DEPARTMENT OF MATHEMATICS

NATIONAL INSTITUTE OF TECHNOLOGY
KURUKSHETRA

Master of Science in Mathematics
Scheme and Syllabi

Scheme and Syllabi

Semester – I

S.No	Code	Course of Study	L	T	P	Credit
1.	MAPC 501	Real Analysis	3	0	0	3
2.	MAPC 503	Linear Algebra	3	0	0	3
3.	MAPC 505	Probability and Statistics	3	0	0	3
4.	MAPC 507	Ordinary Differential Equations	3	0	0	3
5.	MAPC 509	Computer Programming in Python	3	0	2	4
6	MAPC 511	Integral Transforms and Integral Equations	3	0	0	3
					Total	**19**

Semester – II

S.No	Code	Course of Study	L	T	P	Credit
1.	MAPC 502	Complex Analysis	3	0	0	3
2.	MAPC 504	Topology	3	0	0	3
3.	MAPC 506	Partial Differential Equations	3	0	0	3
4.	MAPC 508	Numerical Analysis	3	0	2	4
5.	MAPE 5**	Program Elective -I	3	0	0	3
6.	MAPE 5**	Program Elective -II	3	0	0	3
7.	MAPC***	Seminar/Viva	1	0	2	2
					Total	**21**

Semester – III

S.No	Code	Course of Study	L	T	P	Credit
1.	MAPC 513	Functional Analysis	3	0	0	3
2.	MAPC 515	Fluid Dynamics	3	0	0	3
3.	MAPC 517	Discrete Mathematics	3	0	0	3
4.	MAPC 519	Numerical Solutions of Differential Equations	3	0	2	4
5.	MAPE 5**	Program Elective - III	3	0	0	3
6.	** OE ***	Open Elective I	3	0	0	3
7.	MAPC 521	Preparative Research Project	0	0	4	2
					Total	**21**

Semester – IV

S.No	Code	Course of Study	L	T	P	Credit
1.	MAPC 512	Constrained and Unconstrained Optimization	3	0	0	3
2.	MAPE 5**	Program Elective – IV	3	0	0	3
3.	MAPE 5**	Program Elective V	3	0	0	3
4.	**OE ***	Open Elective II	3	0	0	3
5.	MAPC 524	Research Project and Comprehensive Viva	0	0	20	10
					Total	**22**

Total Credits: 83

PC: Program Core **PE**: Program Elective
OE: Open Elective **AU**: Audit Course

List of Program Electives

Course Code	Course Title
MAPE 522	Introduction to Advanced Computing Languages
MAPE 551	Advanced Modern Algebra
MAPE 552	Number Theory
MAPE 553	Special Functions and Lie Theory
MAPE 554	Lie Algebra
MAPE 555	Fourier Analysis
MAPE 556	Differential Geometry
MAPE 557	Measure and Integration
MAPE 558	Graph theory
MAPE 559	Mathematical Programming
MAPE 560	Multivariate Data Analysis
MAPE 561	Integral Equations and Calculus of Variations
MAPE 562	Symbolic Computing
MAPE 563	Wavelet Analysis
MAPE 564	Iterative Methods
MAPE 565	Perturbation Methods
MAPE 566	Spectral Methods
MAPE 567	Computational Fluid Dynamics
MAPE 568	Finite Element Method
MAPE 569	Dynamical Systems
MAPE 570	Mathematics for Data Science

Note:

1. In addition to the above listed electives, a student can register for one elective from SWAYAM - NPTEL courses on satisfying the minimum pre- requisite of the specific course(s) with the approval of DAC.

List of Open Electives

Course Code	Course Title
OE *	Environmental Science & Sustainable Development
OE *	Educational Leadership
OE *	Brief Introduction to Psychology
OE *	Entrepreneurship
OE *	Learning Analytics Tools
OE *	Computer Design
OE *	Fundamentals of Artificial Intelligence
OE *	An Introduction to Coding Theory
OE *	Artificial Intelligence : Search Methods For Problem Solving
OE *	Management Information Systems
OE *	Cyber Security and Privacy
OE *	Deep Learning
OE *	Combinatorics
OE *	Galois Theory
OE *	Introduction to Algorithms And Analysis
OE *	Introduction to Internet Of Things
OE *	Introduction to Fuzzy Set Theory, Arithmetic And Logic
OE *	Introduction to Machine Learning
OE *	Introduction to Methods of Applied Mathematics
OE *	Machine Learning And Deep Learning - Fundamentals And Applications

SWAYAM / NPTEL COURSES:

1. A student may complete SWAYAM - NPTEL courses and transfer equivalent credits to partially complete the mandatory credit requirements for Open Elective courses of the M. Sc. Program.
2. The Department may permit students to register from other platforms, by taking care of evaluation and grading.
3. Before the commencement of each Semester, Department shall release a list of SWAYAM - NPTEL courses approved as Open Elective courses.
4. A student shall only request for transfer of credits from such notified SWAYAM - NPTEL Courses as

published by the Department.

5. SWAYAM - NPTEL Courses are considered for transfer of credits only if the concerned student has successfully completed and obtained the SWAYAM - NPTEL Certificate to this effect.

6. A student cannot transfer credits from SWAYAM - NPTEL Courses for any other type of Courses not permitted in the Curriculum.

7. Students shall register for the approved Courses as per the schedule announced by SWAYAM - NPTEL.

8. The credit equivalence for SWAYAM - NPTEL Courses: 12 weeks/8 weeks – 3 credits; 4 weeks – 2 credits.

9. The grading system for such SWAYAM - NPTEL Courses with transfer of credits is specified in Table given below:
Table: Grading System for SWAYAM - NPTEL Courses

Final Score on the SWAYAM - NPTEL Certificate	Grade Awarded
85 ≤ Percentage ≤ 100	A^+
75 ≤ Percentage <85	A
65 ≤ Percentage <75	B
50 ≤ Percentage <65	C
40≤ Percentage <50	D
0 ≤ Percentage <40	E

10. A student must submit the original SWAYAM - NPTEL Course Certificates to the Head of Department concerned, with a written request for the transfer of the equivalent credits. On verification of the SWAYAM - NPTEL Course Certificates and approval by the Head of the Department, the SWAYAM - NPTEL

Course(s) and equivalent Credits will be included in Course (with associated Credits) Registration of the concerned student in the Semester immediately following the completion of the SWAYAM - NPTEL Course(s).

11. If any faculty is assigned for the evaluation of the courses taken through these platforms, he/she can evaluate like any regular course by following the assessment and evaluation guidelines.

12. A student may submit a request for credit transfer from SWAYAM - NPTEL Courses before the last instruction day of the fourth (4th) Semester of the M.Sc. program as specified in the Academic Calendar.

13. The Institute shall not reimburse any fees/expenses, a student may incur for the SWAYAM - NPTEL Courses.

Course Code MAPC 501	Real Analysis	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Basic Topology & Riemann Stieltje's integral : Introduction, Definition and existence of the integral, Properties of the integral, Integration and differentiation of integral with variable limits.

Unit 2: **10L**

Improper Integrals: Definitions and their convergence, Tests of convergence, Beta and Gamma functions.

Unit 3: **10L**

Uniform Convergence: Tests for uniform convergence, Theorems on limit and continuity of sum functions, Ascoli's theorem, Weierstrass approximation theorem.

Unit 4: **10L**

Power Series: Convergence and their properties.

Fourier Series: Dirichlet's conditions, Existence, Problems, Half range sine and cosine series.

Text Books:

1. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill, Third Edition, 2017.
2. Brian S. Thomson, Andrew M. Bruckner, Judith B. Bruner, Real Analysis, Prentice Hall International, 2008.

Reference Books:

1. William F. Trench, Introduction to Real Analysis, Library of Congress Cataloging-in- Publication Data, Free Edition 1.04, April 2010.
2. N.L. Carothers, Real Analysis,Cambridge University Press, 2000.
3. Tom M. Apostol, Mathematical Analysis, Addison Wesley, Second Edition, 1974.

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

CO1	Find whether a given function can be Riemann integrable
CO2	Test whether a given improper integral can be convergent
CO3	Examine uniform convergence of given sequence and /or series of functions
CO4	Expand a given function into Fourier series

Course Code MAPC 502	Complex Analysis	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: MAPC 501

Unit 1: **10L**

Functions of Complex Variables: Complex variable, Functions of a complex variable, Continuity, Differentiability and Analytic functions.

Unit 2: **10L**

Complex Integration: Cauchy's theorem, Cauchy's integral formula, Morera's theorem, Cauchy's inequality, Liouville's theorem, Schwartz lemma.

Unit 3: **10L**

Series Expansions: Taylor's theorem, Laurent's theorem, Zeros of an analytic function, Singularities.

Contour Integration: Residue, Cauchy's residue theorem, Contour integration, Fundamental theorem of algebra, Poisson's integral formula.

Unit 4: **10L**

Conformal Mapping: The Maximum modulus theorem-mean values of f(z), Conformal representation, Bilinear transformation, Transformation by elementary functions, Uniqueness of conformal transformation, Representation of any region on a circle.

Text Books:

1. R.V. Churchill and J.W. Brown, Complex Variables and Applications, McGraw Hill, Tokyo, Eighth Edition, 2009.

2. E.T. Copson, Theory of Complex Variables, Oxford University Press, New Delhi, 1974.

Reference Books:

1. S. Ponnusamy and Herb Silverman, Complex Variables with Applications, Birkhauser, Boston, First Edition, 2006.
2. Murray Spiegel, Seymour Lipschutz, John Schiller and Dennis Spellman, Complex Variable, Schaum's Outlines Series, McGraw Hill, Revised Second Edition, 2017.

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

CO1	Introduce the analyticity of complex functions and study their applications
CO2	Evaluate complex integrals and expand complex functions
CO3	Determine and classify the zeros and singularities of the complex functions
CO4	Evaluate improper integrals by residue theorem
CO5	Learn the uniqueness of conformal transformation

Course Code MAPC 503	**Linear Algebra**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: 10L

System of Linear Equations: Matrices and elementary row operations, Uniqueness of Echelon forms, Solutions of homogeneous and non- homogeneous linear system of equations.

Unit 2: 10L

Vector Spaces and Linear Transformations: Vector spaces, Subspaces, LI and LD vectors, Bases and dimension, Coordinates, Linear transformations and its algebra and representation by matrices, Algebra of polynomials.

Unit 3: 10L

Diagonalization of Matrices: Elementary canonical forms, Characteristic values and characteristic vectors, Cayley-Hamilton theorem, Annihilating polynomial, Invariant subspaces, Simultaneous triangularization, Simultaneous diagonalization, Jordan form.

Unit 4: 10L

Inner Product Spaces: Inner product spaces, Unitary and normal operators, Bilinear forms.

Text Books:

1. K.Hoffman and R.Kunze,Linear Algebra, Prentice Hall of India, New Delhi, 2003.
2. Sheldon Axler,Linear Algebra Done Right, Springer nature, Third Edition, 2015.

Reference Books:

1. P.G. Bhattacharya, S.K. Jain and S.R. Nagpaul, First Course in Linear Algebra, Wiley Eastern Ltd., New Delhi, 1991.

2. K.B. Datta, Matrix and Linear Algebra, Prentice Hall of India, New Delhi, 2006.

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

CO1	Test the consistency of system of linear algebraic equations
CO2	Verify rank nullity theorem for a given linear transformation
CO3	Find eigenvalues and canonical forms of a linear operator
CO4	Identify the importance of orthogonal property in the spectral theory
CO5	Demonstrate the knowledge of bilinear form and its nature

Course Code MAPC 504	Topology	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: MAPC 501

Unit 1: 10L

Topological Spaces and Continuous Functions: Definition, Basis for a topology, Order topology, Product topology, Subspace topology, Closed sets, T1 axiom and Hausdorff spaces, Continuous functions, Homeomorphisms, Product and box topologies, Metric topology.

Unit 2: 10L

Connectedness and Compactness in Topological Spaces: Connected spaces, Components of a space, Compact spaces.

Unit 3: 10L

Countability and Separation Axioms: Countability axioms, Separation axioms, Normal spaces, Urysohn Lemma, Urysohn Metrization theorem, Brief introduction to: Tietze Extension theorem, Tychonoff theorem, Stone-Cech Compactification.

Unit 4: 10L

Completeness: Complete metric spaces, Baire's Category theorem.

Text Books:

1. James R. Munkres, Topology, Prentice Hall of India, Second Edition, 2007.

2. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Inc., 2004.

Reference Books:

1. Fred H. Croom, Principles of Topology, Cengage Learning, 2008
2. John L. Kelley, General Topology, Springer, 1991.

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

CO1	Compare nature of spaces with different topologies
CO2	Understand connectedness and compactness in spaces with different topologies
CO3	Categorize spaces based on countability and separation axioms
CO4	Combine results in proving results such as Urysohn Lemma and Urysohn metrization theorem
CO5	Understand the notion of completeness with its importance in Baire's Category theorem

Course Code	Probability and Statistics	L - T - P - C
MAPC 505		3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Random Variables: Review of probability, Probability distributions with discrete and continuous random variables, Joint probability mass function, Marginal distribution function, Joint density function, Independent random variables, Mathematical Expectation, Moment generating function, Chebyshev's inequality, Weak law of large numbers.

Unit 2: **10L**

Theoretical Probability Distributions: Binomial, Bernoulli trials, Negative Binomial, Geometric, Poisson, Normal, Rectangular, Exponential, Gaussian, Beta and Gamma distributions and their moment generating functions, Fit of a given theoretical model to an empirical data.

Unit 3: **10L**

Sampling and Testing of Hypothesis: Introduction to testing of hypothesis, Tests of significance for large samples(z-test), t, F and Chi-square tests.

Unit 4: **10L**

Theory of Estimation: Characteristics of estimation - Minimum variance unbiased estimator, Method of maximum likelihood estimation.

Correlation and Regression: Scatter diagram, Linear and polynomial fitting by the method of least squares, Linear correlation and linear regression , Rank correlation, Correlation of bivariate frequency distribution.

Text Books:

1. S.C. Gupta and V.K. Kapur, Fundamentals of Mathematical Statistics, S. Chand & Sons, New Delhi, 2008.
2. V.K. Rohatgi and A.K. Md. Ehsanes Saleh, An Introduction to Probability theory and Mathematical Sciences, Wiley, 2001.

Reference Books:

1. Richard A. Johnson, Miller & Freund's Probability and Statistics for Engineers, Pearson, Ninth Edition, 2018.

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

CO1	Determine the mean, standard deviation and m^{th} moment of a probability
CO2	Apply theoretical model to fit the empirical data
CO3	Differentiate between Large and small sample tests
CO4	Use the method of testing of hypothesis for examining the validity of a hypothesis
CO5	Estimate the parameters of a population from knowledge of statistics of a sample

Course Code MAPC 506	**Partial Differential Equations**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: MAPC 507

Unit 1: 10L

Equations of the First Order: Formulation, Classification of first order partial differential equations (PDEs), Lagrange's method, Cauchy problem and method of characteristics for linear and quasilinear PDEs, Pfaffian equation, Condition for integrability, First order non-linear equations, Complete integrals, Envelopes and singular solutions, Method of Charpit and Method of characteristics.

Unit 2: 10L

Equations of Higher Order: Method of solution for the case of constant coefficients, Classification of second order equations, Reduction to canonical forms, Method of solution by separation of variables.

Unit 3: 10L

Diffusion Equation: Derivation of the heat equation, Method of separation of variables, Solutions of heat equation with homogeneous and non-homogeneous boundary conditions, Inhomogeneous heat equation, Duhamel's principle.

Unit 4: 10L

Wave Equation: Derivation of the wave equation, D'Alembert solution of wave equation, Domain of dependence and range of influence, Method of separation of variables, Inhomogeneous wave equation, Duhamel's principle.

Laplace's Equation: Basic concepts, Types of boundary value problems, The maximum and minimum principles, Method of separation of variables.

Text Books:

1. I. Sneddon, Elements of Partial Differential Equations, Dover Publications, 2013.
2. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, Birkhauser, Bostan, Fourth Edition, 2007.

Reference Books:

1. P. Prasad and R. Ravindran, Partial Differential Equations, New Age International (P) Ltd., New Delhi, 2010.
2. T. Amaranath, An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, Second Edition, 2003.

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

CO1	Solve linear and nonlinear first order partial differential equations
CO2	Demonstrate the concept of characteristic curves and characteristic strips
CO3	Solve higher order partial differential equations with constant coefficients
CO4	Find canonical forms of second order partial differential equations
CO5	Utilize the knowledge of PDES in solving various physical problems

Course Code	Ordinary Differential Equations	L - T - P - C
MAPC 507		**3 - 0 - 0 - 3**

Pre-Requisites: NIL

Unit 1: **10L**

First Order Equations: Picard's theorem, Non-Local existence theorem.

Second Order Equations: Linear dependence and independence - A formula for the Wronskian, the non - homogeneous equations, linear equations with variable coefficients, Reduction of the order of the homogeneous equation, Sturm comparison theorem, Sturm separation theorem.

Unit 2: **10L**

Stability: Autonomous systems, the phase plane and its phenomena, Critical points and stability for Linear systems.

Unit 3: **10L**

Systems of Differential Equations: Existence theorems - homogeneous linear systems, non-homogeneous linear systems, Linear systems with constant coefficients-Eigenvalues and eigenvectors, Diagonal and Jordan matrices.

Unit 4: **10L**

Boundary Value Problems: Two-point boundary value problems, Green's functions, construction of Greens functions, non-homogeneous boundary conditions.

Text Books:

1. G.F. Simmons, Differential Equations with Applications and Historical Notes, McGraw Hill, Second Edition, 2017.

2. E.A. Coddington, An Introduction to Ordinary Differential Equations, PHI Learning, 1999.
3. U. Tyn Myint, Ordinary Differential Equations, Elesvier, North- Holland, 1978.
4. V. Raghavendra, Rasmita Kar, S.G. Deo, V. Lakshmikantham, Textbook of Ordinary Differential Equations, McGraw Hill India, Third Edition, 2015.

Reference Books:

1. M. Braun, Differential Equations and Their Applications, Springer-Verlag, Third Edition, 1983.
2. P.J. Collins, Differential and Integral Equations, Oxford University Press, 2006.
3. W.E. Boyce and R.C. Di-Prima, Elementary Differential Equations and Boundary Value Problems, John Wiely & Sons, 2001.

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

CO1	Determine linearly independent solutions and general solution of a non -homogeneous differential equations
CO2	Find power series solution to a differential equation containing variable coefficients
CO3	Discuss the existence and uniqueness of solution for an initial value problem
CO4	Use Green's function to solve a non-homogeneous boundary value problem

Course Code MAPC 508	**Numerical Analysis**	L - T - P - C 3 - 0 - 2 - 4

Pre-Requisites: NIL

Unit 1: **10L**

Interpolation: Existence and uniqueness of interpolating polynomial, Error of interpolation, Equally spaced data - Finite difference operators and their properties, Unequally spaced data - Lagrange's and Newton's divided difference formulae, Inverse interpolation, Hermite interpolation.

Unit 2: **10L**

Differentiation: Finite difference approximations for first and second order derivatives.

Integration: Newton-cotes closed type methods - particular cases and error terms, Newton cotes open type methods - Romberg integration, Gaussian quadrature, Legendre, Chebyshev formulae.

Unit 3: **10L**

Solution of Nonlinear and Transcendental Equations: Regula-Falsi method, Newton- Raphson method, Muller's method, System of nonlinear equations.

Approximation: Norms, Least square (using monomials and orthogonal polynomials), Uniform and Chebyshev approximations.

Unit 4: **10L**

Solution of Linear Algebraic System of Equations: Gauss-Seidal methods, Solution of tridiagonal system, ill conditioned equations, Eigen values and eigen vectors using Power method.

Solution of Ordinary Differential Equations - Initial Value Problems: Single step methods- Taylor's, Euler's, Runge-Kutta methods, Error analysis, Multistep methods- Milne's predictor-corrector methods, System of IVP's and higher orders IVP's.

Practicals:
Students can use PYTHON programming language

1. To solve nonlinear equations.
2. To solve a system of nonlinear equations.
3. To solve a system of linear equations using direct methods.
4. To solve a system of linear equations using indirect methods.
5. To find the eigenvalue of a matrix.
6. To make a difference table.
7. For interpolating arbitrary spaced and equally spaced data.
8. To approximate the derivative numerically.
9. To integrate a function numerically.
10. To solve the initial value problems of order one and more and system of first order ODEs.

Text Books:

1. MK Jain, SRK Iyengar and RK Jain, Numerical Methods for Engineers and Scientists, New Age International, 2008.
2. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Addison-Wesley, 1984.

Reference Books:

1. K. Atkinson, An Introduction to Numerical Analysis, Numerical Analysis, John Wiley, 1989.

2. F.B. Hildebrandt, Introduction to Numerical Analysis, Courier Coporation, 1987.

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

CO1	Construct the Polynomial to the given data
CO2	Evaluate the integrals numerically
CO3	Find the roots of nonlinear equations
CO4	Approximate the function by a polynomial
CO5	Solve Initial value problems numerically

Course Code MAPC 509	Computer Programming in Python	L - T - P - C 3 - 0 - 2 - 4

Pre-Requisites: NIL

Unit 1: 10L

Introduction to Python: Python variables, Python basic Operators, Python Data Types, variables, Declaring and using Numeric data types: int, float etc., Basic Input-Output Operations, Basic Operators.

Unit 2: 10L

Conditionals and Loops: Boolean Values, if, else and else if, Simple for loops in python, for loop using ranges, string, list and dictionaries. Use of while loops in python, Loop manipulation using pass, continue, break and else.

Unit 3: 10L

Strings: Assigning values in strings, String manipulations, String special operators, String formatting operators, Triple Quotes, Raw String, Unicode String, Build-in-String methods.

Lists: Lists Introduction, accessing values in list, List manipulations, List Operations, Indexing, slicing & matrices, use of tuple data type, string, list and Dictionary, string manipulation methods, programming using string, list and dictionary in-built functions.

Unit 4: 10L

Functions: Built–in Functions and methods, Functions, writing functions in Python, returning a result from a function, Pass by value & pass by reference, function arguments & its types, recursive functions.

Python Packages: Simple programs using the built-in functions of packages matplotlib, numpy, pandas etc.,

Practicals:

Students can use PYTHON programming language

1. Conditional control constructs
2. loops
3. Strings
4. Lists
5. user defined functions and library functions
6. built-in functions of packages matplotlib
7. numpy
8. pandas

Text Books:

1. William Mitchell, Povel Solin, Martin Novak et al., Introduction to Python Programming, NCLab Public Computing, 2012.
2. Jacob Fredslund, Introduction to Python Programming, 2007.

Reference Books:

1. John C. Lusth, An Introduction to Python, The University of Alabama, 2011.
2. Dave Kuhlman, Introduction to Python, 2008.

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

CO1	Introduce the fundamental concepts of Python
CO2	Provide a foundation to use basic building blocks of Python
CO3	Learn to write Python Scripts.
CO4	Explore various exception handling mechanisms
CO5	Develop Python packages

Course Code MAPC 511	**Integral Transforms and Integral Equations**	**L - T - P - C** **3 - 0 - 0 - 3**

Pre-Requisites: NIL

Unit 1: **10L**

Laplace Transform: Definition, Functions of exponential order and examples, Transforms of elementary, transcendental and special functions, Transforms of derivatives and integrals, Transforms of periodic, unit-step and impulse functions, The inverse transform –Properties, Partial fraction, Convolution theorem, Solution of differential equations by the use of the transform, Laplace inverse integral, Solution of Laplace equation (in two dimensions), One-dimensional heat and wave equation, Demonstrations with simple examples.

Unit 2: **10L**

Fourier Transform: The Fourier transform, Inverse Fourier transform, Fourier transform properties, Convolution integral, Convolution theorem, Correlation, Correlation theorem, Parseval's theorem, Wave from sampling, Sampling theorem, Frequency sampling theorem, Demonstrations with simple examples.

Unit 3: **10L**

Z - Transform: Z - transform, Inverse Z - transform, Z - transform properties, Solution of linear difference equations by using Z - transform. Discrete Fourier Transform - Fourier transform of sequences, Discrete Fourier transform, transfer function.

Unit 4: **10L**

Integral Equations: Classification of integral equations, Connection with differential equations, Integral equations of the convolution type, Method of successive approximations, the resolvent, Fredholm theory, Laplace and Fourier transforms with applications to integral equations, Green's functions, Non-homogeneous boundary value problems, one-dimensional Green's function.

Text Books:

1. R.V. Churchill, Operational Mathematics, McGraw Hill, 1972.
2. F. B. Hildebrand, Methods of Applied Mathematics, PHI, New Jercy, 1960.
3. E. I. Jury, Theory and applications of Z-Transform method, John Wiley, 1964.

Reference Books:

1. I.N. Snedden, The use of Integral Transforms, Tata Mc-Graw Hill, 1979.
2. John W. Dettman, Mathematical methods in Physics & Engineering, McGraw Hill, NewYork, 1962.

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

CO1	Understand the concepts of certain integral transforms
CO2	Solve differential equations using Laplace transforms
CO3	Find the solution of BVP's using Fourier transforms
CO4	Solve finite difference equations by using Z transforms
CO5	Solve an integral equation
CO6	Find the Greens function to a differential equation/integral equation

Course Code MAPC 513	**Functional Analysis**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: MAPC 503

Unit 1: **10L**

Banach Spaces: Normed linear spaces, Banach spaces-Definition and some examples, Incomplete normed linear spaces, Bounded linear operators, Hahn-Banach theorem.

Unit 2: **10L**

Dual Spaces: Conjugate (or dual) spaces, Natural imbedding of normed linear space N in its second conjugate N**, Open mapping theorem, Closed graph theorem, Conjugate of an operator, Uniform boundedness principle.

Unit 3: **10L**

Hilbert Spaces: Definition and basic properties, Orthogonal complements , Orthonormal sets, Bessel's inequality, Riesz representation theorem.

Unit 4: **10L**

Dual of a Hilbert Space: The dual of a Hilbert space, Adjoint of an operator, Projections and Projection theorem.

Text Books:

1. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Inc., 2004.

2. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons, 2007.

3. Balmohan V. Limaye, Functional Analysis, New Age International, Revised Third Edition, 2017.

Reference Books:

1. J. Conway, A Course in Functional Analysis, Springer, Second Edition, 2007.
2. Casper Goffman and George Pedrick, A First Course in Functional Analysis, AMS Chelsea Publishing, Second Edition, 1983.
3. Peter D. Lax, Functional Analysis, Wiley-Interscience, 2002.

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

CO1	Understand the nature of Banach spaces
CO2	Understand the nature of Hilbert spaces
CO3	Prove the open mapping theorem, closed graph theorem and uniform boundedness principle
CO4	Apply results of this course in solving operator equations

Course Code MAPC 515	**Fluid Dynamics**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: MAPC 507

Unit 1: **10L**

Kinematics: Lagrangian and Eulerian methods, Equation of continuity, Boundary surfaces, Stream lines, Path lines and streak lines, Velocity potential, Irrotational and rotational motions, Vortex lines.

Unit 2: **10L**

Equations of Motion: Lagrange's and Euler's equations of motion, Conservative field of force, Bernoulli's theorem, Equation of motion by flux method, Impulsive actions, Circulation, Kelvin's circulation theorem, Minimum energy theorem.

Unit 3: **10L**

Motion in Two Dimensions: Stream function, Irrotational motion in two-dimensions, Complex velocity potential , Sources, sinks, doublets and images, Milne - Thomson circle theorem, Theorem of Blasius.

Unit 4: **10L**

Motion of Cylinder: Motion of a circular cylinder, Liquid streaming past a fixed circular cylinder, Motion of two co-axial cylinders, Elliptic cylinder moves in an infinite liquid, Liquid streaming past a fixed elliptic cylinder, Circulation about an elliptic cylinder, Kutta-Joukowski theorem.

Text Books:

1. Frank Chorlton, Fluid Dynamics, CBS Publishers, Delhi, 2004.

2. L.M. Milne Thomson, Theoretical Hydrodynamics,

Macmillan Company, NewYork,1960.

3. S.W. Yawn, Fundamental Books on Fluid Mechanics Foundation of Fluid Mechanics.
4. O'Neil, M. E., and Chorlton, F., Ideal and Incompressible Fluid Dynamics. Ellis Horwood Ltd, 1986.

Reference Books:

1. Franz Durst, Fluid Mechanics: An Introduction to the Theory of Fluid Flow, Springer - Verlag Berlin Heidelberg, 2008.
2. Stephen Whitaker, Introduction to Fluid Mechanics, Ed-Tech Press, 2018.
3. Yuan, S.W., Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.

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

CO1	Understand the basic principles of fluid dynamics, such as Lagrangian and Eulerian approach etc.
CO2	Use the concept of stress in fluids with applications
CO3	Analyse irrotational and rotational flows in fluids and some of their properties
CO4	Find analytical solution of Navier Stoke equation and solutions of some benchmark problems

Course Code MAPC 517	Discrete Mathematics	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Mathematical Logic: Connectives, Tautologies, Equivalence of formulas, Duality law, Tautological implications, Normal forms, Theory of inference for statement calculus, Methods of proof, Predicative logic, Statement functions, Variables and quantifiers, Free and bound variables, Inference theory for predicate calculus.

Unit 2: **10L**

Counting: Basics of counting, Permutations and combinations, Generalized Permutations and combinations, Pascal's identity, Vandermonde's identity, Principles of inclusion– exclusion, Pigeonhole principle and its application.

Unit 3: **10L**

Recurrence Relations: Generating functions, Generating functions of permutations and combinations, Formulation as recurrence relations, Solving recurrence relations by substitution and generating functions, Method of characteristic roots, Solving inhomogeneous recurrence relations, Applications of recurrence relations.

Relations: Binary relations - Properties of binary relations, Equivalence relations and partitions, Matrix representation of relations, Adjacency matrices, Incidence matrices, Transitive closure and Warshal's algorithm, Partial and total ordering relations, Lattices.

Unit 4: **10L**

Graph Theory: Basic concepts of graphs, Sub graphs, Matrix representation of graphs: Adjacency matrices, Incidence matrices, Isomorphic graphs, Paths and circuits, Eulerian and Hamiltonian graphs, Multigraphs, Planar graphs, Euler's formula, Graph coloring and covering, Chromatic number, Spanning trees, Algorithms for spanning trees (problems only and theorems without proofs).

Text Books:

1. J. R. Mott, A. Kandel and Baker, Discrete Mathematics for Computer Scientists, PHI, 2006.
2. C. L. Liu, Elements of Discrete Mathematics, McGraw Hill, 1985.

Reference Books:

1. K. H. Rosen, Discrete Mathematics and its Applications with Combinatorics and Graph Theory,Tata McGraw Hill, Seventh Edition, 2015.
2. Bernand Kolman, Robert C. Busby and Sharon Cutler Ross, Discrete Mathematical Structures, PHI, Sixth Edition, 2009.

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

CO1	Apply Propositional logic and First order logic to determine the validity of the statement
CO2	Construct induction proofs involving summations, inequalities, and divisibility
CO3	Implement the principles of counting, permutations and combinatory to solve real world problems
CO4	Formulate and solve recurrence relations
CO5	Determine whether a given relation is an equivalence relation/poset and will be able to draw a Hasse diagram
CO6	Develop and analyze the concepts of Boolean algebra

Course Code MAPC 519	Numerical Solution of Differential Equations	L - T - P - C 3 - 0 - 2 - 4

Pre-Requisites: MAPC 508

Unit 1: 10L

Ordinary Differential Equations: Multistep (explicit and implicit) methods for initial value problems, Linear and nonlinear boundary value problems, Quasilinearization and Shooting methods.

Unit 2: 10L

Finite Difference Methods: Finite difference approximations for derivatives, Boundary value problems with explicit and implicit boundary conditions, Error analysis, Stability analysis, Convergence analysis.

Unit 3: 10L

Partial Differential Equations: Finite difference approximations for partial derivatives and finite difference schemes for parabolic equations, Schmidt's two level and Multi-level explicit methods, Crank-Nicolson's two level, Multi-level implicit methods, Dirichlet's problem, Neumann problem, Mixed boundary value problem.

Unit 4: 10L

Hyperbolic Equations: Explicit methods, Implicit methods, One space dimension.

Elliptic Equations: Laplace equation, Poisson equation, Iterative schemes, Dirichlet's problem, Neumann problem, Mixed boundary value problem, ADI methods.

Practicals:

Student can use PYTHON programming language for constucting

1. FDM for Second order linear & nonlinear BVP with both Dirichlet boundary conditions
2. FDM for Second order linear & nonlinear BVP with both Neumann boundary conditions
3. FDM for Second order linear & nonlinear BVP with right Neumann and left Dirichlet boundary conditions
4. FDM for Second order linear & nonlinear BVP with left Neumann and right Dirichlet boundary conditions
5. An Explicit and Crank- Nicolson FDM for One dimensional heat conduction problem
6. An Explicit and Implicit FDM for one dimensional wave equation
7. An Explicit FDM for one dimensional Laplace equation
8. An Explicit FDM for one dimensional Poisson equation

Text Books:

1. M. K. Jain, Numerical Solution of Differential Equations, Wiley Eastern, Delhi, Fourth Edition, 2018.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Computational Methods for Partial Differential Equations, Wiley Eastern, 2016.

Reference Books:

1. G. D. Smith, Numerical Solution of Partial Differential Equations, Oxford University Press, 2004.

2. S. S. Sastry, Introductory Methods of Numerical Analysis, PHI, Fifth Edition, 2012.

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

CO1	Apply the explicit and implicit multistep methods to solve the linear and non-linear initial value problems in ordinary differential equations
CO2	Apply the cubic splines method to solve the two-point boundary value problems in ordinary differential equations
CO3	Apply the iterative schemes to finite difference equations.
CO4	Find the numerical solution of the heat equation, wave equation and the Laplace equation in one dimensional and 2-dimensional space using the finite difference
CO5	Analyse the stability, convergence and the error analysis of the finite difference methods

Course Code	Constrained and Unconstrained Optimization	L - T - P - C
MAPC 512		**2 - 0 - 2 - 3**

Pre-Requisites: NIL

Unit 1: 10L

Linear Programming Problem, LPP with artificial variable, More on LPP & Introduction to Sensitivity Analysis.

Unit 2: 10L

Sensitivity and duality, Revised and Dual simplex method, Discussion on application with examples.

Unit 3: 10L

Unconstrained optimization with a single variable, Discussion on Elimination techniques, Unconstrained optimization with multiple variables.

Unit 4: 10L

KKT conditions, Constrained optimization – direct method, Constrained optimization – indirect method.

Text Books:

1. Optimization: Theory and Applications By S. S. Rao.
2. Operations Research - An Introduction By Hamdy A. Taha.
3. Nonlinear Multiobjective Optimization By Kaisa Miettinen.

Reference Books:

1. OPTIMIZATION FOR ENGINEERING DESIGN.
2. Algorithms and Examples By KALYANMOY DEB.

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

CO1	Understand and Apply Linear Programming (LP) Techniques
CO2	Analyze the Sensitivity and Duality in Optimization Problems
CO3	Solve Unconstrained Optimization Problems
CO4	Apply the Karush-Kuhn-Tucker (KKT) Conditions for Constrained Optimization
CO5	Develop Problem-Solving Skills for Real-World Optimization Applications

Course Code MAPE 522	Introduction to Advanced Computing Languages	L - T - P - C 2 - 0 - 2 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Introduction to Mathematica: Difference between Numeric computing and Symbolic computing, Parts of Mathematica, Basics of programming in Mathematica, Built-in functions and constants, Numeric calculation using Mathematica, Symbolic computing with Mathematica.

Unit 2: **10L**

Built-in function for Matrices and Linear Algebra: Built-in function for Matrices and Linear Algebra, solving equations, Calculus with Mathematica, Graphics and built-in graphics functions, User defined functions, Conditionals and looping in Mathematica.

Unit 3: **10L**

Introduction to Maple: Inputting Basic Maple Expressions, Variables, Functions, Sums and Products, Packages, Loops, Decision Structures.

Unit 4: **10L**

Basic Commands: Elements of LaTeX, graphics in LaTeX, PSTricks, Beamer presentation.

Text Books:

1. Paul R. Wellin, Mathematica, Wolfram Research Inc., 2005.

2. William P. Fox, William C. Bauldry, Advanced Problem solving with Maple: A first Course.

3. L. Lamport. LATEX: A Document Preparation Sys-

tem, User's Guide and Reference Manual, Addison-Wesley, New York, second edition, 1994.

Reference Books:

1. M.L. Abell, J.P. Braselton, Mathematica by example, Academic Press, 2021.

2. M.B. Monagan, K.O. Geddes, K.M. Heal, G. Labahn, S.M. Vorkoetter, J.S. Devitt, M.L. Hansen, D. Redfern, K.M. Rickard, Maple V Programming Guide: For Release 5, Springer Science & Business Media, 2012.

3. David F. Griffiths, Desmond J. Higham, Learning LaTeX: Second Edition, SIAM, 2016.

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

CO1	Understand the basic principles of the Wolfram Language
CO2	Learn the use of commands and functions for solving and visualizing mathematical problems
CO3	Use Wolfram Language to solve problems graphically, numerically and analytically
CO4	Understanding the basic Maple commands
CO5	Make documents, presentation and draw geometries using LATEX

Course Code MAPE 551	Advanced Modern Algebra	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Groups: Group actions, Cayley's theorem Class equation, Automorphisms, Sylow theorems and applications.

Unit 2: **10L**

Rings: Ring homomorphisms and quotient rings, Quadratic integer rings, Properties of ideals, Rings of fractions, Chinese Remainder theorem.

Unit 3: **10L**

Classes of Rings: Euclidean domains – norm, division algorithm, field norm on quadratic integer rings, results, Principal ideal domains – properties and results, Dedekind-Hasse norm, Unique factorization domains, irreducible elements, prime elements, associates, properties and results, Polynomial rings over fields, polynomial rings that are UFDs, irreducibility criteria.

Unit 4: **10L**

Fields: Brief introduction to fields, field extensions, finite fields.

Text Books:

1. David S. Dummit and Richard M. Foote, Abstract Algebra, John Wiley & Sons, Third Edition, 2004.
2. I. N. Herstein, Topics in Algebra, John Wiley & Sons, Second Edition, 1975.

Reference Books:

1. Michael Artin, Algebra, Pearson, Second Edition, 2016.

2. Joseph A. Gallian, Contemporary Abstract Algebra, Cengage Learning, Eighth Edition, 2013.

3. Serge Lang, Algebra, Springer, Revised Third Edition, 2002.

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

CO1	Analyse the structure of groups
CO2	Distinguish the properties among ring structures
CO3	Understand extension of fields and their constructions
CO4	Apply the concepts and results to solve problems of Modern Algebra
CO5	Construct proofs that arise in various algebraic structures

Course Code MAPE 552	Number Theory	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Congruences: Linear congruences, Solution of congruence, Fermat's theorem, Wilson's theorem, Chinese Remainder Theorem, Quadratic reciprocity and Quadratic residue, Legendre Jacobi symbol, Binary quadratic forms.

Unit 2: **10L**

Arithmetic Functions on Number Theory: Greatest integer function, Arithmetic function, Mobius inversion formula, recurrence function, divisor function, Structure of units modulo n, Euler's ϕ function.

Unit 3: **10L**

Algebraic Numbers and Unique Factorization: Algebraic numbers and fields, Algebraic integers, Quadratic fields, Unique Factorization, Integral ring extensions, Dedekind domains, Unique factorization of ideals, Action of the Galois group on prime ideals.

Unit 4: **10L**

Infinitude of Primes and Elliptic Curves: Infinitude of primes, discussion of the Prime Number theorem, infinitude of primes in specific arithmetic progressions, Dirichlet's theorem (without proof), Representations of integers as sum of squares, Some Diophantine equations: Simultaneous linear equations, Elliptic Curve, Finite Continued Fraction, Infinite continued fraction, Pell's equation.

Text Books:

1. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd ed., Springer-Verlag, Berlin, 1990.
2. S. Lang, Algebraic Number Theory, Addison- Wesley, 1970.
3. Neal Koblitz, Introduction to Elliptic Curves and Modular Form, Springer, Second Edition, 1984.
4. Kenneth H. Rosen, Elementary Number Theory Its Applications, Sixth Edition, Pearson.

Reference Books:

1. Ivan Niven, H. S. Zuckerman and Hugh L. Montomery, An Introduction to the Theory of Numbers.
2. J.S. Milne, Algebraic Number Theory.
3. D.A. Marcus, Number Fields, Springer-Verlag, Berlin, 1977.
4. T M Apostal, Introduction to Analytic Number Theory, Springer.
5. Joseph H. Silverman, The Arithmetic of Elliptic Curves, Second Edition, Springer, 2009.

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

CO1	Solve the system of congruences
CO2	Test the quadratic residues and reciprocity
CO3	Know the basic arithmetic functions
CO4	Study the algebraic numbers and Unique factorization
CO5	Learn about the primes and elliptic curves

Course Code MAPE 553	Special Functions and Lie theory	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 503 & MAPC 507

Unit 1: **10L**

Gamma and Beta Functions :

Infinite products:- Introduction, definition of an infinite product, a necessary condition for convergence, the associated series of logarithms, absolute convergence, uniform convergence, Gamma and Beta functions- The Euler and Mascheroni constant, the Gamma function, a series for $\Gamma'(z)/\Gamma(z)$), evaluation of $\Gamma(1)$ and $\Gamma'(1)$, the Euler product for $\Gamma(z)$, the difference equation $\Gamma(z+1)$ = z$\Gamma(z)$, Evaluation of certain infinite products, Euler's integral for $\Gamma(z)$, the Beta function, the value of $\Gamma(z)$ $\Gamma(1-z)$, the Factorial function, Legendre's Duplication formulae, Gauss's multiplication theorem, a Summation formula due to Euler.

Unit 2: **10L**

Hypergeometric Function: The hypergeometric function F(a,b, c, z), a simple integral form, F(a,b,c,1) as a function of the parameters, evaluation of F(a,b,c,1), Contiguous hypergeometric function relations, the Hypergeometric Differential Equation, F(a,b,c,z) as a function of its parameters, elementary series manipulations, Simple transformations, Series Solution of hyepr geometric differential equations, Confluent hypergeometric Functions.

Unit 3: **10L**

Some More Special Functions: Legendre Polynomials and Functions. Legendre equation and its solution, Generating function, Legendre series, Associated Legendre functions, Properties of associated Legendre functions, Bessel function, Bessel's equation and its solutions, Generating function, Integral representation, Recurrence relations, Hankel functions, Equations reducible to Bessel's equation. Modified Bessel's functions, Recurrence relations for modified Bessel's functions.

Unit 4: **10L**

Lie theory: Introduction to Lie groups and Lie algebras, Relation between the Lie groups and Lie algebras, Classification of some low dimensional Lie algebras, Concept of Lie group through Symmetry and Transformations, Bilinear forms and construction of Classical Lie groups and Classical Lie algebras, Homomorphism and Isomorphism of Lie algebras, Introduction to Representation theory of Lie algebras.

Text Books:

1. E.D. Rainville, Special functions, Chelsa Publishing Company, New York, 1960.

2. J. E Humphreys, Introduction to Lie algebras and Representation Theory, Springer-Verlag

3. G.E. Andrews, R. Askey, R. Roy, Special Functions, Encyclopedia of Mathematics and its Applications 71, Cambridge University Press, Cambridge.1999.

Reference Books:

1. Willard Miller, Lie theory and special functions, Academic Press.

2. G. Gasper, M.Rahman, Basic hypergeometric series, Cambridge University Press.

3. D.A. Marcus, Number Fields, Springer-Verlag, Berlin, 1977.

4. Alexander Kirillov, JR., An introduction to Lie Groups and Lie algebras, CUP.

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

CO1	Develop concepts in Gamma, Beta functions and hypergeometric functions.
CO2	Study Legendre polynomials and Bessel's functions.
CO3	Study the generating functions and recurrence relations of Legendre and Bessel's functions
CO4	Get acquainted with the Lie algebras and Lie groups
CO5	Develop the connection of Lie groups and Lie algebras and understand the application part of it
CO6	Understand the concept of Lie group through symmetry and transformations.

Course Code MAPE 554	Lie Algebras	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Structure of Algebra's : Definition of Lie algebras-classical examples, ideals, standard isomorphism theorems, nilpotent Lie algebras, solvable Lie algebras, simple Lie algebras, Engel's theorem.

Unit 2: **10L**

Lie Theory: Lie's theorem, Jordan decomposition, Cartan's criterion for solvability, Cartan-Killing form, semisimplicity, SL(2) representations, Total and Cartan subalgebras leading to root systems.

Unit 3: **10L**

Root Systems: Learn definition of root systems, basics, Weyl group- properties, Study of simple root systems, Dynkin diagrams, classification of simple root systems.

Unit 4: **10L**

Finite Dimensional Lie Algebra: Universal enveloping algebra, statement of PBW theorems, roots and weights calculation in classical set up, statement of Serre's theorem, definition and basic properties of Verma modules, statement of classification of finite dimensional representations of simple Lie algebras.

Text Books:

1. Karin Erdmanm, Introduction to Lie Algebra's, 2006.

2. J E Humphreys, Introduction to Lie Algebras and Representation Theory, Springer-Verlag.

3. Brian C. Hall, Lie Groups, Lie Algebra's and Repre-

sentations.

Reference Books:

1. J. Humphreys, Introduction to Lie Algebras and Representation Theory, GTM 9, Springer-Verlag, 1972.
2. G. Gasper, M.Rahman, Basic hypergeometric series, Cambridge University Press.

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

CO1	Learn basics of Lie algebras, solvable and nilpotent Lie algebras
CO2	Learn semi simple Lie algebras, Cartan's criterion, connection between solvable and semi simple Lie algebras, classification of SL(2) modules, Weyl's theorem on complete reducibility
CO3	Learn notion of total and Cartan sub algebras, using Cartan sub algebras slowly lead to root systems
CO4	Learn basics of root systems, Weyl group combinatorics
CO5	Study Classification of root systems leading to classification of simple Lie algebras
CO6	Universal enveloping algebra definition, statement of Serre's theorem, basics of Verma modules and statement of classification of finite dimensional irreducible representations of semi simple Lie algebras

Course Code MAPE 555	Fourier Analysis	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Fourier Series: Fourier coefficient and series, Criteria for point-wise convergence, Fourier series of continuous functions, Convergence in norm, Summability methods.

Unit 2: **10L**

Fourier Integral: Fourier transforms of L_1 functions, Fourier transform on L_p, $p > 2$, The convergence and summability of Fourier integrals.

Unit 3: **10L**

The Hilbert Transform: The conjugate Poisson kernel, Theorems of M. Riesz and Kalmogrov, Truncated integrals and point- wise convergence, Multipliers.

Unit 4: **10L**

The Hardy-Littlewood Maximal Functions: Approximation of the identity, Weak- type inequalities and almost everywhere convergence, Marcinkiewicz interpolation theorem, Hardy-Littlewood maximal function, Dyadic maximal function.

Text Books:

1. J. Duoandikoetxea, Fourier Analysis, AMS Bookstore, 2001.
2. T.W. körner, Fourier Analysis, Cambridge University Press.

Reference Books:

1. Gerald B. Folland, Fourier Analysis and Its Applications, American Mathematical Society, 1992.
2. J. Arias-De-Reyna, Pointwise Convergence of Fourier Series,
   Journal of the London Mathematical Society, 65(1) , pp. 139-153, 2002.
   DOI: https://doi.org/10.1112/S0024610701002824

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

CO1	Expand a given function into Fourier series.
CO2	Test convergence and summability of Fourier integrals.
CO3	Apply Marcinkiewicz interpolation theorem.
CO4	Find conjugate Poission kernel and Hilbert transform.

Course Code MAPE 556	**Differential Geometry**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Local Curve Theory: Serret-Frenet formulation, Fundamental existence theorem of space curves.

Unit 2: **10L**

Plane Curves and their Global Theory: Rotation index, Convex curves, Isoperimetric inequality, Four vertex theorem.

Unit 3: **10L**

Local Surface Theory: First fundamental form and arc length, Normal curvature, Geodesic curvature and Gauss formulae, Geodesics, Parallel vector fields along a curve and parallelism, the second fundamental form and the Weingarten map, Principal, Gaussian, Mean and normal curvatures, Riemannian curvature and Gauss's theorem Egregium, Isometrics and fundamental theorem of surfaces.

Unit 4: **10L**

Global Theory of Surfaces: Geodesic coordinate patches, Gauss-Bonnet formula and Euler characteristic, Index of a vector field, Surfaces of constant curvature.

Text Books:

1. R. S. Millman and G. D. Parker, Elements of Differential Geometry, Prentice Hall Inc., 1977.

2. D. Laugwitz, Differential and Riemannian Geometry, Academic Press, 2014.

Reference Books:

1. Andrew Pressley, Elementary Differential Geometry, Springer, 2010.
2. M. P. doCarmo, Differential Geometry of Curves and Surfaces, Prentice Hall, 1976.
3. B. O'Neill, Elementary Differential Geometry, Academic Press, New York, 1966.

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

CO1	Determine the directions of tangent, normal and binormal at point on the given
CO2	Find the geodesic curve on a given surface
CO3	Find surfaces of constant curvature
CO4	Form tensor quantities and find the corresponding metric tensors

Course Code MAPE 557	Measure and Integration	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 501

Unit 1: **10L**

Lebesgue Measure: Outer measure, Measurable sets, A non-measurable set, Example of measurable set which is not a Borel set, Lebesgue measure and its properties, Measurable functions.

Unit 2: **10L**

Abstract Integration: The concept of measurability, Simple functions, Elementary properties of measures, Arithmetic in $[0, \infty]$, Integration of positive functions.

Unit 3: **10L**

Lebesgue's Theorems: Lebesgue's monotone convergence theorem, Fatou's lemma, Lebesgue's dominated convergence theorem, Integration of complex functions, the role played by sets of measure zero.

Unit 4: **10L**

Product Measures: Integration on cartesian products, Product measures, Fubini's theorem.

Text Books:

1. H. L. Royden, Real Analysis, Pearson, Third Edition, 2003.
2. W. Rudin, Real and Complex Analysis, Tata McGraw-Hill Edition, Third edition, 2006.

Reference Books:

1. G. de Barra, Measure and Integration, Wiley Eastern, 1981.
2. Terence Tao, An Introduction to Measure Theory, Graduate Studies in Mathematics, AMS, 2011.
3. G.B. Folland, Real Analysis: Modern Techniques and Their Applications, John wiley and sons inc. , Second Edition, 1999.
4. Paul R. Halmos, Measure Theory, Springer New York, Illustrated Edition, 2014.

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

CO1	Identify the class of measurable sets
CO2	Derive properties of Lebesgue measurable sets and functions
CO3	Determine whether the given function is Lebesgue integrable or not
CO4	Prove Fatou's Lemma, Lebesgue's Monotone convergence theorem and Lebesgue dominated convergence theorem

Course Code MAPE 558	Graph Theory	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Basic Concepts: Graph definition- various kinds of graphs, incidence matrix, Isomorphism, decomposition, Special graphs, Paths, cycles and trails - connection in graphs, Bipartite graphs, Eulerian circuits, Vertex degree and counting, Hamiltonian Cycles - necessary and sufficient conditions, Review of digraphs.

Unit 2: **10L**

Trees: Trees and distance - properties, Spanning trees, Kruskal and Prim algorithms with proofs of correctness, Shortest paths - Dijkstra's algorithm, BFS and DFS algorithms, Application to Chinese postman problem, Trees in Computer science - rooted trees, binary trees, Huffman's Algorithm.

Unit 3: **10L**

Matchings: Matching in a graph and maximum matchings, Hall's matching theorem, Maximum bipartite matching - augmenting path algorithm.

Connectivity: Connectivity, Characterizing 2-connected graphs, Menger's theorem, Network flow problems-Ford-Fulkerson labeling algorithm, Max-flow Min-cut theorem.

Unit 4: **10L**

Coloring: Chromatic number, Greedy coloring algorithm, Brooks' theorem, Graphs with large chromatic number, Turan's theorem.

Planar Graphs: Planar graphs, Euler's formula, dual of a plane graph, Kuratowski's theorem, Five Color theorem, Four Colour Problem.

Text Books:

1. Douglas B. West, Introduction to Graph Theory, Pearson, 2015, Second Edition.
2. R. Diestel, Graph Theory, Springer, 2017, Fifth Edition.

Reference Books:

1. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall, 1979.
2. J. A. Bondy and U. S. R. Murty, Graph Theory, Springer, 2008.

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

CO1	Examine whether the graphs are isomorphic or not
CO2	Determine whether graphs are Hamiltonian and/or Eulerian
CO3	Construct minimal spanning trees and shortest paths
CO4	Determine the matching in a graph and solve the assignment problem
CO5	Construct planar graphs, colouring of graphs and their applications

Course Code MAPE 559	Mathematical Programming	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 503

Unit 1: **10L**

Linear Programming: Lines and hyperplanes- convex sets, convex hull, Formulation of a Linear Programming Problem - Theorems dealing with vertices of feasible regions and optimality, Graphical solution, Simplex method (including Big-M method and Two-phase method), Revised simplex method, Dual problem, Duality theory, Dual simplex method, Sensitivity analysis.

Unit 2: **10L**

Trnsportation Problem: Existence of solution, Degeneracy, MODI method (including the theory), Assignment problem, Travelling salesman problem.

Unit 3: **10L**

Integer Programming: Gomory's cutting plane method for an integer linear programming problem and a mixed integer linear programming problem.

Unit 4: **10L**

Dynamic Programming: Multistage decision process, Concept of sub optimization, Principle of optimality, Computational procedure in dynamic programming, Application to problems involving discrete variables, continuous variables and constraints involving equations and inequations.

Text Books:

1. H.A.Taha, Operations Research: An Introduction, Prentice Hall of India, 2019.

2. Kanti Swarup, Manmohan and P.K.Gupta, Opera-

tions Research, Sultan Chand and Co., 2006.

3. J.C.Pant, Introduction to Operations Research, Jain Brothers, 2008.

Reference Books:

1. N.S. Kambo, Mathematical Programming Techniques, East-West Pub., Delhi, 1999.

2. H.M.Wagner, Principles of Operations Research, Prentice Hall of India, 1980.

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

CO1	Formulate a LPP and understand graphical solution
CO2	Determine the solution of a LPP by simplex methods
CO3	Application of post optimality analysis
CO4	Solution of transportation and assignment problems
CO5	Determine the solution of ILPP
CO6	Determine an optimal solution by dynamic programming

Course Code MAPE 560	Multivariate Data Analysis	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 505

Unit 1: **10L**

Multivariate Analysis of Variance: Introduction - Differences between MANOVA and discriminant analysis, A hypothetical illustration of MANOVA, A decision process for MANOVA.

Unit 2: **10L**

Conjoint Analysis: Comparing conjoint analysis with other multivariate methods, Designing a conjoint analysis experiment, Managerial applications of conjoint analysis, Alternate conjoint methodologies – an illustration of conjoint analysis.

Unit 3: **10L**

Canonical Correlation Analysis: Analysing relationships with canonical correlation- interpreting the canonical variate, Validation and diagnosis.

Unit 4: **10L**

Cluster Analysis: Cluster analysis decision process, Multidimensional scaling, Comparing MDS to other interdependence techniques, A decision framework for perceptual mapping, Correspondence analysis.

Text Books:

1. Joseph F. Hair et al, Multivariate Data Analysis, CENGAGE, Eighth Edition, 2018.

2. M. G. Kendall, A Course in Multivariate Analysis, Charles Griffith, 1968.

Reference Books:

1. Trever Cox, An Introduction of Multivariate Data Analysis, Holder Education, 2005.
2. Kohei Adachi, Matrix Based Introduction to Multivariate Data Analysis, Springer, 2021.
3. Francois Husson, Exploratory Multivariate Analysis by Example using R, CRC Press, Second Edition, 2020.

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

CO1	Analyse Multivariate Distributions and their characteristics
CO2	Perform MANOVA
CO3	Perform Conjoint analysis
CO4	Analyze Cluster analysis and canonical correlation
CO5	Interpret Multidimensional scaling

Course Code MAPE 561	**Integral Equations and Calculus of Variations**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Classification of Liner Integral Equations: Fredholm, Volterra, Integro- Differential Equations, Singular Integral Equations, Differentiation under the sign of integration, Relation between differential and integral equations, Solution of Fredholm's integral equations of second kind by successive substitutions, Iterated Kernel and Resolvent Kernal, Convolution type integral equations.

Unit 2: **10L**

Volterra Integral Equations: Volterra's integral equations of fist kind, Solution of Volterra's integral equation by the method of successive substitutions, Solution of the Volterra's integral equation by the method of successive approximation, Integral equations with degenerated Kernels, Reciprocal functions, Volterra's solution of Fredholm's equations.

Unit 3: **10L**

Calculus of Variations: Introduction, Euler's equations and its solutions, Isoperimetric problems, Approximate solution of boundary value problems by (a) Rayleigh-Ritz method (b) Galerkin's method.

Unit 4: **10L**

Variation Problems: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema, Variational methods for boundary value problems in ordinary and partial differential equations.

Text Books:

1. A. S. Gupta, Calculus of Variations, Prentice-Hall Of India Pvt. Ltd., 2004.
2. M. L. Krasnov, A. I. Kiselev, and G. I. Makarenko, Problems and Exercises in Integral Equations, Mir Publ., Moscow, 1971.
3. J. N. Reddy, An introduction to the Finite Element Method, McGraw Hill, NY, 2006.
4. Shanti Swarup, Linear Integral Equations, Krishna Prakashan Media (Pvt.) Ltd., 2003.

Reference Books:

1. A. J. Jerri, Introduction to Integral Equation with Application, Wiley Interscience, 1999.
2. A. C. Pipkin, A Course on Integral Equations, Springer-Verlag, New York, 1991.

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

CO1	To study Integral Equations and to know what is the relationship between the integral equations and ordinary differential equations
CO2	To solve the linear and non-linear integral equations by different methods
CO3	To understand the concept of different type of variational problems
CO4	To understand some computation techniques for optimizing single variable functions

Course Code MAPE 562	Symbolic Computing	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Introduction to Mathematica: Difference between Numeric computing and Symbolic computing, Parts of Mathematica, Basics of programming in Mathematica, Built-in functions and constants, Numeric calculation using Mathematica, Symbolic computing with Mathematica.

Unit 2: **10L**

Built-in function for Matrices and Linear Algebra: Built-in function for Matrices and Linear Algebra, solving equations, Calculus with Mathematica, Solving ordinary Differential equations with Mathematica, Graphics and built-in graphics functions, User defined functions, Conditionals and looping in Mathematica, Modules, Simple programs using Mathematica.

Unit 3: **10L**

Introduction to MATLAB: Advantages and disadvantages of MATLAB, MATLAB environment, MATLAB basics, Programming in MATLAB, Built-in functions.

Unit 4: **10L**

Application to Linear Algebra: Application to Linear algebra, curve fitting and interpolation, numerical integration and solving Ordinary differential equations. Branching statements, loops and program design, User defined functions, Input and output functions, introduction to plotting, handling Graphics.

Text Books:

1. Paul R.Wellin, Mathematica, Wolfram Research Inc., 2005.
2. Cleve Moler, Numerical Computing with MATLAB, SIAM, 2004.

Reference Books:

1. M.L. Abell, J.P. Braselton, Mathematica by example, Academic Press, 2021.
2. Pratap R. Getting started with MATLAB: a quick introduction for scientists and engineers. Oxford University Press, Inc.; 2009.

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

CO1	Introduce the fundamental concepts of symbolic computing
CO2	Provide a foundation to use basic building blocks of Mathematica and Matlab
CO3	Learn to write Mathematica and Matlab Scripts.
CO4	Explore various applications of Matlab in Mathematics
CO5	Provide the basic knowledge to use Matlab for programming

Course Code	Wavelet Analysis	L - T - P - C
MAPE 563		3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Haar Wavelets: Heuristic treatment of the wavelet transform, Wavelet transform – Haar wavelet expansion, Haar functions and Haar series, Haar sums and Dyadic projections, Completeness of the Haar functions.

Unit 2: **10L**

Haar Series: Haar series in C_0 and L_p spaces, Point wise convergence of Haar series, Construction of standard Brownian motion, Haar function representation of Brownian motion.

Unit 3: **10L**

Multi-Resolution Analysis: Orthogonal systems, Scaling functions, from scaling function to MRA, Meyer wavelets, from scaling function to ortho-normal wavelet, Wavelets with compact support - From scaling filter to scaling function, Explicit representation of compact wavelets, Daubechies recipe, Hernandez-Weiss recipe, Smoothness of wavelets.

Unit 4: **10L**

Convergence Properties of Wavelet Expansions: Wavelet series in L_p spaces, Large scale analysis, Almost everywhere convergence, Convergence at a pre-assigned point, Wavelets in several variables, Tensor product of wavelets, general formulation of MRA and wavelets in Rd, Examples of wavelets in Rd.

Text Books:

1. Mark A. Pinsky, Introduction to Fourier Analysis and Wavelets, Cenage Learning India Pvt. Ltd, 2002.
2. M. V. Altaisky, Wavelets Theory: Applications Implementation, University Press, 2009.

Reference Books:

1. Walnut, David F, An Introduction to Wavelet Analysis, Springer Nature Switzerland AG, 2021.
2. Sabrine Arfaoui, Anouar Ben Mabrouk, Carlo Cattani, Wavelet Analysis Basic Concepts and Applications, Chapman and Hall/CRC, 2021.
3. Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, First Edition, 1999.

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

CO1	Expand a function in Haar wavelets
CO2	Construct Meyer wavelets to a given function
CO3	Find Daubechies wavelet series to a given function
CO4	Analyse two or more dimensional problems using wavelets

Course Code MAPE 564	Iterative Methods	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Adomian Decomposition Method (ADM):
The ADM for solving differential equations, Convergence of ADM, ADM in several dimensions, Solving boundary value problems using ADM, Modified ADM, Mathematica code of ADM.

Unit 2: **10L**

Homotopy Perturbation Method (HPM):
The HPM algorithm, Convergence analysis, Applications.

Unit 3: **10L**

Homotopy Analysis Method (HAM): The HAM algorithm, Convergence analysis, The role of auxiliary parameter, Control of convergence, Relation to ADM and HPM, Applications of HAM to solve nonlinear equations.

Unit 4: **10L**

Variational Iteration Method (VIM): The VIM algorithm, Convergence of VIM, Applications to solve ordinary differential equations, Solving system of fractional differential equations using ADM.

Text Books:

1. G. Adomian, Solving frontier problems in Physics: The decomposition method, Kluwer Academic Publishers, London, 1994.

2. S. Liao, Beyond perturbation: introduction to the homotopy analysis method, CRC press, 2003.

3. Belal Batiha, Variational Iteration Method and its

applications, LAP Lambert Academic Publishing, 2012.

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

CO1	Solve differential equations using ADM
CO2	Get solutions of differential equations by HPM
CO3	Find solutions of fluid dynamics problems using HAM
CO4	Apply VIM for ODEs

Course Code MAPE 565	**Perturbation Methods**	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Introduction: Parameter perturbations, Coordinate perturbations, Order symbols and Gauge functions, Asymptotic expansions and sequences, Convergent versus asymptotic series, Nonuniform expansions, Elementary operations on asymptotic expansions.

Unit 2: **10L**

Straight Forward Expansions and Sources of Nonuniformity: Infinite domains, A small parameter multiplying highest derivative, Type change of partial differential equations, The presence of singularities, The role of coordinate systems.

Unit 3: **10L**

The Method of Strained Coordinates: The method of strained parameters, Lighthill's technique, Temple's technique, Renormalization technique, Limitations of the method of strained coordinates.

The methods of Matched and Composite Asymptotic Expansions: The methods of matched asymptotic expansions, The methods of composite asymptotic expansions.

Unit 4: **10L**

Variation of Parameters and Methods of Averaging: Variation of parameters, The method of averaging, Struble's technique, The Krylov-Bogoliubov-Mitropolski technique, The method of averaging by using canonical variables, Von-Zeipel's procedure, averaging by using the Lie series and transforms, averaging by using Lagrangians.

Text Books:

1. A. H. Nayfeh, Perturbation Methods, Wiley, New York, 2008.
2. A.H. Nayfeh, Introduction to Perturbation Techniques, John Wiley & Sons, 2011.

Reference Books:

1. Carl M. Bender Steven A. Orszag, Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory, Springer-Verlag New York, First Edition, 1999.
2. J. Kevorkian and J. D. Cole, Perturbation Methods in Applied Mathematics, Springer, New York, Revised Edition, 1981.
3. Milton Van Dyke, Perturbation Methods in Fluid Dynamics, Academic Press, Digitized Version, 2008.

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

CO1	Solve perturbation problems in differential equations
CO2	Understand boundary layer in fluid flow problems
CO3	Understand regular and singular perturbation theory
CO4	Use asymptotic expansions to solve perturbation problems

Course Code MAPE 566	Spectral Methods	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 508

Unit 1: **10L**

Basics of Matlab: Introduction to Matlab, Programming in Matlab, Branching and looping, Built-in functions and user defined functions.

Spectral Methods: Historical background, Introduction to spectral methods via orthogonal functions, some examples of spectral methods, Spectral differentiation versus Finite differences, MATLAB as a tool in problem solving, Basic layout of spectral methods.

Unit 2: **10L**

Fourier Spectral Differentiation: Fourier approximation, Fourier spectral differentiation via differentiation matrices, Smoothness and accuracy, Aliasing and aliasing removal, MATLAB demonstrations.

Unit 3: **10L**

Chebyshev Spectral Differentiation: Polynomial approximation, Jacobi polynomials, Chebyshev spectral differentiation via Differentiation matrices, Smoothness and accuracy, MATLAB demonstrations.

Unit 4: **10L**

Initial Value Problems: Spectral method treatment of problems with mixed initial/boundary conditions, Semi-implicit methods, Case studies and MATLAB demonstrations.

Boundary Value Problems: Spectral method treatment of problems Dirichlet/Neumann/Robin type boundary conditions, Eigen boundary value problems, Boundary value problems in Polar coordinates, Differential eigen problems, Case studies and MATLAB demonstrations.

Text Books:

1. Cleve Moler, Numerical Computing with MATLAB, SIAM, 2004.
2. L. N. Trefethen, Spectral Methods in Matlab, SIAM, 2000.
3. C. Canuto, M.Y. Hussaini, Spectral Methods: Fundamentals in Single Domain, A. Quarteroni and T. A. Zang, Springer Verlag, First Edition, 2006.

Reference Books:

1. D. Gottlieb and S. A. Orszag, Numerical Analysis of Spectral Methods: Theory and Applications, CBMS-NSF 26, Philadelphia: SIAM, 1987.
2. C. Canuto, M.Y. Hussaini, A. Quarteroni and T.A. Zang, Spectral Methods in Fluid Dynamics, Springer-Verlag Berlin Heidelberg, First Edition, 1988.

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

CO1	Understand the basics of MATLAB
CO2	Understand the basics of spectral methods
CO3	Evaluate Fourier and Chebyshev spectral differentiation using differentiation matrices and FFT's
CO4	Solve IVP's and BVP's using spectral methods
CO5	Determine stability, convergence criterions and stiffness
CO6	Understand the mathematical concepts of spectral element methods

Course Code MAPE 567	Computational Fluid Dynamics	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 515

Unit 1: **10L**

Basics of Computational Fluid Dynamics: Governing equations of fluid dynamics – Continuity, Momentum and Energy equations, Chemical species transport – Physical boundary conditions, Time-averaged equations for Turbulent Flow, Turbulent–Kinetic Energy Equations, Mathematical behaviour of PDEs on CFD, Elliptic, Parabolic and Hyperbolic equations.

Unit 2: **10L**

Finite Difference Methods: Mixed derivatives, Accuracy, Finite difference formulation, Explicit and Implicit schemes, von Neumann stability analysis, schemes for Parabolic, Elliptic and Hyperbolic equations, Schemes for Burger's equation.

Unit 3: **10L**

Coordinate Transformation and Boundary Conditions: Arbitrary geometries, Determination of Jacobians and Transformed equations, Applications of Neumann Boundary Conditions, Artificial compressibility method, Pressure Correction method (Self-Implicit method).

Unit 4: **10L**

Nonlinear Equations: Euler equations, Quasilinearization, eigenvalues and compatibility relations, Characteristic variables, Central schemes with combined space and time discretization, Nonlinear problems, Convection dominated flows, Linearized Burger's equations.

Text Books:

1. T. J. Chung, Computational Fluid Dynamics, Cambridge Univ. Press, 2003.
2. C.A.J. Fletcher, Computational Techniques for Fluid Dynamics, Springer-Verlag, Berlin, Volumes: I and II, 1991.

Reference Books:

1. K. Muralidhar and T. Sundarajan, Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 2003.
2. W.F.Ames, Numerical Method for Partial Differential Equation, Academic Press, 2014.

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

CO1	Classification of physical behaviours of governing equations
CO2	Understand the effect of turbulent fluctuations on properties of the mean flow
CO3	Handle the errors and uncertainty in CFD modelling
CO4	Differentiate DNS, LES, subgrid scale models in turbulence flow
CO5	Simulate the flow in complex geometries using unstructured grids

Course Code MAPE 568	Finite Element Method	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities:MAPC 506 & MAPC 507

Unit 1: **10L**

Calculus of Variations: Introduction, Euler's Equation, Euler Lagrange Equations, Ostrogradsky equation.

Unit 2: **10L**

Variational Formulation: Variational Formulation for a boundary value problem with homogeneous and non-homogeneous boundary conditions, Rayleigh- Ritz minimization, Weighted residuals - Collocation, Least squares method, Galerkin, Petrov-Galerkin methods for boundary value problems.

Unit 3: **10L**

One Dimensional Problem: Solution of one - dimensional boundary value problems by linear, quadratic and cubic shape functions.

Unit 4: **10L**

Two Dimensional Problems: Solution of two - dimensional boundary value problems by linear, quadratic and cubic rectangular, serendipity and triangular shape functions. **Time Dependent Problems:** One - dimensional heat and wave equations.

Text Books:

1. J. N. Reddy, An introduction to the Finite Element Method, McGraw Hill, 4th Edition, 2020.

2. I. J. Chung, Finite Element Analysis in Fluid Dynamics, McGraw-Hill International Book Company, Digitized Version, 2007.

Reference Books:

1. O. C. Zienkiewiez and K. Morgan, Finite Elements and Approximation, John Wiley, 1983.

2. P. E. Lewis and J. P. Ward, The Finite Element Method – Principles and Applications, Addison Wesley, 1991.

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

CO1	Determine an extremum by calculus of variations approach
CO2	Formulate a variational problem for a boundary value problem
CO3	Find the solution of one-dimensional problems
CO4	Find the solution of two-dimensional problems by rectangular elements
CO5	Find the solution of two-dimensional problems by triangular elements
CO6	Solve the time dependent problems

Course Code MAPE 569	Dynamical Systems	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisities: MAPC 508 & MAPE 551

Unit 1: 10L

Qualitative Features: Autonomous and nonautonomous Systems- Equilibrium Points, Phase space/phase plane and phase trajectories, Stability, Attractors and Repellers, Classification of equilibrium points, Limit cycle motion, Periodic attractor, Poincare - Bendixson theorem, Higher dimensional systems, Lorenz equations, Quasiperiodic attractor, Poincare map, Chaotic attractor - Dissipative and conservative systems, Hamiltonian systems.

Unit 2: 10L

Bifurcations and Onset of Chaos in Dissipative Systems: Saddle-node bifurcation - Pitchfork bifurcation, Transcritical bifurcation, Hopf bifurcation, Discrete dynamical systems, Logistic map - Equilibrium points and their stability, Periodic solutions or cycles, Period doubling phenomenon, Onset of chaos- Sensitive dependence on initial conditions, Lyapunov exponent, Bifurcation diagram, Logistic map, Strange attractor in the Henon map, Self-similar structure, Route to chaos.

Unit 3: 10L

Chaos in Conservative Systems: Poincare cross section, Orbits in conservative systems - Regular and irregular trajectories, Canonical perturbation theory, Overlapping resonances and chaos, Periodically driven undamped duffing oscillator, The standard map, Linear stability and invariant curves, Numerical analysis: Regular and chaotic motions.

Unit 4: **10L**

Characterization of Regular and Chaotic Motions: Lyapunov exponents, Numerical computation of Lyapunov exponents, One-dimensional map, Computation of Lyapunov exponents for continuous time dynamical systems, Power spectrum and dynamical motion, Autocorrelation, Criteria for chaotic motion.

Text Books:

1. M. Lakshmanan, S. Rajasekar, Nonlinear Dynamics: Integrability, Chaos and Patterns, Springer, First edition, 2010.
2. George F. Simmons, Differential Equations with Applications and Historical Notes, McGraw-Hill, Second Edition, 2003.

Reference Books:

1. Hirsch, Smale and Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos, Elsevier Academic Press, USA, 2004.
2. Lawrence Perko, Differential Equations and Dynamical Systems, Third Edition, Springer-Verlag, 2010.

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

CO1	Identify Autonomous and Nonautonomous Systems
CO2	Understand Limit Cycle Motion and Periodic Attractor
CO3	Differentiate Dissipative and Conservative Systems
CO4	Understand different types of bifurcations
CO5	Apply Poincare Bendixson Theory.

Course Code MAPE 570	Mathematics of Data Science	L - T - P - C 3 - 0 - 0 - 3

Pre-Requisites: NIL

Unit 1: **10L**

Introduction and Algebra: Introduction of Data Science, Visualization of data, Resampling, Distributions, Linear Model & Baysian Model, Simple examples, Gradients of Vector-Valued Functions, Gradients of Matrices, Useful Identities for Computing Gradients, Backpropagation and Automatic Differentiation.

Unit 2: **10L**

Statistics: Parameter Estimation, Bayesian Linear Regression, Maximum Likelihood as Orthogonal Projection, Principal Component Analysis (PCA), Spectral Clustering, Cheeger's inequality, Concentration of measure and tail bounds in probability, Dimension reduction through Johnson-Lindelstrauss Lemma and Gordon's Escape through a Mesh theorem.

Unit 3: **10L**

Graph Theory: Approximation algorithms in Theoretical Computer science and the Max-cut problem, Clustering of random graphs, Stochastic Block model, Synchronization, Inverse problems on graphs.

Unit 4: **10L**

Optimization: Continuous Optimization, Basics of duality in Optimization, Convex Optimization.

Text Books:

1. Joel Grus, Data science from scratch, O'Reilly Media, 2015.

2. Murtaza Haider, Getting started with data science,

IBM Press, 2016.

Reference Books:

1. Lillian Pierson, Data science for Dummies, Wiley, Second Edition, 2017.
2. J Koponen & J Hidden, Data Visualization Handbook, CRC Press, 2019.
3. A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Marc Peter Deisenroth, Cambridge University Press, 2019.

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

CO1	Analyze the basics of data science
CO2	Apply PCA
CO3	Analyze spectral clustering
CO4	Compute dimension reduction and clustering of random graphs
CO5	Apply approximation algorithms

Course Code	Preparative Research Project	L - T - P - C
MAPC 521		0 - 0 - 4 - 2

Course Outcomes:

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

CO1: Learn about numerous fields of research.

CO2: Increase their skills in the relevant areas of expertise.

CO3: Improve collaboration abilities.

CO4: Participate in group activities.

CO5: Formulate the problem of engineering and sciences into mathematical form.

Syllabus:

Students will work on a research topic in a group under the guidance of faculty member(s).

Preparative Research Project:

DAC will assign each student to a faculty member for this term project work. It must be carried out on a topic selected by the student in consultation with the supervisor. Throughout the semester, the project supervisor will periodically evaluate the student's progress. Every student is required to give a seminar, which will be evaluated by DAC.

Course Code	Research Project and Comprehensive Viva	L - T - P - C
MAPC 524		0 - 0 - 20 - 10

Course Outcomes:

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

CO1: Strengthen their skills in the appropriate fields of expertise.

CO2: Enhance ability to collaborate.

CO3: Take part in teamwork activity.

CO4: Formulate the problem of engineering and sciences into mathematical form.

Syllabus:

Students will work on a research topic in a group under the guidance of faculty member(s).

Research Project:

DAC will assign each student to a faculty member for this term project work. It must be carried out on a topic selected by the student in consultation with the supervisor. Throughout the semester, the project supervisor will periodically evaluate the student's progress. DAC will evaluate the progress of the work in the middle of the semester. Finally, the student must submit the project report before the completion of the IV semester examinations and present the findings for the final grade.