibration of a string. Existence. Uniqueness and continuous dependence of the solution on the initial conditions. Method of separation of variables. D'Alembert's solution for the vibration of an infinite string. Domain of dependence	5
Heat equation - Heat conduction problem for an infinite rod – Heat conduction in a finite rod - existence and uniqueness of the solution	7
Fundamental solution of Laplace's equations in two variables. Harmonic function.	5

Characterization of harmonic functions by their mean value property. Uniqueness. Continuous dependence and existence of solutions. Method of separation of variables for the solutions of Laplace's equations. Dirichlet's and Neumann's problems	
Solution of Dirichlet's and Neumann's problems for some typical problems, like a disc and a sphere. Poisson's integral formula	5
Green's functions for the Laplace equations in two dimensions	5
Test functions. Regular and singular generalized functions. Dirac delta function. Operations on generalized functions. Derivatives. Transformation properties of generalized functions. Fourier transform of generalized functions	7
Total Lecture	**60 hours**

Further Readings:

Text Books:

1. Y. Pinchover and J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press, 2005.
2. S. Rao, Introduction to Partial Differential Equations, 3rd Edition, PHI Learning Private Limited, New Delhi, 2011.
3. J. J. Duistermaat and J. A. C. Kolk, Distributions Theory and Applications, Birkhäuser Basel, 2010.

Reference Books:

1. F. John, Partial Differential Equations, Springer-Verlag, New York, 1978.
2. Gelfand, I. M. and Shilov, G.E., Generalized Functions, AMS, Recent Edition, 2016.

OR

Major Elective – 05
Fuzzy Mathematics and Soft Computing
[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

FUZZY MATHEMATICS

Course Objectives:

The main objectives of this course are:

1. To introduce the basic concepts and properties of fuzzy sets, fuzzy relations, and fuzzy numbers for modeling uncertainty.
2. To develop analytical skills in applying fuzzy measures, defuzzification techniques, and fuzzy decision-making methods.
3. To apply fuzzy ranking and fuzzy linear programming techniques for solving real-life optimization and management problems.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of fuzzy sets, fuzzy relations, fuzzy numbers, and fuzzy measures, along with their properties and representations.

CO2: Apply defuzzification techniques, fuzzy ranking methods, and fuzzy linear programming to solve decision-making and optimization problems in uncertain environments.

Syllabus:

Course content	No. of Lectures
Basic concept and definition of fuzzy sets. Standard fuzzy set operations and their properties.	**4**
Basic terminologies such as Support, α-Cut, Height, Normality, Convexity, etc..	**3**
Fuzzy relations, Properties of α-Cut, Zadeh's extension principle, Interval number and its arithmetic.	**4**
Fuzzy numbers and their representation, Arithmetic of fuzzy numbers..	**4**
Fuzzy measures. Evidence theory. Necessity measure. Possibility measure. Possibility distribution.	**3**
Defuzzification: centre of area, centre of maxima, and mean of maxima methods	**2**
Decision Making in Fuzzy Environment- Individual decision making. Multiperson decision making. Multicriteria decision making. Multistage decision making.	**5**
Fuzzy ranking methods. Fuzzy linear programming.	**5**
Total Lecture	**30**

Further Readings:

Text Books:

1. Klir, G.J. and Yuan, B.(1995) Fuzzy sets and fuzzy logic, Prentice-Hall of India, New Delhi.
2. Dubois, D.J.(1980) Fuzzy sets and systems: theory and applications, Academic press.

Reference Books:

1. Bector, C.R. and Chandra, S. (2005) Fuzzy mathematical programming and fuzzy matrix games, Berlin: Springer.
2. Zimmermann, H. J. (1991) Fuzzy set theory and its Applications, Allied Publishers Ltd, New Delhi

GROUP-B

SOFT COMPUTING

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts and architectures of soft computing techniques such as neural networks, genetic algorithms, and fuzzy logic.
2. To develop problem-solving and optimization skills using biologically inspired and uncertainty-based computing methods.
3. To enable students to apply soft computing tools in real-world engineering, scientific, and decision-making problems.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of soft computing, including artificial neural networks, genetic algorithms, and fuzzy logic, along with their architectures, principles, and applications.

CO2: Apply soft computing techniques to solve real-life optimization, decision-making, and problem-solving tasks in engineering and scientific domains.

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Syllabus:

Course content	No. of Lectures
Introduction Evolution of Computing: Soft Computing Constituents, "Soft" versus "Hard" computing, Characteristics of Soft computing, Some applications of Soft computing techniques	5
Artificial Neural Network Biological neurons and their working, Simulation of biological neurons to problem-solving, Different ANNs architectures, Learning rules and various activation functions, Basic models of ANN, Single layer Perceptrons, and Applications of ANNs to solve some real-life problems.	10
Genetic Algorithm Goals of optimization, Concept of "Genetics" and "Evolution" and its application to probabilistic search techniques, Basic GA framework and different GA architectures, Working Principle, Various Encoding methods, Fitness function, GA Operators- Reproduction, Crossover, Mutation, Solving single-objective optimization problems using GAs.	10
Fuzzy Logic Fuzzy relations, rules, propositions, implications and inferences, De-fuzzification techniques, Fuzzy logic controller design, and some applications of Fuzzy logic.	5

3

	Total Lecture	**30 hours**

Further Readings:

Text Books:

1. Sivanandam, S.N. and Deepa, S.N., 2007. PRINCIPLES OF SOFT COMPUTING, John Wiley & Sons
2. Jang, J.S.R., Sun, C.T. and Mizutani, E., 1997. Neuro-fuzzy and soft computing; a computational approach to learning and machine intelligence. Prentice Hall, Upper Saddle River NJ (1997).

Reference Books:

1. Ogly Aliev, R.A. and Aliev, R.R., 2001. Soft computing and its applications, World Scientific.
2. Karray, F.O. and De Silva, C.W., 2004. Soft computing and intelligent systems design: theory, tools, and applications. Pearson Education.

OR

Major Elective – 05

Integral Transforms and Topology

[Credits: 3T FM – 40 (45L) + 1P FM-20 (30L)]

GROUP-A

INTEGRAL TRANSFORMS

Course Objectives:

The main objectives of this course are:

1. To introduce the theoretical foundations and mathematical formulations of Fourier, Laplace, and Wavelet transforms.
2. To understand the properties, inversion formulas, and convolution theorems associated with various integral transforms.
3. To develop problem-solving skills for applying these transforms to differential equations, signal processing, and image analysis.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts and properties of Fourier, Laplace, and Wavelet transforms, including inversion formulas, convolution, and Parseval's relation.

CO2: Apply Fourier, Laplace, and Wavelet transforms to solve ordinary and partial differential equations, and analyze signals and images in engineering and scientific applications.

Syllabus:

Course content	No. of Lectures
Fourier Transform: Fourier Transform, Properties of Fourier transform, Inversion formula, Convolution, Parseval's relation, Multiple Fourier transform, Bessel's inequality, Application of transform to Heat, Wave and Laplace equations (Partial differential equations).	10
Laplace Transform: Laplace Transform, Properties of Laplace transform, Inversion formula of Laplace transform (Bromwich formula), Convolution theorem, Application to ordinary and partial differential equations.	10
Wavelet Transform: Time-frequency analysis, Multi-resolution analysis, Spline wavelets, Sealing function, Short-time Fourier transforms, Wavelet series, Orthogonal wavelets, Applications to signal and image processing.	10
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. P.P.G.Dyke, An Introduction to Laplace Transforms and Fourier Series, Springer, 2001, Springer-Verlag London Limited.
2. Lokenath Debnath, Integral Transforms and Their Applications, CRC Press, 1995.
3. D. F. Walnut, An introduction to Wavelet Analysis, Birkhauser, 2002.
4. R.P. Kanwal, Linear Integral Equations; Theory & Techniques, Academic Press, NewYork, 1971.

Reference Books:

1. I.N. Sneddon: The use of Integral Transforms, Tata McGraw Hill, Publishing Company Ltd, New Delhi, 1974

2. H.T. Davis: Introduction to Nonlinear Differential and Integral Equations, Dover Publications, 1962.
3. M.L. Krasnov: Problems and Exercises Integral Equations, Mir Publication Moscow, 1971.
4. F.B. Hildebrand: Methods of Applied Mathematics, Dover Publication, 1992.

GROUP-B

TOPOLOGY

Course Objectives:

The main objectives of this course are:

1. To introduce the foundational concepts and structures of topological spaces, including open and closed sets, bases, continuity, and convergence.
2. To develop an understanding of key topological properties such as connectedness, compactness, and countability.
3. To apply separation axioms, metrization theorems, and topological constructions to analyze mathematical spaces and their applications in analysis.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of topological spaces, including open and closed sets, neighborhoods, bases, subspaces, continuity, connectedness, and compactness.

CO2: Apply separation axioms, metrization theorems, and topological properties to analyze and solve problems in mathematical analysis and related fields.

Syllabus:

Course content	No. of Lectures
Topological spaces, Examples, open sets, closed sets, neighborhoods, basis, sub-basis	**5**
Subspace topology, Limit points, Closure, interiors	**4**
Continuous functions, homeomorphisms	**3**
Product topology, metric topology, order topology, Quotient Topology	**3**
Connected spaces, connected subspaces of the real line, Components and local connectedness	**3**
Compact spaces, Local–compactness, Tychonoff's theorem on compact spaces	**4**
First and second countable spaces, Hausdorff spaces, Regularity, Complete Regularity, Normality	**5**
Urysohn Lemma, Urysohn Metrization Theorem, Tietze Extension theorem (statement only)	**3**
Total Lecture	**30hrs**

Further Readings:

Text Books:

1. J. R. Munkres, Topology, 2nd Ed., Pearson Education (India), 2000.
2. M. A. Armstrong, Basic Topology, Springer (India), 1983.

Reference Books:

1. K. D. Joshi, Introduction to General Topology, New Age International Private Limited, New Delhi, 2014.
2. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York, 1963.

MAJOR ELECTIVE- 06

[to be studied by Honours students only]

Major Elective – 06

Advanced Complex Analysis and Machine Learning

[THEORY; CREDITS: 04; FM- 75; 60L]

GROUP-A

ADVANCED COMPLEX ANALYSIS

Course Objectives:

The main objectives of this course are:

1. To introduce the theory of complex mappings and transformations, including linear and bilinear transformations.
2. To develop understanding of conformal mappings and their geometric and physical interpretations.
3. To apply conformal mapping and analytic continuation techniques to solve boundary value problems in physical sciences and engineering.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of complex mappings, including linear and bilinear transformations, branches of functions, Riemann surfaces, and analytic continuation.

CO2: Apply conformal mapping techniques to solve boundary value problems in heat conduction, fluid flow, and other two-dimensional physical systems.

Syllabus:

Course content	No. of Lectures
Mapping by Elementary Functions: Linear Transformations, Translation, Rotation-Dilation, Contraction, Inversion, Mappings by 1/z, Bilinear/Linear Fractional Transformations and its properties, An Implicit Form: Cross ratios, Fixed points of Bilinear Transformation, Normal/Canonical Form of Bilinear Transformation. Mappings of the Upper Half Plane, The Transformation w = sin z, Mappings by z^2 and Branches of $z^{\frac{1}{2}}$, Square Roots of Polynomials, Riemann Surfaces	10
Conformal Mapping: Preservation of Angles, Scale Factors, Local Inverses, Harmonic Conjugates, Transformations of Harmonic Functions, Transformations of Boundary Conditions	8
Application of Conformal Mapping: steady temperature, steady temperature in a half plane and related problems, two-dimensional fluid flow	6
Analytic Continuation: Direct and indirect analytic continuation, indirect analytic continuation using power series and along curve, regular and singular points.	6
Total Lecture	**30hours**

Further Readings:

Text Books:

1. Complex Variable and Applications, J. W. Brown and R. V. Churchill, 8th Edition, McGraw Hill.
2. A Text Book of Complex Analysis, P.K.Nayek and M.R.Seikh, Universities Press, 2018.

Reference Books:

1. Foundations of Complex Analysis, S. Ponnusamy, Narosa, 1995.
2. Functions of one Complex Variable, J. B. Conway, 2nd edition, Narosa, 1997.

GROUP-B

MACHINE LEARNING

Course Objectives:

The main objectives of this course are:

1. To introduce the foundational principles, models, and algorithms of machine learning and their mathematical underpinnings.
2. To develop the ability to implement supervised, unsupervised, and reinforcement learning models for data-driven problem solving.
3. To enable students to critically analyze and interpret the performance of machine learning algorithms in real-world applications.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts, models, and algorithms of machine learning, including supervised, unsupervised, and reinforcement learning, as well as computational learning theory.

CO2: Apply regression, classification, clustering, and reinforcement learning techniques to solve real-world problems and analyze data-driven decision-making scenarios.

Syllabus:

Course content	No. of Lectures
Basic definitions; types of learning; hypothesis space and inductive bias; evaluation and cross-validation; computational learning theory; PAC learning model; sample complexity; VC dimension; ensemble learning; numerical computation and optimization; introduction to machine learning packages.	9
Linear regression with one variable; linear regression with multiple variables; bias/variance tradeoff; regularization; variants of gradient descent; maximum likelihood estimation (MLE); maximum a posteriori (MAP); applications.	6
Logistic regression; support vector machines (SVM); kernel functions and kernel SVM; Bayesian regression; binary decision trees; random forests; Naïve Bayes; applications.	6
k-Means clustering; k-Nearest Neighbors (kNN); Gaussian mixture models (GMM); expectation-maximization algorithm; applications.	6
Introductory concepts of reinforcement learning; Markov decision processes (MDP); examples and applications in sequential decision-making.	6
Total Lectures	**30hrs**

Further Readings:

Text Books:

1. Alpaydin, Ethem. Introduction to machine learning. MIT press, 2020.
2. Daumé, Hal. A course in machine learning. Alanna Maldonado, 2023.

References Books:

1. Shalev-Shwartz, Shai, and Shai Ben-David. Understanding machine learning: From theory to algorithms. Cambridge University Press, 2014.
2. Pradhan, Manaranjan, and U. Dinesh Kumar. Machine learning using Python. Wiley, 2019.

OR

Major Elective – 06

Stochastic Process and Statistical Methods

[THEORY; CREDITS: 04; FM- 75; 60L]

STOCHASTIC PROCESS AND STATISTICAL METHODS

Course Objectives:

The main objectives of this course are:

1. To introduce the basic concepts and classifications of stochastic processes, including Markov chains and continuous-time Markov processes.
2. To explain the long-term and limiting behavior of stochastic models and their applications in various scientific and engineering contexts.
3. To develop an understanding of multiple regression, correlation, and estimation techniques for analyzing multivariate data.
4. To familiarize students with the principles and applications of Analysis of Variance (ANOVA) for interpreting experimental and observational data.
5. To introduce time series analysis and forecasting models (AR, MA, ARMA) for modeling stochastic trends and making data-driven predictions.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of stochastic processes, including Markov chains, continuous-time processes, birth-death processes, Wiener process, and branching processes.

CO2: Analyze the limiting behavior, stationary distributions, and applications of Markov processes in discrete and continuous state spaces.

CO3: Apply multiple regression, correlation analysis, linear estimation, and ANOVA techniques to model and interpret real-world data.

CO4: Understand and implement time series analysis methods, including smoothing, AR, MA, and ARMA models, for forecasting and data-driven decision-making.

Syllabus:

Course content	No. of Lectures
Markov Chains: Markov chains with finite and countable state space; classification of states; limiting behavior of n-step transition probabilities; stationary distribution; random walk; gambler's ruin problem; examples and applications.	10
Continuous-Time Markov Processes: Markov processes in continuous time; birth and death processes; examples and applications.	8
Markov Processes with Continuous State Space: Wiener process; branching process; applications in stochastic modelling; illustrative examples.	8
Multiple Regression and Correlation: Multiple regression; partial correlation; multiple correlations; estimation and interpretation of coefficients; examples and problem-solving.	8
Linear Estimates: Linear estimation theory; ordinary and best linear unbiased estimates; applications.	8
Analysis of Variance (ANOVA): One-way and two-way ANOVA; assumptions; interpretation of results; applications.	8

Time Series Analysis: Introduction to time series analysis; components of a time series; moving averages; smoothing techniques. AR, MA, ARMA models; forecasting techniques; examples and applications in stochastic processes.	10
Total Lecture	**60hrs**

Further Readings:

Text Books:

1. J.Medhi, Stochastic Process, New Age International Publisher, 2ed, 1984.
2. Suddhendu Biswas and G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011.

Reference Books:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (1968) Fundamentals of Statistics, Vol. 1 & 2, Calcutta: The World Press Private Ltd.
2. Montgomery, D.C., Peck, E.A. and Geoffrey, G. (2012) Vining, Introduction to Linear Regression Analysis, 5ed, Wiley.

OR

Major Elective – 06

Differential Geometry and Manifold Theory

[THEORY; CREDITS: 04; FM- 75; 60L]

DIFFERENTIAL GEOMETRY

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts of curves, surfaces, and their geometric properties such as curvature and torsion.
2. To develop an understanding of affine and Riemannian connections, covariant differentiation, and curvature tensors.
3. To apply the concepts of differential geometry in the analysis of geometric structures, geodesics, and conformal symmetries.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of curves, surfaces, and Riemannian manifolds, including arc-length, fundamental forms, curvature, torsion, and affine connections.

CO2: Apply the concepts of covariant differentiation, Riemann curvature, Ricci tensor, Weyl tensor, and geodesics to analyze geometric structures and solve problems in differential geometry.

Syllabus:

Course content	No. of Lectures
Curves in plane and space; arc-length; reparameterization; closed curves; simple closed curves; Four-vertex theorem; examples and applications.	**6**
Regular surfaces; tangents and normals; orientability; first fundamental form; developable surfaces; second fundamental form; Gauss's formula; Weingarten formula; Gauss & Codazzi equations; curvatures.	**6**
Affine connection (Koszul); torsion and curvature tensor fields; covariant differentiation; parallel transport; illustrative examples.	**6**
Riemannian manifold; Riemannian connection; Riemann curvature tensor; Bianchi identity; Ricci tensor; scalar curvature; Einstein manifold; examples.	**6**
Semi-symmetric metric connection; Weyl conformal curvature tensor; conformally symmetric Riemannian manifolds; consequences; geodesics; applications.	**6**
Total Lecture	**30 hours**

Further Readings:

Text Books:

1. A. Pressley, Elementary Differential Geometry, Springer, 2nd Volume, 2010.
2. S. Kumaresan, A Course in Differential Geometry and Lie Groups, Hindustan Book Agency.

Reference Books:

1. W.M. Boothby, An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press, Revised 2003.

MANIFOLD THEORY

Course Objectives:

The main objectives of this course are:

1. To introduce the fundamental concepts of topological and differentiable manifolds and their importance in modern geometry and mathematical physics.
2. To develop an understanding of tangent and cotangent spaces, vector fields, and submanifolds, and their applications in geometric analysis.
3. To enable students to apply smooth maps, push-forward and pull-back operations, and differential forms to study transformations and structures on manifolds.

Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of topological and differentiable manifolds, tangent and cotangent spaces, vector fields, and submanifolds.

CO2: Apply the theory of smooth maps, push-forward and pull-back operations, differential forms, and transformation groups to analyze geometric structures on manifolds.

Syllabus:

Course content	**No. of Lectures**
Topological manifolds; differentiable manifolds; smooth maps and diffeomorphisms; curves in a manifold; tangent vectors; examples and applications.	**5**
Vector fields; integral curves of a vector field; push-forward mapping; f-related vector fields; immersion and submersion; submanifolds; examples.	**5**
Four-parameter group of transformations (local and global); complete vector fields; illustrative examples and applications.	**5**
Cotangent space; r-forms; exterior product; exterior differentiation; pull-back of differential forms; examples and applications.	**5**
Total Lecture	**20 hours**

Further Readings:

1. L.W. Tu, An Introduction to Manifolds, Springer, 2007.

Reference Books:

1. J.M. Lee, Introduction to Smooth Manifolds, Springer, 2003.
2. S. Lang, Introduction to Differential Manifolds, John Wiley & Sons, New York, 1962.

Related Online Contents [MOOC, SWAYAM, NPTEL, other Websites]

PROJECT / DISSERTATION (RD)

[to be undertaken by students opting for and eligible for Hons. with Research]

PROJECT / DISSERTATION
Credit: 8;
Full Marks: 150

Structure of the project / dissertation

Preliminary Pages

- Title Page: Includes name of the student, university, degree, and submission date.
- Certificate/Declaration: Signed statement of originality and supervisor's approval
- Abstract: A 250-350 word summary covering research problem, methodology, and core findings.
- Acknowledgements: To supervisors and others, if any.
- Table of Contents: Clear hierarchical mapping of chapters with page number
- List of Abbreviations: Specialized terms, if any

Introduction

- Background & Context: Situates the topic in historical or theoretical context.
- Research Problem & Objectives: The specific question or gap the research is addressing.
- Thesis Statement/Hypothesis: The core argument the dissertation intends to prove.
- Scope and Significance: Why the study matters.
- Literature Review & Theoretical Framework

Literature Review: Analyzes existing scholarly works to show the gap the study fills.

- Theoretical Framework: Identifies the philosophers, critics, or schools of thought shaping the analysis in the dissertation.

Methodology

- Describes *how* the research was conducted - Anyone or a combination of textual analysis/ archival research/ conducting interviews/ ethnographic/semi-ethno-graphic research involving both textual analysis and field visit etc.
- Thematic or Analytical Chapters

The Core Body: Usually 3 to 4 chapters focusing on the core concerns of the study.

- Structure: Each chapter introduces its specific theme, analyzes primary and secondary sources, and contributes to the overarching thesis.

Conclusion

- Summary & Synthesis: Recaps your main points without simply repeating them.

Final Verdict: Answers the research questions posed in the introduction.

Future Scope: Suggests how future scholars can build upon your work.

- Works Cited/ Reference, and/or Bibliography: A comprehensive list of all primary and secondary sources cited as per the latest MLA style.

Appendices: Transcripts, interview logs, or raw archival data, if any.

Marks distribution-

Sl. No	**Particulars**	**Marks**
1	Research Project / Dissertation Report	70
	▪ Proposal and Abstract (along with some keywords)	10
	▪ Literature Review &Theoretical Framework	10
	▪ Methodology and Research design	10
	▪ Thematic Analysis (Chapter-wise)	20
	▪ Report Quality	20
2	Seminar Presentation	30
3	Viva-Voce	50
Total		**150**

__MINOR (MI)__

Minor-08
Probability and Statistics

[THEORY; CREDITS: 04; FM- 75; 60L]

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand fundamental probability concepts, including probability axioms, random variables, and probability distributions.
b) Analyze discrete and continuous probability distributions, including binomial, Poisson, normal, and exponential distributions.
c) Evaluate joint distributions, conditional expectations, and correlation coefficients, and apply regression analysis for two variables.
d) Apply statistical theorems such as **Chebyshev's inequality, laws of large numbers, and the central limit theorem** in real-world scenarios.
e) Understand the fundamentals of Markov chains, including **state classification and Chapman-Kolmogorov equations**.
f) Perform statistical inference through **sampling distributions, parameter estimation, and hypothesis testing**.

Course contents:

Unit 1: Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential.

Unit 2: Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.

Unit 3: Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central limit theorem for independent and identically distributed random variables with finite variance, Markov chains, Chapman-Kolmogorov equations, classification of states.

Unit 4: Random Samples, Sampling Diatributions, Estimation of parameters, Testing of hypothesis.

Reference Books

6. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
7. Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
8. Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
9. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007
10. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

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