Curriculum and Credit Framework 2025 for PG Programs based on NEP 2020
Vidyasagar University
For
Applied Mathematics

	M.Sc. 1st Year		
Sem	**Course**	**Credit**	**Marks**
I	MTM 101: Measure Theory MTM 102: Complex Analysis	2 (1-1-0) 2 (1-1-0)	50
	MTM 103: Classical Mechanics MTM 104: Abstract Algebra	2 (1-1-0) 2 (1-1-0)	50
	Global No (MTM103): Research Methodology and Ethics	4 (3-1-0)	50
	MTM 105: Elective-1: Data Science & Graph Theory MTM 105: Elective-II: Ordinary Differential Equations	4 (3-1-0)	50
	MTM 106: Elective-I: Programming in Python MTM 106: Elective-II: Programming in C++	4 (3-1-0)	50
	MTM-IKS: Indian Knowledge System (IKS)	2 (1-1-0)	25
	Global name: Vidyasagar: Life and Philosophy	Compulsory non-Credit course	
	Total	**22**	**275**
II	MTM 201: Continuum Mechanics MTM 202: Linear Algebra	2 (1-1-0) 2 (1-1-0)	50
	Electives: MTM 203: Elective-I: Fluid Mechanics & MHD MTM 203: Elective-II: Calculus on R^n & Operator Theory	4 (3-1-0)	50
	Electives: MTM 204: Elective-I: Partial Differential Equations and Generalized Functions MTM 204: Elective-II: Fuzzy Mathematics & Soft Computing	4 (3-1-0)	50
	Electives: MTM 205: Elective-I: Advanced Complex Analysis & Machine Learning MTM 205: Elective-II: Stochastic Process and Statistical Methods	4 (3-1-0)	50
	Electives: MTM 206: Elective-I: Integral Transforms & Topology MTM 206: Elective-II: Differential Geometry & Manifold Theory	4 (3-1-0)	50
	Field Visit / Industry Visit /Case Study / Hands-on Practical/ Skill Enhanced Course	2 (0-0-4)	25

Sem	Course	Credit	Marks
	MTM 207: Elective I: Hands-on Practical in Python MTM 207: Elective II: Hands-on Practical in C++		
	Total	**22**	**275**
	Total: 1st Year of PG	***44***	***550***
	M.Sc. 2nd Year		
Sem	**Course**	**Credit**	**Marks**
III	MTM 301: Functional Analysis	4 (3-1-0)	50
	MTM 302: Integral Equation MTM 303: Cryptography	2 (1-1-0) 2 (1-1-0)	50
	Electives: MTM 304: Elective-I: Advanced Optimization MTM 304: Elective-II: Dynamical Meteorology: Thermodynamics in Atmosphere MTM 304: Elective-III: Linear and Non-Linear Dynamical Systems	4 (3-1-0)	50
	Electives: MTM 305: Elective-I: Operational Research Modeling-I MTM 305: Elective-II: Dynamical Oceanology: Advanced Wave Hydrodynamics MTM 305: Elective-III: Computational Fluid Dynamics	4 (3-1-0)	50
	MTM 306: MOOCs from SWAYAM	4 (3-1-0)	50
	MTM 307: Social Service / Community Engagement	2 (0-0-4)	25
	Total	**22**	**275**
IV	Electives: MTM 401AT: Elective-I: Nonlinear Optimization (Theory) MTM 401AP: Elective-I: Nonlinear Optimization (Practical) MTM 401BT: Elective-II: Dynamical Meteorology: Dynamics in Atmosphere (Theory) MTM 401BP: Elective-II: Dynamical Meteorology: Dynamics in Atmosphere (Practical) MTM 401CT: Elective-III: Mathematical Modeling in Ecological System (Theory) MTM 401CP: Elective-III: Mathematical Modeling in Ecological System (Practical)	2 (1-1-0) (T) 2 (0-0-4) (P)	50
	Electives: MTM 402AT: Elective-I: Operations Research Modeling-II (Theory) MTM 403AP: Elective-I: Operations Research Modeling-II (Practical) MTM 402BT: Elective-II: Dynamical Oceanology: Coastal Processes (Theory)	2 (1-1-0) (T) 2 (0-0-4) (P)	25

	MTM 403BP: Elective-II: Dynamical Oceanology: Coastal Processes (Practical) MTM 402CT: Elective-III: Computational and Semi-Analytical Methods (Theory) MTM 403CP: Elective-III: Computational and Semi-Analytical Methods (Practical)		
	MTM 404: Research Project/Dissertation	8 (0-0-16)	100
	Internship / Capstone Project / Applied Field or Industry Project/ Innovation & Incubation/ Entrepreneurship/ Start-up Proposal or Practice MTM 405: Field Visit (Credit 2) MTM 406: Internship/Industry Project/Innovative Project (Credit 2)	4 (0-0-8)	50
	Electives: MTM 407: Elective-I: Intellectual Property Rights (IPR) MTM 407: Elective-II: Skill-Enhanced Course on **LaTeX**	2 (1-1-0)	25
	Total	**22**	**275**
	Total: 2nd Year of PG	***44***	***550***

Course code	**MTM-102**	**Measure Theory**	**Credit 2(1-1-0)** **Full Marks 25**
Core/Elective/Other		**Core**	**Compulsory**
Course Objectives: The main objectives of this course are to:			
Course Outcomes (COs):			
Syllabus			

	Total Lecture	**20 hours**
Further Readings:		
Related Online Contents [MOOC, SWAYAM, NPTEL, other Websites]		

On successful completion of the program, the student will be able to:

PO1: Advanced Mathematical Knowledge: Acquire advanced knowledge of pure and applied mathematics, including analysis, algebra, topology, mechanics, optimisation, statistics, and computational mathematics.

PO2: Problem Solving and Modelling: Apply mathematical reasoning, abstract thinking, and problem-solving techniques to analyse and model complex real-world problems.

PO3: Computational Proficiency: Develop proficiency in modern computational tools and programming languages (Python, C++, MATLAB, LINGO, etc.) for solving mathematical and interdisciplinary problems.

PO4: Research Skills: Demonstrate research skills through independent inquiry, data collection, analysis, interpretation, and dissemination of findings.

PO5: Interdisciplinary Integration: Integrate mathematical knowledge with other scientific and engineering domains, promoting interdisciplinary problem-solving.

PO6: Communication Skills: Communicate mathematical ideas, proofs, algorithms, and research findings effectively through written, oral, and digital formats.

PO7: Teamwork and Collaboration: Work effectively both independently and collaboratively in academic, professional, and research environments.

PO8: Ethics and Knowledge Systems: Recognise ethical principles, professional responsibilities, and the significance of Indian Knowledge Systems (IKS) and cultural heritage in the development of mathematics.

PO9: Lifelong Learning: Engage in lifelong learning to stay updated with emerging areas in mathematics, data science, machine learning, and scientific research.

PO10: Employability and Entrepreneurship: Demonstrate employability and entrepreneurship skills by applying mathematical knowledge in teaching, research, industry, and innovation.

Program Specific Outcomes (PSOs) for M.Sc. Mathematics

On successful completion of M.Sc. in Applied Mathematics program, the student will be able to:

PSO1. Apply advanced mathematical concepts from analysis, algebra, mechanics, optimization, differential equations, functional analysis, stochastic processes, and topology to theoretical and practical problems.

PSO2. Use computational and algorithmic methods, including programming in Python and C++, data science techniques, graph theory, and numerical methods, to solve complex mathematical models.

PSO3. Conduct independent research and projects in areas like fuzzy mathematics, operations research, dynamical systems, fluid mechanics, cryptography, and mathematical modelling in applied sciences.

PSO4. Appreciate the historical and cultural development of mathematics, including Indian Knowledge Systems, and apply mathematical knowledge in socially relevant, ethical, and interdisciplinary contexts.

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Syllabus in detail

Semester I (PG)

MTM 101: Measure Theory **Credit 2, Full Marks 25**

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	3
Set of measure zero, Cantor set	2
Borel sets and their measurability, Measurable functions, continuity and measurability, Borel measurable functions, sequence of measurable functions	2
Simple functions and it's properties, Integral of nonnegative measurable functions	5
Lebesgue integral on a measurable set: Definition, Basic properties	2
Lebesgue integral of a bounded function over a set of finite measure. Simple properties	2
Comparison of Lebesgue and Riemann integral, Lebesgue criterion of Riemann integrability	1
General Lebesgue integral	2
Bounded convergence theorem for a sequence of Lebesgue integrable functions, Fatou's lemma, Classical Lebesgue dominated convergence theorem. Monotone convergence theorem (Statement only)	1

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.

MTM 102: Complex Analysis   Credit 2, Full Marks 25

Course Outcomes (COs):

Upon successful completion 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
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.	Self Study
Definition of Homotopy, Homotopy version of Cauchy's theorem, Extension of Cauchy's Theorem to Multiply-Connected Regions	2
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,	5
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	7
Winding number, Counting zeros Argument Principle, Rouche's Theorem.	4

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

MTM 103: Classical Mechanics — Credit 2, Full Marks 25

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.	4
Lagrange's equations, Hamiltonian. Hamilton's equations. Cyclic coordinates. Routhian equation.	4
Principle of stationary action, Principle of least action, Hamilton's principle. Variational principle, Brachistochrone problem. Lagrange's equations from Hamilton's principle.	4
Invariance transformations. Conservation laws. Space-time transformations. Canonical transformations. Liouville's theorem.	2
Poisson bracket.	2
The special theory of relativity: Postulates of special relativity. Lorentz transformation. Consequences of Lorentz transformation. Force and energy equations	4

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.

MTM 104: Abstract Algebra Credit 2, Full Marks 25

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]	**6**
Divisibility in integral domains, Unique factorization domain, Euclidean domain. Principal ideal domain	**5**
Normal series, subnormal series, solvable series, and solvable groups.	**4**
Field extensions: finite, algebraic, and finitely generated extensions; Classical ruler and compass constructions.	**5**

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.

COOM No: Research Methodology and Ethics **Credit 4, Full Marks 50**

Research Methodology and Ethics

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	4

and methodology; types of research – basic, applied, qualitative, quantitative, descriptive, analytical, experimental.	
Research Problem and Literature Review Identification and formulation of research problem; research questions and objectives; survey of literature – importance, sources, and research gaps.	3
Hypothesis and Research Process Hypothesis – meaning, role, and types (null, alternative, simple, complex, directional, causal); research process – steps from problem identification to report writing.	3
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	3
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.	3
Sampling Methods Concept of sampling; probability sampling – simple random, stratified, cluster, systematic; non-probability sampling – purposive, convenience, quota, snowball.	2
Reviewing and Proposal Writing Reviewing articles – analysis of objectives, methodology, findings; writing a research proposal – title, abstract, problem statement, literature review, methodology, outcomes, references.	2
Integration and Wrap-up Case discussions and practice on research problems, article reviews, and proposals; recap and integration of the research process.	2
Research Ethics	
Introduction to Ethics Definition, nature, and scope of ethics; different branches of ethics; importance of ethics in research and academic life.	3
Research Ethics Meaning and significance; responsibilities of researchers towards fellow researchers, public, and academic community; concept of academic integrity.	3
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.	4
Privacy and Confidentiality Concepts of privacy, autonomy, confidentiality, and anonymity in research; ethical handling of sensitive data.	2
Publication Ethics Definition and importance of publication ethics; publication misconduct; conflict of interest; authorship issues; responsibilities of editors, reviewers, and publishers.	4
Research Metrics Overview of research metrics; impact factor, h-index, g-index, i10-index; altmetrics and their role in evaluating research impact.	4

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. Sekaran, U., & Bougie, R. (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. Resnik, D. B. (2020). *The Ethics of Research with Human Subjects: Protecting People, Advancing Science, Promoting Trust*. Springer.
2. Shamoo, A. E., & Resnik, D. B. (2015). *Responsible Conduct of Research* (3rd ed.). Oxford University Press.
3. Beauchamp, T. L., & Childress, J. F. (2019). *Principles of Biomedical Ethics* (8th ed.). Oxford University Press.
4. COPE (Committee on Publication Ethics). (2017). *Code of Conduct and Best Practice Guidelines for Journal Editors*. Retrieved from https://publicationethics.org
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.
8. Sugimoto, C. R., & Larivière, V. (2018). *Measuring Research: What Everyone Needs to Know*. Oxford University Press.

MTM 105: Elective-1: Data Science & Graph Theory **Credit 4, Full Marks 50**

Unit I: Data Science **Credit 2, Full Marks 25**

Course Outcomes (COs):

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.	2
Quadratic function, Maxima, minima, Saddle points, vertex, slope, Principal Component Analysis and Dimension Reduction.	2
Basic concept of probability, Bayes' theorem, Distributions: Uniform, Gaussian, Student's *t*, Chi–square.	3
Sample statistics such as mean, median, mode, variance, standard deviations, correlation, regression, parametric and non-parametric tests.	2
Frequency plot, box plots, concepts of quartile, whisker, outlier, parity plot, normal probability plot.	2
Classification: Metrics, Bayes' Rule, Linear and Quadratic Discriminant Analysis, K-Nearest Neighbours, Classification with Scikit–learn.	2
Data visualization techniques: Plotting Qualitative and Quantitative Variables, Data visualization in a Bivariate Setting.	4
Data Science Tools: Python, R, Pandas, NumPy	3

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.

Unit II: Graph Theory — Credit 2, Full Marks 25

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.	2
Paths and cycles.	1
Connectivity, trees, spanning subgraphs, bipartite graphs, Hamiltonian and Euler cycles.	2
Distance and centre.	2
Cut sets and cut vertices.	2
Colouring and matching. Four colour theorem (statement only). Chromatic Polynomial.	3
Planar graphs, Dual graph. Directed graphs and weighted graphs.	2
Matrix representation of graphs	2
Algorithms for shortest path and spanning trees, Applications of graphs in traveling salesman problem	2
Intersection graph	2

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.
2. Gross, J. L., & Yellen, J. (2005). Graph theory and its applications. CRC Press.

MTM 105: Elective-II: Ordinary Differential Equations **Credit 4, Full Marks 50**

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.	5
Green's Function: Green's Function and its properties, Green's function for ordinary differential equations, Application to Boundary Value Problems.	5
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.	6
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.	5
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.	6
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.	8
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.	5

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.

MTM 106: Elective-1: Programming in Python — Credit 4, Full Marks 50

Course Outcomes (COs):

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

CO1: Understand the fundamentals of Python programming, including data types, variables, expressions, statements, and functions with proper scope and recursion.
CO2: Apply flow control constructs, loops, and conditional statements to develop efficient Python programs for problem-solving.
CO3: Utilize Python data structures such as strings, arrays, lists, tuples, and dictionaries, along with file handling and debugging techniques, to write robust programs.
CO4: Design and implement classes and objects, including programmer-defined types, attributes, methods, and practical applications, demonstrating object-oriented programming concepts.

Syllabus:

Course content	No. of Lectures
Python Basics: Introduction to Python and installation, data types: Int, float, Boolean, string, and list; variables, expressions, statements, precedence of operators, comments; modules, functions and its use, flow of execution, parameters and arguments.	6
Flow control: Boolean values and operators, conditional (if), alternative (if-else), chained conditional (if-elif-else); Iteration: while, for, break, continue.	6
Functions and Array: def Statements with Parameters, return values, parameters, local and global scope, function composition, recursion; Strings, string slices, immutability, string functions and methods, string module; Python arrays, Access the Elements of an Array, array methods.	6
Lists, Tuples, Dictionaries: Lists: list operations, list slices, list methods, list loop, mutability, aliasing, cloning lists, list parameters, list comprehension; **Tuples:** tuple assignment, tuple as return value, tuple comprehension; **Dictionaries:** operations and methods, comprehension.	6
Reading and Writing Files: Files and File Paths, The os.path Module, The File Reading/Writing Process, Saving Variables with the shelve Module, Saving Variables with the print.format() Function.	5
Debugging: Raising Exceptions, Getting the Traceback as a String, Assertions, Logging, IDLE‟s Debugger.	5
Classes and objects: Programmer-defined types, Attributes, Rectangles, Instances as return values, Objects are mutable, Copying.	6

Further Readings:
Text Books:

1. Ramalho, Luciano. Fluent Python: Clear, concise, and effective programming. ” O’Reilly Media, Inc.”, 2015.
2. Lutz, Mark. Learning python: Powerful object-oriented programming. ” O’Reilly Media, Inc.”, 2013

Reference Books:

1. Fhrer, Claus, Jan Erik Solem, and Olivier Verdier. Computing with Python. Pearson Education, 2013.

2. Summerfield, Mark. Programming in Python 3: a complete introduction to the Python language. Addison-Wesley Professional, 2010.

MTM 106: Elective-1I: Programming in C++ Credit 4, Full Marks 50

Course Outcomes (COs):

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

CO1: Understand the fundamentals of C++ programming, including data types, variables, operators, control structures, and functions with proper scope and recursion.

CO2: Apply arrays, strings, vectors, pointers, and dynamic memory allocation to develop efficient programs for mathematical and computational problems.

CO3: Design and implement classes and objects, including constructors, destructors, and object-oriented programming concepts such as inheritance, polymorphism, and operator overloading.

CO4: Utilize file handling and the Standard Template Library (STL) to manage data and implement mathematical and algorithmic solutions effectively.

Syllabus:

Course content	No. of Lectures
Introduction to C++ Overview of C++ and its features; basic structure of a C++ program; compilation and execution; input/output using cin and cout; comments; data types – int, float, double, char, bool; variables, constants, and literals; arithmetic and relational operators; operator precedence; typecasting.	5
Control Structures Conditional statements – if, if-else, nested if, if-else-if ladder, switch-case; loops – for, while, do-while; loop control statements – break, continue; nested loops; examples with mathematical problems.	5
Functions and Recursion Defining and calling functions; function arguments – pass by value and pass by reference; return values; scope of variables – local and global; recursion; function overloading; inline functions; mathematical examples using functions.	5
Arrays, Strings, and Vectors One-dimensional and two-dimensional arrays – declaration, initialization, and operations; string handling using C-style strings and std::string; introduction to vectors; operations on vectors; examples using mathematical sequences and matrices.	5
Pointers and Dynamic Memory Concept of pointers; pointer arithmetic; pointers and functions; dynamic memory allocation using new and delete; arrays and pointers; examples related to matrices and arrays.	5
Class and Objects	5

Introduction to classes and objects; defining classes; data members and member functions; access specifiers – private, public, protected; constructors and destructors; this pointer; object creation and usage; examples from mathematical structures (e.g., complex numbers, matrices).	
Overloading and File Handling Function overloading and operator overloading; inheritance – single and multiple; polymorphism and virtual functions; friend functions and classes; static members; file input/output – reading and writing text files; fstream, ifstream, ofstream; simple examples using mathematical applications.	5
Standard Template Library Introduction to STL – vector, list, stack, queue, map; basic operations; examples using STL for mathematical problems; recap and integrated exercises.	5

Further Readings:

Textbooks

1. Malik, D. S. *C++ Programming: From Problem Analysis to Program Design*. Cengage Learning.
2. Kanetkar, Y. P. *Let Us C++*. BPB Publications.

Reference Books

1. Lafore, R. *Object-Oriented Programming in C++*. Sams Publishing.
2. Stroustrup, B. *The C++ Programming Language*. Addison-Wesley.

MTM-IKS: Indian Knowledge System (IKS) **Credit 2, Full Marks 25**

Course Outcomes (COs):

Syllabus:

Further Readings:

Common Code: Vidyasagar: Life and Philosophy **Credit 0, Full Marks 25**

Course Outcomes (COs):

Syllabus:

Further Readings:

Semester II (PG)

MTM 201: Continuum Mechanics **Credit 2, Full Marks 25**

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	1
Stress vector, State of stress at a point, Stress tensor, The stress vector –stress tensor relationship	2
Force and moment equilibrium. Stress tensor symmetry stress quadric of Cauchy	3
Stress transformation laws, Principal stress, Stress invariant, Stress ellipsoid, maximum and minimum shear stress, Mohr's Circles for stresses	2
Strain: Deformation Gradients, Displacement Gradient Deformation tensor, Finite strain tensors	1
Small deformation theory-infinitesimal strain tensor, Relative displacement, Linear rotation tensor, Interpretation of the linear strain tensors	2
Strength ratio, Finite strain interpretation, Principal strains, Strain invariant	2
Cubical dilatation, Compatibility equation for linear strain, Strain energy function	2
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.)	5

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.

MTM 202: Linear Algebra — Credit 2, Full Marks 25

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	4
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.	6
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.	5
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.	5

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.

MTM 203: Elective-I: Fluid Mechanics & MHD Credit 4, Full Marks 50

Unit I: Fluid Mechanics

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, the fluid as continuum, primary dimensions with examples, Real and Ideal Fluids, Viscosity, Types of fluid Flow (Real/Ideal Fluid Flow, Compressible/ Incompressible flow, Newtonian/Non-Newtonian fluids, Rotational/irrotational flows, Steady/Unsteady Flow, Uniform/Non uniform Flow, One, Two or three Dimensional Flow, Laminar or Turbulent Flow).	4
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	3
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. Examples for each of governing equations	8
Non-dimensionalization: Non-dimensionalization process, Reynolds number, Importance of Reynolds number to Navier-Stokes Equation, Examples for Reynold numbers	2
Exact/Analytical Solution of Navier-Stokes Equation: Exact Solution of Navier-Stokes Equation (Couette-Poisseuille flow, Flow of a Viscous Fluid with Free Surface on an Inclined Plate)	3

Further Readings:
Text Books:

1. Computational Fluid Dynamics (The Basics with Applications), John D. Anderson Jr., McGraw-Hill Series in Mechanical Engineering
2. Boundary Layer Theory, Hermann Schlichting, McGraw-Hill Book Company

Reference Books:

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

Unit II: Magneto Hydrodynamics

Course Outcomes (COs):

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

CO1: Understand the fundamental principles of magnetohydrodynamics, including Maxwell's equations for moving media, Lorentz force, magnetic Reynolds number, Alfven theorem, and Ferraro's law of isorotation.

CO2: Analyze and solve practical MHD flow problems, including laminar flow between parallel walls, Couette flow under various boundary conditions, MHD waves, and the effects of Hall currents.

Syllabus:

Course content	No. of Lectures
Maxwell's electromagnetic field equations when medium in motion.	2
Lorentz's force. The equations of motion of a conducting fluid. Basic equations.	2
Simplification of the electromagnetic field equation.	2
Magnetic Reynolds number. Alfven theorem.	2
Magnetic body force. Ferraro's law of isorotation.	2
Laminar Flow of a viscous conducting liquid between parallel walls in transverse magnetic fields.	2
M.H.D. Flow Past a porous flat plate without induced magnetic field.	2
MHD Couelte Flow under diff4th Editionerent boundary conditions	2
Magneto hydro dynamics waves. Hall currents.	2
MHD flow past a porous flat plate without induced magnetic field.	2

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

MTM 203: Elective-II: Calculus on R^n & Operator Theory Credit 4, Full Marks 50

Unit I: Calculus on R^n

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**

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.

Unit II: Operator Theory

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.	**2**
Spectrum of a bounded linear operator; point spectrum (eigenvalues); continuous spectrum; residual spectrum; approximate point spectrum; illustrative examples.	**3**
Spectral radius of a bounded linear operator; Gelfand's formula; examples and applications.	**2**
Spectral properties of bounded linear operators; spectral mapping theorem for polynomials; problem-solving and examples.	**3**
Numerical range; convexity of numerical range (Toeplitz–Hausdorff theorem); closure of numerical range contains the spectrum; examples.	**3**
Numerical radius; relation between numerical radius and norm of a bounded linear operator; applications.	**2**
Normed algebra; Banach algebra; examples; singular and non-singular elements.	**2**

Spectrum of an element in a Banach algebra; spectral radius of an element; illustrative examples.	**1**

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.

MTM 204: Elective-I: Partial Differential Equations and Generalized Functions Credit 4, Full Marks 50

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	**3**
Adjoint and self-adjoint equations	**1**
Laplace, Wave and Heat equations	**1**
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	**5**
Fundamental solution of Laplace's equations in two variables. Harmonic function. Characterization of harmonic function by their mean value property. Uniqueness. Continuous dependence and existence of solutions. Method of	**5**

separation of variables for the solutions of Laplace's equations. Dirichlet's and Neumann's problems	
Solution of Dirichlet's and Neumann's problem for some typical problems like a disc and a sphere. Poisson's integral formula	**3**
Green's functions for the Laplace's equations in two dimensions	**2**
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	**5**

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.

MTM 204: Elective-II: Fuzzy Mathematics & Soft Computing Credit 4, Full Marks 50

Unit I: Fuzzy Mathematics

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.	**3**
Basic terminologies such as Support, α-Cut, Height, Normality, Convexity, etc..	**1**
Fuzzy relations, Properties of α-Cut, Zadeh's extension principle, Interval number and its arithmetic.	**3**
Fuzzy numbers and their representation, Arithmetic of fuzzy numbers..	**3**
Fuzzy measures. Evidence theory. Necessity measure. Possibility measure. Possibility distribution.	**2**

Defuzzification: centre of area, centre of maxima, and mean of maxima methods	**1**
Decision Making in Fuzzy Environment- Individual decision making. Multiperson decision making. Multicriteria decision making. Multistage decision making.	**3**
Fuzzy ranking methods. Fuzzy linear programming.	**4**

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.

Unit II: Soft Computing

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.

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	**3**
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.	**7**
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.	**5**

Fuzzy Logic Fuzzy relations, rules, propositions, implications and inferences, De-fuzzification techniques, Fuzzy logic controller design, and some applications of Fuzzy logic.	**5**

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.

MTM 205: Elective-I: Advanced Complex Analysis & Machine Learning   Credit 4, Full Marks 50

Unit 1: Advanced Complex Analysis

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	5

Conformal Mapping: Preservation of Angles, Scale Factors, Local Inverses, Harmonic Conjugates, Transformations of Harmonic Functions, Transformations of Boundary Conditions	6
Application of Conformal Mapping: steady temperature, steady temperature in a half plane and related problems, two-dimensional fluid flow	3
Analytic Continuation: Direct and indirect analytic continuation, indirect analytic continuation using power series and along curve, regular and singular points.	4

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.

Unit II: Machine Learning

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.	4
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.	4
Logistic regression; support vector machines (SVM); kernel functions and kernel SVM; Bayesian regression; binary decision trees; random forests; Naïve Bayes; applications.	4
k-Means clustering; k-Nearest Neighbors (kNN); Gaussian mixture models (GMM); expectation-maximization algorithm; applications.	4
Introductory concepts of reinforcement learning; Markov decision processes (MDP); examples and applications in sequential decision-making.	4

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.

MTM 205: Elective-II: Stochastic Process and Statistical Methods Credit 4, Full Marks 50

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.	8
Continuous-Time Markov Processes: Markov processes in continuous time; birth and death processes; examples and applications.	6
Markov Processes with Continuous State Space: Wiener process; branching process; applications in stochastic modelling; illustrative examples.	6
Multiple Regression and Correlation: Multiple regression; partial correlation; multiple correlations; estimation and interpretation of coefficients; examples and problem-solving.	6
Linear Estimates: Linear estimation theory; ordinary and best linear unbiased estimates; applications.	4
Analysis of Variance (ANOVA): One-way and two-way ANOVA; assumptions; interpretation of results; applications.	4
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.	6

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.

MTM 206: Elective-I: Integral Transforms & Topology Credit 4, Full Marks 50

Unit I: Integral Transforms (Credit 2)

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).	8
Laplace Transform: Laplace Transform, Properties of Laplace transform, Inversion formula of Laplace transform (Bromwich formula), Convolution theorem, Application to ordinary and partial differential equations.	6
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.	6

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.

Unit II: Topology (Credit 2)

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	**4**
Subspace topology, Limit points, Closure, interiors	**3**
Continuous functions, homeomorphisms	**2**
Product topology, metric topology, order topology, Quotient Topology	**2**
Connected spaces, connected subspaces of the real line, Components and local connectedness	**2**
Compact spaces, Local–compactness, Tychnoff's theorem on compact spaces	**3**
First and second countable spaces, Hausdorff spaces, Regularity, Complete Regularity, Normality	**3**
Urysohn Lemma, Urysohn Metrization Theorem, Tietze Extension theorem (statement only)	**1**

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.

MTM 206: Elective-II: Differential Geometry & Manifold Theory Credit 4, Full Marks 50

Unit I: Differential Geometry (Credit 2)

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.	**4**
Regular surfaces; tangents and normals; orientability; first fundamental form; developable surfaces; second fundamental form; Gauss's formula; Weingarten formula; Gauss & Codazzi equations; curvatures.	**4**
Affine connection (Koszul); torsion and curvature tensor fields; covariant differentiation; parallel transport; illustrative examples.	**4**
Riemannian manifold; Riemannian connection; Riemann curvature tensor; Bianchi identity; Ricci tensor; scalar curvature; Einstein manifold; examples.	**4**
Semi-symmetric metric connection; Weyl conformal curvature tensor; conformally symmetric Riemannian manifolds; consequences; geodesics; applications.	**4**

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.

Unit-II: Manifold Theory (Credit 2)

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.	**4**
Vector fields; integral curves of a vector field; push-forward mapping; f-related vector fields; immersion and submersion; submanifolds; examples.	**4**
Four-parameter group of transformations (local and global); complete vector fields; illustrative examples and applications.	**4**
Cotangent space; r-forms; exterior product; exterior differentiation; pull-back of differential forms; examples and applications.	**4**

Further Readings:

Text Books:

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.

MTM 207: Elective I: Hands-on Practical in Python — Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Apply Python programming to solve mathematical problems involving algebra, calculus, linear algebra, probability, and statistics.

CO2: Develop problem-solving skills through hands-on practice with Python libraries (NumPy, Pandas, Matplotlib) for computation, data handling, and visualization in mathematical applications.

Syllabus:

Course content	No. of Lectures
Writing simple Python programs to perform arithmetic operations, evaluate algebraic expressions, implement conditional statements, and generate number sequences using loops.	**2**
Defining and using functions to compute factorial, Fibonacci sequence, prime numbers, greatest common divisor (GCD), least common multiple (LCM), and solving recursion-based problems.	**2**
Problems involving lists, tuples, sets, and dictionaries, such as matrix representation using nested lists, polynomial addition, frequency counting, and set operations.	**2**
Using NumPy to solve mathematical problems: array operations, solving systems of linear equations, computing eigenvalues and eigenvectors, performing matrix factorizations, and applying vectorized operations.	**3**

Importing datasets, calculating descriptive statistics (mean, median, variance, correlation), filtering and grouping data, constructing frequency tables, and summarizing mathematical data.	**3**
Plotting mathematical functions (e.g., sine, cosine, exponential, polynomial), creating bar charts, histograms, scatter plots, and visualizing statistical data with customized axes, legends, and labels.	**3**
Numerical differentiation and integration, solving differential equations using Euler's method, root finding (Bisection/Newton–Raphson method), optimization of quadratic functions, and applications in probability distributions.	**3**
Students will complete a small project integrating computation, data handling, and visualization (e.g., analyzing real data, solving an optimization problem, or visualizing probability distributions).	**2**

Further Readings:
Textbooks

1. Lutz, M. *Learning Python*. O'Reilly Media.
2. Downey, A. *Think Python: How to Think Like a Computer Scientist*. O'Reilly Media.

Reference Books

1. McKinney, W. *Python for Data Analysis*. O'Reilly Media.
2. Langtangen, H. P. *A Primer on Scientific Programming with Python*. Springer.

MTM 207: Elective II: Hands-on Practical in C++ Credit 2, Full Marks 25

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

CO1: Apply C++ programming constructs (functions, arrays, pointers, classes, file I/O) to implement mathematical algorithms in algebra, calculus, and linear algebra.

CO2: Develop, test, and evaluate computational solutions for mathematical problems (e.g., matrix operations, root-finding, numerical integration/differentiation) with clean code, modular design, and appropriate documentation.

Syllabus:

1. Write a program to compute factorial, Fibonacci sequence, and check prime numbers using loops and conditional statements.
2. Implement recursive functions for factorial, greatest common divisor (GCD), and Tower of Hanoi.
3. Perform addition, subtraction, and multiplication of two matrices using arrays.
4. Write a program to compute the determinant and inverse of a matrix (using arrays).
5. Represent polynomials using arrays; perform polynomial addition, multiplication, and evaluation at a given point.
6. Implement Bisection Method and Newton–Raphson Method to find approximate roots of equations.
7. Write a program to compute derivative of a function numerically; implement Trapezoidal Rule and Simpson's Rule for numerical integration.
8. Define a class for complex numbers; implement addition, subtraction, and multiplication using operator overloading.

9. Create classes for vector and matrix; implement operations like scalar multiplication, dot product, and transpose.
10. Write a program to read student records (name, roll, marks) from a file and compute average/maximum marks.
11. Implement a stack to evaluate postfix expressions.
12. Implement a queue to simulate a simple mathematical process (e.g., series generation).
13. Develop a small C++ project combining mathematical computation, OOP, and file handling. Example topics:
    a. Solving a system of linear equations using Gaussian elimination.
    b. Statistical analysis of a dataset (mean, variance, standard deviation, correlation).
    c. Numerical solution of differential equations (Euler's method).

Further Readings:

Textbooks

3. Malik, D. S. *C++ Programming: From Problem Analysis to Program Design*. Cengage Learning.
4. Kanetkar, Y. P. *Let Us C++*. BPB Publications.

Reference Books

1. Lafore, R. *Object-Oriented Programming in C++*. Sams Publishing.
2. Stroustrup, B. *The C++ Programming Language*. Addison-Wesley.

M.Sc. Second Year

Semester-III

MTM 301: Functional Analysis — Credit 4, Full Marks 50

Course Outcomes (COs):

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

CO1: Understand the fundamental concepts of normed and Banach spaces, bounded linear operators, quotient spaces, and convergence of series in Banach spaces.

CO2: Apply key theorems in Banach spaces, including Hahn-Banach, Open Mapping, Inverse Mapping, Closed Graph, and Uniform Boundedness Principle, to solve functional analysis problems.

CO3: Understand inner product and Hilbert spaces, including orthonormal bases, projections, Riesz representation theorem, and Fourier expansions.

CO4: Analyze self-adjoint, normal, unitary, and positive operators in Hilbert spaces and apply their properties in theoretical and practical contexts.

Syllabus:

Course content	No. of Lectures

Normed spaces, Examples and related theorems, Bounded linear transformation, equivalent norms and their properties, finite dimensional normed linear spaces, Set of all bounded linear transformation B(X, Y) from NLS X into NLS Y is a NLS, Continuity of linear maps	**5**
Banach spaces with examples, B(X, Y) is a Banach space if Y is a Banach space, quotient spaces and its completeness property , consequences of quotient spaces, Riesz lemma and its applications in Banach spaces, space of all square integrable functions over [a.b] and its properties	**4**
Hahn-Banach Extension theorem and Its applications	**3**
Banach spaces, series in Banach spaces, convergence of a series in Banach spaces, A NLS is Banach if and only if every absolutely convergent series is convergent. Conjugate spaces, Reflexive spaces	**2**
Open Mapping Theorem and their applications, Inverse Mapping Theorem, Closed Graph Theorem	**4**
Uniform Boundedness Principle and its applications	**2**
Inner product spaces, Inner product is a continuous operator. Relation between IPS and NLS	**3**
Orthogonal and orthonormal vectors, Bessel'sinequality. Parseval's identity, Cauchy-Schwarz inequality, Parallelogram law	**3**
Hilbert spaces, Orthonormal basis. Complete orthonormal basis	**3**
Projection theorem	**2**
Minimization of norm problems in inner product spaces, Riesz Fischer theorem, Riesz representation theorem for bounded linear functional on a Hilbert space, Fourier expansion	**4**
Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related theorems	**5**

Further Readings:

Text Books:

1. B.V. Limaye, Functional Analysis, 2nd Edition, New Age InternationalPrivate Limited New Delhi, 2014.
1. J. B. Conway, A Course in Functional Analysis, 2nd Edition, Springer-Verlag New York, 1985.

Reference Books:

1. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1989.
2. A. Taylor and D. Lay, Introduction to Functional Analysis, Wiley, New York, 1980.

MTM 302: Integral Equation **Credit 2, Full Marks 25**

Course Outcomes (COs):

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

CO1: Understand the formulation, types, and properties of linear integral equations, including Fredholm and Volterra equations, symmetric kernels, and convolution-type equations.
CO2: Apply various solution techniques such as successive approximations, resolvent kernels, Laplace transforms, and Hilbert-Schmidt theory to solve integral equations arising in physical and engineering problems.

Syllabus:

Course content	No. of Lectures
Formulation of integral equations; linear integral equations of first and second kinds – Fredholm and Volterra types; relation between integral equations and initial and boundary value problems; examples.	**4**
Existence and uniqueness of continuous solutions of Fredholm and Volterra integral equations of the second kind; solution by successive approximations; iterated kernels; reciprocal kernels; Volterra's solution of Fredholm integral equations; resolvent kernel method; integral equations with degenerate kernels; Abel's integral equation; integral equations of convolution type and solutions using Laplace transform.	**6**
Fredholm theory for the solution of Fredholm integral equations; Fredholm's determinant (λ); Fredholm's first minor; Fredholm's fundamental relations and theorems; Fredholm's alternatives; illustrative examples.	**5**
Integral equations with symmetric kernels; Hilbert-Schmidt theory of symmetric kernels; properties of symmetric kernels; existence of eigenvalues for real symmetric kernels; complete set of eigenvalues and complete orthonormal system of eigenfunctions; expansion of iterated kernels in terms of eigenfunctions; Schmidt's solution of Fredholm integral equations.	**5**

Further Readings:
Text Books:

1. Kanwal, R.P. (1971) Linear Integral Equations; Theory & Techniques, Academic Press, NewYork.
2. Lovitt, Linear Integral Equations, Dover Publications, New York, 1950
3. Tricomi, Integral Equations, Inter Science Publishers, New York, 1957

Reference Books:

1. H.T. Davis: Introduction to Nonlinear Differential and Integral Equations, Dover Publications, 1962.
2. M.L. Krasnov: Problems and Exercises Integral Equations, Mir Publication Moscow, 1971.

MTM 303: Cryptography — Credit 2, Full Marks 25

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Understand the fundamental concepts of cryptography, classical and modern encryption techniques, block ciphers, public-key cryptosystems, digital signatures, and secure hashing.

CO2: Apply cryptographic algorithms and protocols to design and analyze secure systems, ensuring confidentiality, integrity, and authentication in computer security applications.

Syllabus:

Course content	**No. of Lectures**
Cryptographic algorithms and protocols, Computer security concepts, Fundamental security design principles	2
Classical Encryption Techniques: Basic terminology: Ciphertext, encryption, decryption, cryptanalysis and cryptology	2
Substitution techniques: Caesar Cipher, Monoalphabetic Cipher, Play-fair Cipher, Hill Cipher, Poly-alphabetic Cipher, Transposition techniques	4
Traditional Block Cipher Structure: Stream Ciphers and Block Ciphers, Motivation for the Feistel Cipher Structure, Feistel Cipher	4
Public-Key Encryption: Public-Key cryptosystems, decryption algorithm.	2
Digital Signatures: One-time signatures, Rabin and ElGamal signatures schemes, Digital Signature Standard (DSS).	4
Hashing: Motivation and applications, Cryptographically Secure Hashing.	2

Further Readings:
Text Books:

1. W. Stallings, Cryptography and Network Security, 4th Ed, Prentice Hall PTR, Upper Saddle River, NJ, 2006
2. W. Trappe and L. C. Washington, Introduction to cryptography with coding Theory, Prentice-Hall, 2nd ED, 2006.

Reference Books:

1. D. R. Stinson, Cryptography: Theory and Practice, Third Edition, Chapman & Hall/ CRC, 2005
2. W. Mao, "Modern Cryptography – Theory and Practice", Pearson Education.
3. Charles P. Pfleeger, Shari Lawrence Pfleeger – Security in computing – Prentice Hall of India.

MTM 304: Elective-I: Advanced Optimization **Credit 4, Full Marks 50**

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Understand and apply revised and dual simplex methods, post-optimal analysis, and sensitivity analysis for linear programming problems.
CO2: Formulate and solve integer programming, quadratic programming, and goal programming problems using appropriate algorithms.
CO3: Analyze and solve dynamic programming and unconstrained optimization problems using numerical and analytical methods.

CO4: Apply constrained optimization techniques, including penalty and barrier methods, augmented Lagrangian methods, and sequential quadratic programming, to solve practical engineering and management optimization problems.

Syllabus:

Course content	No. of Lectures
Revised simplex method: With and without artificial variable, Dual simplex method, Modified dual simplex method.	**4**
Post-optimal analysis: Changes in the cost vector and the resource vector, Addition of a variable, Deletion of an existing variable, and Addition of a new constraint.	**4**
Integer Programming: Gomory's cutting plane algorithm, Gomory's mixed-integer problem algorithm, and the branch-and-bound algorithm.	**4**
Quadratic Programming Wolfe's modified simplex method, Beale's method, and convex programming.	**4**
Goal Programming Introduction, Concept of Goal Programming (GP), Difference between LP and GP, formulation, graphical solution, modified simplex method.	**4**
Unconstrained Optimization Techniques General structure of a numerical method for unconstrained optimization problems, exact and inexact line search, trust region method, Dogleg technique, Fibonacci section method and its convergence, Golden section method and its convergence, Newton's method (for line search) and its convergence, Steepest descent and its convergence, Newton's method (for several variable optimizations) and its convergence, Conjugate direction method, Conjugate gradient methods: Beale's and preconditioned methods, Global convergence and convergence rate of conjugate gradient methods	**15**
Constrained optimization techniques Penalty and barrier function method, Augmented Lagrangian Method, Feasible direction methods: Reduced gradient and projected gradient methods, Sequential quadratic programming techniques: Lagrange-Newton and Watch-dog technique	**5**

Further Readings:

Text Books:

1. S. S. Rao. Engineering optimization: theory and practice. John Wiley & Sons, 2009.
2. Belegundu, Ashok D., and Tirupathi R. Chandrupatla. Optimization concepts and applications in engineering. Cambridge University Press, 2011.

References Books:

1. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
2. Sharma, S. D. Operations Research, Kedar Nath Ram Nath& Co., Meerut.

MTM 304: Elective-II: Dynamical Meteorology: Thermodynamics in Atmosphere Credit 4, Full Marks 50

Course Outcomes (COs):

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

CO1: Understand the structure, composition, and fundamental thermodynamic laws governing the atmosphere, including hydrostatic equilibrium and thermodynamic processes.

CO2: Analyze the variation of atmospheric pressure, temperature, and stability of dry and moist air, including adiabatic lapse rates and potential temperature.

CO3: Apply concepts of moist thermodynamics, including dew point, equivalent temperature, wet-bulb temperature, and pseudo-adiabatic processes, to atmospheric phenomena.

CO4: Utilize thermodynamic diagrams, CAPE, CINE, and stability analysis methods to assess atmospheric stability, convective activity, and vertical and horizontal air mass mixing.

Syllabus:

Course content	No. of Lectures
Structure and composition of the atmosphere, Equation of state for dry, Laws of thermodynamics	3
Different thermodynamic processes and its applications in atmosphere, Hydrostatic Equation and its application	3
Pressure and its variation with height, variation of temperature with height, stability of dry air, potential temperature	3
Equation of state of moist air, Virtual temperature, Humidity Parameters	3
Standard Atmosphere, Barometric Altimetry, Hypsometric Equation	3
Adiabatic lapse rate for moist unsaturated air, effect of ascent and descent on lapse rare and stability	4
Clausius – Clapeyron equation, saturated adiabatic lapse rate and stability, saturation by Isobaric cooling	4
Dew point changes in adiabatic motion, saturation by adiabatic ascent, Pseudo-adiabatic process	3
Equivalent Temperature, Equivalent Potential Temperature, Wet-bulb temperature, Wet-bulb potential temperature	3
Thermodynamic Diagrams. Uses of thermodynamic diagrams: LCL, LFC, Precipitable Water Vapor	4
Role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in thunderstorm development, Reduction of pressure to sea level	3
Stability and Instability of Atmosphere: Parcel Method, Slice method of stability analysis, Horizontal mixing of air masses, vertical mixing of air masses.	4

Further Readings:

Text Books:

1. Dynamical and Physical Meteorology: George J. Haltiner and Frank L.Martin, McGraw Hill
2. An introduction to Dynamical Meteorology: Holton J.R., Academic Press

Reference Books:

1. Physical and Dynamical Meteorology: D. Brunt, Cambridge University Press
2. Atmospheric Thermodynamics: Iribarne, J.V. and Godson, W.L.

MTM 304: Elective-III: Linear and Non-Linear Dynamical Systems Credit 4, Full Marks 50

Course Outcomes (COs):

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

CO1: Understand the fundamental concepts of dynamical systems, including autonomous and non-autonomous systems, existence and uniqueness theorems, and discrete and continuous dynamics.

CO2: Analyze equilibrium points, classify saddles, nodes, foci, and centers, and determine stability and asymptotic stability using phase space and Jordan canonical forms.

CO3: Apply advanced stability analysis techniques, including Liapunov functions, Floquet's theorem, Hartman–Grobman theorem, and periodic solution concepts, to study global behavior.

CO4: Utilize Poincaré maps and bifurcation theory to investigate local and global bifurcations and predict qualitative changes in the behavior of dynamical systems.

Syllabus:

Course content	No. of Lectures
Dynamical System, autonomous and non-autonomous	3
Fundamental existence uniqueness theorem, discrete and continuous	4
sEquilibrium point: saddles, nodes, foci, centres	4
Jordon canonical form, stability, asymptotic stability, configuration space and phase space	4
Floquet's theorem, Hartman – Grobman Theorem	4
Liapunov function, periodic solution	4
Global stability: limit sets, attractors, periodic orbit, limit cycles	4
Poincare Map, Poincare – Bendixson Theorem	5
Bifurcation analysis, local: Hof bifurcation saddle – node bifurcation, transcritical	4
bifurcation, global: homoclinic bifurcation, heteroclinic bifurcation, infinite period bifurcation	4

Further Readings:

Text Book:

1. Differential Equations and Dynamical Systems, Lawrence Perko, Springer

Reference Books:

1. An Introduction to Dynamical System, D. K. Arrow smith, Cambridge University Press;
2. Nonlinear Dynamics and Chaos: with Applications to Physics, Biology, Chemistry and Engineering, Strogatz, S. H., CRC Press.

MTM 305: Elective-I: Operational Research Modeling-I Credit 4, Full Marks 50

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Understand and apply deterministic, probabilistic, and dynamic inventory control models, including multi-item and price-break scenarios, within the framework of supply chain management.
CO2: Analyze project networks using PERT and CPM techniques, perform critical path analysis, and evaluate project time–cost trade-offs under uncertainty.
CO3: Formulate and solve replacement and maintenance problems, queuing models, and simulate stochastic systems using Monte Carlo and other simulation techniques.
CO4: Apply dynamic programming principles to optimize multi-stage decision processes, production scheduling, and routing problems in deterministic and stochastic environments.
Syllabus:

Course content	No. of Lectures
Inventory control: Deterministic including price breaks and Multi-item with constraints, Probabilistic inventory control (with and without lead time), and Dynamic inventory models. Basic concept of supply–chain management.	7
Network analysis: PERT and CPM: Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis, Probability in PERT analysis, Project time-cost, trade-off.	8
Replacement and Maintenance Models: Failure Mechanism of items, Replacement of items deteriorates with time, Replacement policy for equipment when value of money changes with constant rate during the period, Replacement of items that fail completely – individual replacement policy and group replacement policy, Other replacement problems-staffing problem, equipment renewal problem.	6
Simulation: Steps of simulation process, Advantages and disadvantages of simulation, Stochastic simulation and random numbers— Monte Carlo simulation, Random number, Generation, Simulation of inventory Problems, Simulation of queuing problems, Role of computers in simulation, Applications of simulations.	6
Queueing theory: Basic Structures of queuing models, Poisson queues – M/M/1, M/M/C for finite and infinite queue length, Machine-Maintenance (steady state).	7
Dynamic Programming: Introduction, Nature of dynamic programming, Deterministic processes, Non-Sequential discrete optimisation, Allocation problems, Assortment problems, Sequential discrete optimisation, Long-term planning problem, Multi-stage decision process. Application of Dynamic Programming in production scheduling and routing problems.	6

Further Readings:
Text Books:

1. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.
2. Sharma J.K. (2006) Operations Research: theory and application, Macmillan Publishers.

Reference Books:

1. Taha, H. A. (2004) Operations research: An introduction. Pearson Education India.
2. Hillier, F.S., (2012) Introduction to operations research. Tata McGraw-Hill Education.

MTM 305: Elective-II: Dynamical Oceanology: Advanced Wave Hydrodynamics Credit 4, Full Marks 50

Course Outcomes (COs):

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

CO1: Understand the fundamental concepts of liquid surface waves, including progressive and stationary waves, and the kinematical and pressure conditions at the free surface.

CO2: Analyze surface waves in canals and deep water, evaluating kinetic and potential energy distributions for different wave types.

CO3: Apply steady motion theories to surface waves, including wave propagation over varying depths, interfaces of two liquids, and sinuous bottoms, using first and second order approximations.

CO4: Examine the effects of capillarity, wind, and long-wave phenomena, including solitary waves, and interpret their applications in hydrodynamics and coastal engineering.

Syllabus:

Course content	No. of Lectures
Liquid Surface Waves: Introduction, General equation of wave motion, Mathematical representation of (a) Progressive waves (b) Stationary waves.	4
Kinematical condition at the free surface, Pressure condition at the free surface	2
Surface waves: (a) Progressive waves on the surface of a canal of finite depth (b) Progressive waves on deep water (c) Stationary waves on the surface of a canal of finite depth (d) Stationary waves on deep water	6
Kinetic and Potential energy of stationary waves	4
Steady motion: (a) Progressive waves on the surface of a canal of finite depth (b) Progressive waves on deep water (i) First order approximation to the wave speed (ii) Second order approximation to the wave speed (c) Progressive waves at an interface of two liquids (d) Progressive waves at an interface of two liquids when upper surface is free (e) Waves over a sinuous bottom	8
Group velocity, Dynamical significance of group velocity,	4
Capillary waves, Effect of capillarity on surface waves, Effect of capillarity on surface waves at an interface	6
Effect of wind on deep water, Long waves, Steady motion for long waves, Solitary waves	6

Further Readings:

Text Books:

1. Gupta A.: Groundwork of mathematical fluid dynamics, Academic Publishers, 2013.
2. Batchelor G. K.: An Introduction to fluid dynamics, Cambridge University Press, 1967.
3. Frank M. White: Fluid mechanics. Tata McGraw - Hill publishing company, New Delhi, 2008.

Reference Books:

1. Milne-Thomson L.M.: Theoretical hydrodynamics, The Macmillan Company, New York, 1950.
2. Streeter V.L.: Fluid dynamics, McGraw Hill Book Company Inc. New York, 1948.
3. Streeter V.L.: Handbook of Fluid dynamics, McGraw Hill Book Company Inc. New York, 1948.
4. Yuan S.W.: Foundations of fluid mechanics, Prentice-Hall of India Pvt. Ltd., New Delhi, 1969

MTM 305: Elective-III: Computational Fluid Dynamics **Credit 4, Full Marks 50**

Course Outcomes (COs):

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

CO1: Understand the fundamentals of CFD, including computational grids, variable arrangements, boundary condition implementation, and solution techniques for discretized equations.

CO2: Apply finite difference methods to solve parabolic and hyperbolic partial differential equations, using explicit, implicit, and semi-implicit schemes.

CO3: Analyze convergence, consistency, stability, and accuracy of numerical methods, and evaluate solutions using theoretical principles such as the Lax Equivalence Theorem and Von Neumann stability analysis.

CO4: Implement finite volume methods and discretization schemes, including central difference and upwind-biased schemes, to solve steady and unsteady convection-diffusion and Navier-Stokes equations for practical fluid flow problems.

Syllabus:

Course content	No. of Lectures
Preliminaries for Computational Fluid Dynamics(CFD): Advantage of CFD, overview of CFD, Size of Computational Domain, Consideration of Grid (uniform/non-uniform), Variable arrangement (Cell center / Collocated arrangement and Staggered Gird), Space discretization and Time discretization (Explicit Algorithm, Implicit Algorithm, and Semi-implicit Algorithm), Implementation of boundary conditions (inlet/outlet/wall boundary) for collocated and staggered grid, Solution of discretised equation: Tri-diagonal matrix algorithm, Line-Gauss Seidel method, relaxation method	7
Finite Difference Methods (FDM): Space discretisation (Simple and general methods based on Taylor's series), Accuracy of the Discretisation Process, *Conceptual Implementation to* *(i)* *Parabolic type:* 1D transient heat conduction (diffusion) problem and Couette Flow using FTCS , DuFort-Frankel, Richardson , Leap-frog schemes and Crank-Nicolson methods, and ***(ii)*** *Hyperbolic*: 1D first order Linear Convection-dominated problems and second order linear Wave Problems using FTCS, Upwind and the CFL conditions, Lax-Friedrich, Leap Frog, Lax-Wendroff, Crank-Nikolson, linear convection of a truncated sine wave	12

Theoretical Background: Convergence (Lax Equivalence Theorem, Analytical Treatment of Convergence), Consistency (FTCS, Fully Implicit Scheme), Stability (Matrix Method and Von Neumann Method) and Solution Accuracy (Richardson Extrapolation **)**	8
Finite Volume Method (FVM): Equations with First order Derivatives Only, with second order Derivatives, The Finite Volume Method for Steady/unsteady one/two/three-dimensional heat conduction equation, Steady/unsteady one/two/three-dimensional convection and diffusion equation, continuity, Navier-Stokes Equation, Central Difference Scheme (CDS), Different Upwind Schemes for uniform and non-uniform grids: First Order Upwind (FOU) , Second Order Upwind Scheme (SOU), Third Order Upwind differencing (QUICK), Assessment (Conservativeness, Boundedness, Transportiveness and Accuracy) of CDS, FOU and Stability problems of QUICK and remedies, Generalisation of upwind-biased discretization schemes	13

Further Readings:
Text Books:

1. C. A. J. Fletcher- Computational Techniques for Fluid Dynamics, Vol-I, Springer, 1988.
2. H.K.Versteeg and W Malalasekera, An Introduction to Computational Fluid Dynamics, Pearson, 2008.

Reference Book:

2. G.D.Smith, Numerical Solution of Partial Differential Equations: Finite Difference Methods (Oxford Applied Mathematics & Computing Science Series) by G. D. Smith, Oxford University Press.

MTM 306: MOOCs **Credit 4, Full Marks 50**
(Name of course will be declared time to time)

MTM 307: Social Service / Community Engagement **Credit 2, Full Marks 25**

Semester IV

MTM 401AT: Elective-I: Nonlinear Optimization (Theory) **Credit 2, Full Marks 25**

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Analyze and solve stochastic, geometric, and multi-objective nonlinear programming problems using appropriate optimization techniques and game-theoretic approaches.
CO2: Apply the principles of optimality, differentiability, and duality in nonlinear programming to formulate and solve real-world optimization problems.

Syllabus:

Course content	No. of Lectures
Stochastic Programming: Chance constraint programming technique.	2

Geometric Programming: Geometric programming (unconstraint) with positive and negative degree of difficulty.	2
Games: Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming).	3
Multi-objective Non-linear Programming: Introductory concept and solution procedure. Fuzzy Multi-objective Nonlinear Programming	3
Non-Linear Optimization: The general nonlinear programming problem, The nature of optimization and scope of the theory,	1
Optimality without differentiability: Convex sets and separation theorem, Optimality in the absence of differentiability and constraint qualification, Karlin's constraint qualification, Kuhn-Tucker's saddle point necessary optimality theorem, Fritz-John saddle point optimality theorem	3
Optimality with differentiability: Differentiable convex and concave functions, Optimality criterion with differentiability and Convexity, Kuhn-Tucker's sufficient optimality theorem, Fritz-John stationary point optimality theorem,	4
Duality in non-linear programming: Duality in non-linear programming, Weak duality theorem, Wolfe's duality theorem, Duality for quadratic programming.	2

Further Readings:

Text Books:

1. Olvi L.Mangasarian, Nonlinear Programming, Society for Industrial and Applied Mathematics, 1994.
2. S.S. Rao, Engineering Optimization: Theory and Practice, John Wiley & Sons, 1996.

Reference Books:

1. Mokhtar S. Bazaraa, Hanif D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, 2006.
2. Kaisa Miettinen, Nonlinear Multi-objective Optimization, Kluwer Academic Publishers, Boston, 1999.
3. Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2010.

MTM 401AP: Elective-I: Nonlinear Optimization (Practical) **Credit 2, Full Marks 25**

Course Outcomes (COs):

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

CO1: Solve Operations Research and advanced optimization problems, including LPP, QPP, Fuzzy LPP, Goal Programming, Stochastic Programming, Bi-matrix Games, and Nonlinear Optimization using MATLAB and LINGO.

CO2: Interpret and analyze computational results effectively, applying software tools to practical optimization and decision-making scenarios.

Syllabus:

OR methods using MATLAB and LINGO

Problems on Advanced Optimization and Operations Research are to be solved by using MATLAB (one question carrying 09 marks) and LINGO (one question carrying 06 marks) (Total: 15 Marks)
Lab Note: 5 Marks, Viva-Voce : 5 Marks
Problems on LPP, QPP, Fuzzy LPP, Goal Programming Problem, Stochastic Programming, Bi-matrix Game, Nonlinear Optimization with Equality and Inequality Constraints.

Further Readings:
Text Books:
1. Gilat, A. (2008) MATLAB: an Introduction with Applications. New York: Wiley.
2. Palm III, W. J. (2011) Introduction to MATLAB for Engineers. New York: McGraw-Hill.

Reference Books:
1. Chapman, S. J. (2012) MATLAB programming with applications for engineers. Cengage Learning.
2. Lopez, C. (2014) MATLAB programming for numerical analysis. Apress.

MTM 401BT: Elective-II: Dynamical Meteorology: Dynamics in Atmosphere (Theory)
Credit 2, Full Marks 25

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Analyze fundamental atmospheric forces, equations of motion, and force balances, including geostrophic, gradient, inertial, cyclostrophic, and thermal winds.
CO2: Apply thermodynamic energy equations, and concepts of circulation, vorticity, and divergence to understand atmospheric motion and dynamic processes.

Syllabus:

Course content	No. of Lectures
Fundamental atmospheric forces, inertial and non-inertial frame of references	3
Equation of momentum of an air parcel: in vector form, Cartesian coordinates spherical coordinates, natural coordinates and isobaric coordinates	4
Balance of forces: Geostrophic wind, Gradient wind, inertial wind	3
Cyclostrophic wind and Thermal wind	2
Thermodynamic energy equation, Atmospheric energy equation	3
Circulation, vorticity, divergence. Surface of discontinuity	5

Further Readings:
Text Books:
1. Dynamical and Physical Meteorology: George J. Haltiner and Frank L.Martin, McGraw Hill
2. An introduction to Dynamical Meteorology: Holton J.R., Academic Press

Reference Books:
1. Physical and Dynamical Meteorology: D. Brunt, Cambridge University Press
2. Atmospheric Thermodynamics: Iribarne, J.V. and Godson, W.L.

MTM 401BP: Elective-II: Dynamical Meteorology: Dynamics in Atmosphere (Practical) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Measure and analyze key atmospheric parameters including surface temperature, potential temperature, virtual temperature, wet-bulb temperature, pressure, humidity, mixing ratio, vapor pressure, wind speed and direction, and rainfall.

CO2: Interpret T-diagrams, station models, and experimental data from meteorological laboratories to understand and apply practical concepts in atmospheric and weather analysis.

Syllabus:

Course content	No. of Lectures
Surface temperature, potential temperature, virtual temperature, wet bulb temperature, pressure	4
Relative humidity, specific humidity, mixing ratio, saturation pressure, vapor pressure, Wind speed and direction measurements	4
Rainfall and rain measurements	2
T- diagram: Geopotential height by isotherm / adiabatic method, To find dry bulb and wet bulb temperature, potential, virtual, equivalent, potential, dew point temperatures and mixing ratio.	6
Station model analysis	2
Students should go to one of the University/Institute/Organization laboratory to understand experimental set-ups in advance meteorology.	2

Text Books:

1. Haltiner, G. J. and Martin, F. L. Dynamical and Physical Meteorology, McGraw Hill.
2. Holton, J.R. An introduction to Dynamical Meteorology, Academic Press.

Reference Books:

1. Brunt, D. Physical and Dynamical Meteorology, Cambridge University Press.
2. Iribarne, J.V. and Godson, W.L. Atmospheric Thermodynamics.

MTM 401CT: Elective-III: Mathematical Modeling in Ecological Systems (Theory) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Analyze and solve mathematical models for single-species population dynamics including Malthus, Logistic, and Gompertz models.

CO2: Develop, interpret, and analyze models for interacting species and epidemiological systems, including Lotka–Volterra, Kolmogorov, prey–predator models, SIR, SIRS, SCI, SIS models, and compute the basic reproductive number.

Syllabus:

Course content	No. of Lectures
Models for single species: Malthus model, Logistic model, Gompertz model and its analysis	6
Models for interacting Species: Lotka-Voltera model, Kolmogorov model, Prey-predator Syste and its analysis	6
Models in Epidemiology: Kermack- McKendrick epidemic model, SIR, SIRS, SCI, SIS	6
The Basic Reproductive Number	2

Further Readings:

Text Books:

1. Dynamical Systems for Biological Modeling: An Introduction, Fred Brauer, Christopher Kribs, CRC Press
2. Mathematical Models in Population Biology and Epidemiology, Fred Brauer, Carlos Castillo-Chavez, Springer.

Reference Books:

1. Dynamical Systems with Applications using MATLAB, StephenLynch, Springer International Publishing.
2. Population Ecology: An Introduction to Computer Simulations, Ruth Bernstein, John Wiley & Sons.
3. Mathematical Modeling and Simulation with MATLAB, Lee, S., Buzby, M.

MTM 401CP: Elective-III: Mathematical Modeling in Ecological Systems (Practical) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Implement MATLAB programs to visualize and analyze phase portraits, limit cycles, bifurcation diagrams, periodic orbits, and Poincaré maps for population and epidemiological models.

CO2: Interpret computational results to understand the dynamics of single-species, interacting species, and epidemiological systems, including stability, periodicity, and bifurcation behavior.

Syllabus:

Course content	No. of Lectures
MATLAB Programs to draw and analyse phase portraits of the above-mentioned models	9
MATLAB Programs to draw and analyse limit cycles, bifurcation diagram map of the above-mentioned models	8
MATLAB Programs to draw and analyse periodic orbits, Poincaré map of the above-mentioned models	8

Text Books:

1. Brauer, F. and Kribs, C. Dynamical Systems for Biological Modeling: An Introduction, CRC Press.
2. Brauer, F. and Castillo-Chavez, C. Mathematical Models in Population Biology and Epidemiology, Springer.

Reference Books:

1. Lynch, S. Dynamical Systems with Applications using MATLAB,Springer International Publishing.
2. Bernstein, R. Population Ecology: An Introduction to Computer Simulations, John Wiley & Sons.
3. Lee, S. and Buzby, M. Mathematical Modeling and Simulation with MATLAB.

MTM 402AT: Operations Research Modeling-II (Theory) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Apply principles of optimal control, including calculus of variations and Pontryagin's principle, to solve engineering and mechanical optimization problems, including bang–bang control scenarios.

CO2: Analyze system reliability, maintainability, and information theory concepts, including entropy, mutual information, and encoding techniques, to evaluate and optimize engineering systems and communication processes.

Syllabus:

Course content	No. of Lectures
Optimal Control: Performance indices, Methods of calculus of variations, transversal conditions, Simple optimal problems of mechanics, Pontryagin's principle (with proof assuming smooth condition), Bang–bang Controls.	6
Reliability: Concept, reliability definition, System Reliability, System Failure rate, Reliability of the Systems connected in Series or/and parallel. MTBF, MTTF, optimization using reliability, reliability and quality control comparison, reduction of the life cycle with reliability, maintainability, availability, Effect of age, stress, and mission time on reliability.	5
Information Theory: Introduction, Communication Processes- memoryless channel, the channel matrix, Probability relation in a channel, noiseless channel. A Measure of information- Properties of Entropy function, Marginal and joint entropies, conditional entropies, expected mutual information,	5
Encoding-Objectives of Encoding. Shannon-Fano Encoding Procedure, Necessary and Sufficient Condition for Noiseless Encoding.	4

Further Readings:

Text Books:

1. Sharma, S.D. Operations Research, Ram Nath, Kedar Bath & Co. Meerut.

2. Swarup, K., Gupta, P.K and Man, M. Operations Research, Sultan Chand & Sons.

References Books:

1. Sharma, J.K Operation Research – Theory and Application, Macmillan.
2. Gupta, P.K. and Hira, D.S., Operations Research, S. Chand &Co.Ltd.
3. Taha, H.A., Operations Research –an Introduction, PHI.
4. Bronson, R. and Naadimuthu. G., Theory and Problems of Operations Research, Schaum's Outline Series, McGraw-Hill.

MTM 402AP: Operations Research Modeling-II (Practical) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Formulate and solve advanced Operations Research and optimization problems, including queuing theory, inventory models, Monte Carlo simulation, dynamic programming, and reliability, using MATLAB, LINGO, C++, or Python.

CO2: Analyze and interpret computational results effectively, applying software tools to practical decision-making and optimization scenarios in engineering and management contexts.

Syllabus:

Problems on Advanced Optimization and Operations Research are to be solved by using MATLAB /LINGO/C++/Python

Problems with Queuing Theory, Inventory, Monte Carlo Simulation Technique, Dynamic Programming, and Reliability.

Further Readings:

Text Books:

1. Sharma, S.D. Operations Research, Ram Nath, Kedar Bath & Co. Meerut.

References Books:

1. Sharma, J.K Operation Research – Theory and Application, Macmillan.
2. Gupta, P.K. and Hira, D.S., Operations Research, S. Chand &Co.Ltd.
3. Taha, H.A., Operations Research –an Introduction, PHI.
4. Bronson, R. and Naadimuthu. G., Theory and Problems of Operations Research, Schaum's Outline Series, McGraw-Hill.

MTM 402BT: Dynamical Oceanology: Coastal Processes (Theory) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Analyze and evaluate wave propagation phenomena including shoaling, refraction, diffraction, reflection, wave breaking, run-up, and the effects of currents.

CO2: Apply principles of tsunami propagation, wave interaction with real seabeds, and sediment transport to predict inundation, wave deformation, and long-shore sediment movement.

Syllabus:

Course content	No. of Lectures

Wave Propagation: Wave Shoaling, Refraction, Diffraction, Reflection	2
Effect of Currents, Wave Breaking, Wave Set up and Set down, Wave Run-up.	2
Tsunamis, Properties of tsunamis, Inundation levels, Conservation of mass equation, Prediction of storm surge	4
Waves over Real Sea beds: Waves over smooth, rigid, impermeable bottoms	4
Water waves over a viscous mud bottom, Waves over rigid porous bottoms	4
Wave deformation	2
Sediment characteristics and long-shore sediment transport	2

Further Readings:

Text Books:

1. Robert G. Dean and Robert A. Dalrymple, Water Wave Mechanics for Engineers and Scientists, World Scientific Publishing Co. Pte. Ltd., Volume 2, 2002.
2. M. C. Deo, Waves and Structures, 2013.
3. Silvester, R. and Hsu, J.R.C. Coastal Stabilisation, Advances on Ocean Engineering-Volume 14, World Scientific, 1997.

Reference Books:

1. Kamphius, J.W. Introduction to Coastal Engineering and Management, Advances on Ocean Engineering-Volume 16, World Scientific, 2002.
2. Goldstein S.: Modern Developments in Fluid Dynamics, Oxford University Press, New York, 1938.
3. Lamb H.: Hydrodynamics, Dover Publications, New York, 1932.
4. McCormack P. D. and L. Crane: Physical Fluid Dynamics, Academic Press, New York, 1973.

MTM 402BP: Dynamical Oceanology: Coastal Processes (Practical) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Measure and analyze stream-wise, transverse, and wall-normal mean velocities, turbulence intensity, and Reynolds shear stress profiles for current-only and wave-current flows using vertical velocity measurements.

CO2: Compute and interpret statistical parameters including skewness, kurtosis, probability density functions, and joint probability density functions to characterize turbulence and flow behavior in laboratory experiments.

Syllabus:

Course content	No. of Lectures
Determine the distribution of stream-wise, transverse, wall-normal mean velocity from 15 vertical measurements for current only flow.	5
Determine the turbulence intensity and Reynolds shear stress profile from 15 vertical measurements for current only flow.	4
Evaluate the coefficient of skewness and kurtosis, distribution of probability density function and Joint probability density function from 15 vertical measurements for the current only flow.	5

Determine the distribution of stream-wise, transverse, wall-normal mean velocity from 15 vertical measurements for wave-current flow.	5
Determine the turbulence intensity and Reynolds shear stress profile from 15 vertical measurements for wave-current flow.	4
Evaluate the coefficient of skewness and kurtosis, distribution of probability density function and Joint probability density function from 15 vertical measurements for wave-current flow.	5

Further Readings:

Text Books:

1. Nezu I, Nakagawa H. Turbulence in Open-Channel Flows. A.A. Balkema, CRC Press, Rotterdam 1993.

Reference Books:

1. Pope S.B. Turbulent Flows, Cambridge University Press, Cambridge, 1-771, 2000
2. Dey, S. Fluvial Hydrodynamics – Hydrodynamic and Sediment Transport Phenomena, Springer, 2014

MTM 402CT: Computational and Semi-Analytical Methods (Theory) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Apply numerical and semi-analytical methods such as SIMPLE/SIMPLER, Adomian Decomposition Method (ADM), and Variational Iteration Method (VIM) to solve ordinary and partial differential equations arising in incompressible viscous flow problems.

CO2: Utilize homotopy-based advanced methods—including Homotopy Perturbation Method (HPM), Homotopy Analysis Method (HAM), Optimal HAM (O-HAM), and Optimal/Modified HPM (OM-HPM)—to obtain accurate and convergent solutions for complex flow and differential equation systems.

Syllabus:

Course content	No. of Lectures
Primitive Variable Formulation for Incompressible Viscous Flow: The Momentum equation, Pressure and Velocity Corrections, Pressure-Correction equation, Semi-Implicit Method for Pressure-Linked Equation (SIMPLE), Boundary Condition for Pressure-Correction equation, Revised-SIMPLE (SIMPLER), Numerical Examples	4
Adomian Decomposition Method (ADM): ADM for ODEs, Solving System of ODEs by ADM, ADM for Solving Partial Differential Equations, ADM for System of PDEs, Numerical Examples	3
Variational Iteration Method (VIM): Methodology, Linear Operator and Lagrange's Multiplier, Advantages and limitations, Applications to Ordinary and fractional order differential equations, Revised-VIM (R-VIM).	3

Homotopy Based Advanced Semi-Analytical Methods: Introduction to concept of Homotopy in topology and traditional Perturbation method. Then following advance methods are to be discussed: 1. **Homotopy Perturbation Method (HPM)** : Basic Idea of HPM, Numerical Examples, Advantages and limitations 2. **Homotopy Analysis Method (HAM)**: Zeroth order Homotopy equation, Higher order deformation equation, convergence of homotopy-series solution, essence of convergence control parameter, Choice of linear operator and initial guess, Advantages and limitations 3. **Optimal HAM** (**O-HAM**): Different types of residual calculating and optimal methods) and their flexibility Generalised Newtonian Iteration formula, Advantages and limitations 4. **Optimal and Modified HPM (OM-HPM):** Introduction of convergence control parameter in the auxiliary linear operator, its methodology, its superiority over HPM, HAM and Optimal HAM.	10

Further Readings:
Text Books:

1. Subhash V Patanker, Numerical Heat Transfer and Fluid Flow, McGrow-Hill Book Company.
2. S. Chakraverty, N R Mahato, P. Karunakar, and T. D. Rao, Advanced Numerical and Semi-Analytical Methods for Differential Equations, Wiley, 2019.

Reference Books:

1. H.K.Versteeg and W Malalasekera-An Introduction to Computational Fluid Dynamics, Pearson 2008

MTM 402CP: Computational and Semi-Analytical Methods (Practical) Credit 2, Full Marks 25

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Implement computational fluid dynamics methods in MATLAB to solve steady and unsteady diffusion and convection problems, as well as incompressible viscous flow problems using Finite Difference, Finite Volume, and SIMPLE algorithms.
CO2: Apply advanced semi-analytical methods such as ADM, VIM, HPM, HAM, O-HAM, and OM-HPM using Mathematica to obtain accurate solutions for ordinary, fractional, and partial differential equations relevant to fluid dynamics.

Syllabus:
In MTM304C (Computational Fluid Dynamics), the focus was primarily on introducing computational fluid dynamics methods, with some computational solution for their understanding of those methods. However, the present course goes a step further by incorporating **practical implementation of these methods along with advanced semi-analytical approaches** such as ADM, VIM, HPM, HAM, and OM-HPM. Without the integration of these practical components

and semi-analytical frameworks, the knowledge from MTM304C remains incomplete. This course therefore provides the **necessary complement** to MTM304C by equipping students with both **theoretical understanding and hands-on implementation skills**, making the learning process holistic and directly applicable to complex fluid dynamics problems.

1. **MATLAB-Based Numerical Code for Computational Methods: Numerical experiments for the solution of steady/unsteady one-dimensional diffusion and / or convection equations using Finite difference method (FTCS , Lax-Friedrichs, Leap Frog, Crank-Nicolson methods) and Finite volume method (Central Difference Scheme (CDS) and different upwind schemes**). Numerical experiments for the solution of some problems on fluid dynamics using SIMPLE algorithm
2. **MATHEMATICA-Based Code for Semi-analytical Methods**: Series semi-analytical solutions of some ordinary as well as fractional differential equations using advanced semi-analytical approaches such as ADM, VIM, HPM, HAM, O-HAM and OM-HPM with the help of Mathematica software.

Further Readings:

Text Books:

1. H.K.Versteeg and W Malalasekera-An Introduction to Computational Fluid Dynamics, Pearson 2008
2. C. A. J. Fletcher, Computational Techniques for Fluid Dynamics, Vol-I, Springer, 1988.
3. S. Chakraverty, N R Mahato, P. Karunakar, and T. D. Rao, Advanced Numerical and Semi-Analytical Methods for Differential Equations, Wiley, 2019.

Reference book:

1. Subhash V Patanker, Numerical Heat Transfer and Fluid Flow, McGrow-Hill Book Company

MTM 404: Research Project/Dissertation Credit 8, Full Marks 100

Course Outcomes (COs):

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

CO1: Identify, formulate, and analyze mathematical research problems by reviewing existing literature and recognizing gaps in knowledge.

CO2: Apply appropriate mathematical tools, techniques, and methodologies to develop models, perform computations, and derive results for the chosen research problem.

CO3: Critically interpret research outcomes, validate results, and assess their significance in the context of the problem and existing literature.

CO4: Communicate research findings effectively through well-structured reports, presentations, and publications while adhering to academic integrity and ethical standards.

Guidelines for Undergraduate Research (8 Credits)

1. Selection of Topic

The research topic must be carefully chosen so that it is relevant to the student’s subject area and aligned with their academic interests. It should be practical and feasible to complete within the available time frame and resources, ensuring that the objectives can be realistically achieved.

Finally, the selected topic must be reviewed and formally approved by the assigned Research Guide or Mentor to ensure its suitability and academic value.

2. Role of Student

Students must actively participate in the entire research process by identifying a clear problem, conducting a literature survey to find gaps, and preparing a structured plan with objectives, methodology, and timeline. They should collect and analyse data appropriately, then compile findings into a well-organised research report or dissertation (to be submitted for evaluation).

3. Role of Research Guide / Mentor

The Research Guide or Mentor plays a crucial role in supporting the student's research journey by assisting in the selection of a suitable topic and refining the research questions. They are responsible for providing guidance in the choice of methodology, data collection techniques, and methods of analysis. The mentor also ensures that the student follows ethical practices, including avoiding plagiarism and maintaining confidentiality in handling data. In addition, the guide monitors the student's progress through regular meetings and constructive feedback, helping to keep the research work on track and of high academic quality.

4. Report Format

- **Title Page** (with student name, guide name, department, date).
- **Abstract** (summary of research in 250–300 words).
- **Introduction & Objectives**.
- **Review of Literature**.
- **Research Methodology** (design, data collection, sampling, tools).
- **Analysis and Results**.
- **Discussion** (interpretation of findings).
- **Conclusion & Future Scope**.
- **References** (APA / standard style).
- **Appendices** (if any).

5. Ethical Considerations

Students must maintain academic integrity by avoiding plagiarism, ensuring confidentiality and anonymity of data sources, and properly acknowledging all references and contributions. In case of publication, they should strictly follow the norms of publication ethics, upholding transparency, credibility, and honesty in presenting their research findings.

6. Evaluation

The department will form an evaluation committee consisting of the research guide(s), departmental faculty members, and external subject experts. At least one external member must be part of the committee and present during the student's presentation. The committee will assess and evaluate the complete research report and presentation.

7. Marks distribution

Total marks 100; Credits 8

- Proposal and Abstract – 10 marks
- Literature Review – 10 marks
- Methodology & Data Collection – 10 marks
- Data Analysis & Interpretation – 10 marks
- Report Quality – 30 marks or full 70 marks

- Viva-Voce & Presentation – 30 marks

MTM 405: Field Visit (Credit 2) Credit 2, Full Marks 25

Course Outcomes (COs):

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

CO1: Analyze and interpret real-world applications of mathematical concepts, techniques, and computational methods observed during field visits, connecting theoretical knowledge with practical scenarios.

CO2: Demonstrate effective communication and documentation skills by preparing detailed reports and presentations on mathematical applications, insights, and learning outcomes from professional or research environments.

Guidelines for Field Visit

Objective:

The field visit aims to provide students with practical exposure to real-world applications of mathematical concepts, techniques, and computational tools in industry, research institutions, laboratories, or other relevant organizations. It enhances observational, analytical, and problem-solving skills.

Duration:

The field visit should cover at least 1-3 full days or equivalent hours spread over multiple visits, depending on the host organization's schedule and course requirements.

Preparation:

1. Students must form groups (3–5 members per group) for better coordination and reporting.
2. Prior to the visit, students should study the background of the organization and identify key areas where mathematics is applied.
3. Prepare a list of questions or topics to explore during the visit.

During the Visit:

1. Students should actively observe and note mathematical applications in real-world scenarios such as data analysis, modelling, computational simulations, optimisation, operations research, or statistical applications.
2. Interact respectfully with professionals, asking relevant questions about their work and mathematical methods used.
3. Maintain discipline and adhere to the organization's rules and safety guidelines.

Post-Visit Requirements:

1. Each group/student must submit a field visit report including:
    - Objectives of the visit
    - Overview of the organization/institution
    - Mathematical techniques, tools, or applications observed
    - Learning outcomes and reflections
2. Submit the report and presentation within the timeline specified by the instructor.

Assessment:

- Field Visit Report: 50%
- Presentation/Discussion: 30%
- Participation and Engagement during the Visit: 20%

MTM 406: Internship/Industry Project/Innovative Project Credit 2, Full Marks 25

Course Outcomes (COs):

Guidelines

MTM 407: Elective-I: Intellectual Property Rights (IPR) — Credit 2, Full Marks 25

Course Outcomes (COs):
Upon successful completion of this course, students will be able to:
CO1: Understand the fundamental concepts, types, and importance of Intellectual Property Rights (IPR) in research, innovation, and entrepreneurship.
CO2: Apply IPR knowledge in practical scenarios, including patent searches, copyright issues, and ethical considerations in academic and startup environments.

Syllabus:

Course content	**No. of Lectures**
Definition, scope, and importance of IPR, Historical perspective and evolution of IPR, Role of IPR in knowledge economy and innovation, International framework: WIPO, TRIPS agreement.	4
Patents: Definition, features, patentable inventions, process of patent filing in India. Copyrights: Basics, protection, duration, fair use. Trademarks: Definition, types, and importance for businesses. Industrial Designs: Concepts and protection. Geographical Indications (GIs): Examples and relevance in India. Trade Secrets and Emerging Areas (software, digital rights).	8
IPR in research and academia: plagiarism, ethics, and authorship rights. Case studies of Indian IPR success stories (e.g., basmati rice, turmeric, pharmaceuticals). IPR and entrepreneurship/startups. National IPR Policy of India. Introduction to online resources and databases for patents and copyrights.	8

Further Readings:
Text Books:

1. Ganguli, P. (2001). *Intellectual Property Rights: Unleashing the Knowledge Economy.* McGraw Hill.
2. Pandey, N., & Dharni, K. (2014). *Intellectual Property Rights.* PHI Learning.

References Books:

1. WIPO (2020). *Understanding Industrial Property.* World Intellectual Property Organization.
2. Cornish, W., Llewelyn, D., & Aplin, T. (2019). *Intellectual Property: Patents, Copyright, Trade Marks and Allied Rights.* Sweet & Maxwell.
3. National IPR Policy 2016, Government of India.

or

MTM 407: Elective-II: Skill-Enhanced Course on LaTeX **Credit 2, Full Marks 25**

Course Outcomes (COs):

CO1: Create well-structured LaTeX documents including sections, equations, tables, figures, and bibliographies.

CO2: Apply advanced LaTeX features such as custom commands, packages, and page formatting for professional documents.

CO3: Prepare mathematical, scientific, and project reports with proper referencing and formatting standards.

CO4: Develop presentations using LaTeX beamer class for academic and research communication.

Syllabus:

Course content	No. of Lectures
Introduction to LaTeX History, importance, and applications of LaTeX in scientific and mathematical writing. Installation of LaTeX distributions (TeX Live, MikTeX) and editors (Overleaf, TeXstudio). Overview of document structure: preamble, body, and document classes (article, report, book).	3
Basic Document Preparation Creating a simple document, title, author, date, sections, subsections, paragraphs, line breaks, and indentation. Compiling LaTeX documents into PDF and common compilation errors. Introduction to environments (itemize, enumerate, description).	3
Mathematical Typesetting Inline and display math modes, superscripts and subscripts, Greek letters, operators, fractions, roots, summation, integrals, limits. Using align, equation, gather environments. Matrices, multi-line equations, and common math symbols.	4
Tables and Figures Creating and formatting tables using tabular and tabularx environments. Adding captions, labels, and referencing. Importing figures using graphicx package, figure placement options, captions, labels, and cross-references.	3
Document Structuring and Referencing Sections, subsections, table of contents, lists of figures and tables. Labels and cross-references. Creating bibliographies using thebibliography environment. Introduction to BibTeX and natbib for reference management.	3
Advanced LaTeX Features Custom commands, packages, page layout settings, headers and footers. Using geometry, fancyhdr, hyperref packages. Footnotes, margin notes, and including code snippets.	2
Presentations and Project Documents Introduction to beamer class for presentations. Creating slides, frames, themes, overlays, and animations. Structuring research/project reports with proper formatting, chapters, sections, and appendices.	2
Project Work and Practical Applications	2

Hands-on preparation of a complete scientific document with title page, abstract, sections, tables, figures, equations, and bibliography. Individual or group project submission.	

Further Readings:

Textbooks:

1. Leslie Lamport, *LaTeX: A Document Preparation System* (2nd Edition), Addison-Wesley, 1994.
2. Helmut Kopka and Patrick W. Daly, *A Guide to LaTeX* (4th Edition), Springer, 2003.

Reference Books:

1. Tobias Oetiker, et al., *The Not So Short Introduction to LaTeX2e*, 2017. (Free PDF)
2. Frank Mittelbach and Michel Goossens, *The LaTeX Companion* (2nd Edition), Addison-Wesley, 2004.