ST. JOSEPH'S COLLEGE (AUTONOMOUS)
JAKHAMA-NAGALAND

SYLLABUS

(Outcome Based Education)

CURRICULUM AND CREDIT FRAMEWORK
FOR
UNDERGRADUATE PROGRAMMES (NEP-2020)

DEPARTMENT OF MATHEMATICS

With effect from the Academic Year 2023-2024
(1st to 4th FYUGP)

Preamble

Since ancient times, mathematics has been studied, and it has been essential to the advancement of both science and technology. This subject has been applied to solve issues in computer science, engineering, physics, and economics, among other subjects. An educated and informed citizenry requires a fundamental foundation of mathematics and statistics as well as the capacity for statistical and mathematical reasoning. The goal of the National Education Policy (NEP) 2020 is to give pupils a comprehensive, multidisciplinary education. The revised Four Year Under-Graduate Programme (FYUGP) Mathematics Program syllabus has been developed in accordance with NEP 2020 criteria. In addition to giving students a solid foundation in mathematics, the syllabus aims to get them ready for advanced coursework in the subject. Numerous topics, including calculus, algebra, analysis, statistics, are included in the course. The curriculum aims to improve students' analytical and problem-solving abilities as well as their ability to apply mathematical ideas to practical issues.

B.Sc. Mathematics (Honors) Programme Outcomes (PO):

By the end of the program the students will be able to:

PO 1	Disciplinary Knowledge: Bachelor's degree in mathematics is the culmination of in-depth knowledge of algebra, calculus, geometry, differential equations and several other branches of mathematics. This also leads to study of related areas like computer science and statistics. Thus, this programme helps learners in building a solid foundation for higher studies in mathematics.
PO 2	Communication Skills: Capacity to successfully explain a variety of mathematical ideas through examples and their geometrical representation. This program's knowledge and abilities will help students become proficient in analytical reasoning, which they can use to model and solve situations in real life.
PO 3	Critical thinking and analytical reasoning: Students enrolled in this program gain the capacity to think critically, reason logically, and recognize and discern between the numerous facets of real-world problems.
PO 4	Problem Solving: Students who complete this program with a strong foundation in mathematics will be able to assess issues and determine what kind of computing resources are needed to solve them. In addition to improving children' general development, this program gives them problem-solving and mathematical modeling skills.
PO 5	Research related skills: The completing this programme develop the capability of inquiring about appropriate questions relating to the Mathematical concepts in different areas of Mathematics.
PO 6	Information/digital Literacy: The completion of this programme will enable the learner to use appropriate softwares to solve system of algebraic equation and differential equations.
PO 7	Moral and ethical awareness/reasoning: The student completing this program will develop an ability to identify unethical behavior such as fabrication, falsification or misinterpretation of data and adopting objectives, unbiased and truthful actions in all aspects of life in general and mathematical studies in particular.
PO 8	Lifelong learning: This programme provides self-directed learning and lifelong learning skills. This programme helps the learner to think independently and develop algorithms and computational skills for solving real word problems.
PO 9	Ability to peruse advanced studies and research in pure and applied Mathematical sciences.
PO 10	Students undergoing this programme learn to logically question assertions, to recognise patterns and to distinguish between essential and irrelevant aspects of problems. They also share ideas and insights while seeking and benefitting from knowledge and insight of others. This helps them to learn behave responsibly in a rapidly changing interdependent society.
PO 11	Completion of this programme will also enable the learners to join teaching profession in primary and secondary schools.
PO 12	This programme will also help students to enhance their employability for government jobs, jobs in banking, insurance and investment sectors, data analyst jobs and jobs in various other public and private enterprises.

Programme Structure

Semester	Major or Discipline Specific Core Paper (DSC) (4 credits each)	Interdisciplinary Minor Paper (IDM) (4 credits each)	Multidisciplinary course (MDC) (4 credits each)	Skill Enhancement courses (SEC) OR Internship/ Apprenticeship/Project/Community Outreach (2 credits each)	Ability enhancement courses (AEC) (2 credits each)	Value addition course (VAC) (2 credits each)	Total Credits
I	MTC 1.1: Calculus (3) MTC 1.1(P): Calculus (1) MTC 1.2: Algebra (4)	MTM 1: Calculus (3) MTM 1(P): Calculus (1)	MDC 1: EVS (4)	MTS 1: Logic and Sets (2)	AEC 1: English Communication (2)	VAC 1: Constitutional Values (2)	22
II	MTC 2.1: Real Analysis (4) MTC 2.2: Differential Equation (3) MTC 2.2(P): Differential Equation (1)	MTM 2: Differential Equation (3) MTM 2(P): Differential Equation (1)	MDC 2: Programming using Python (4)	MTS 2: LaTeX & HTML (2)	AEC 2: Basic Functional English (2)	VAC 2: Consumer Rights (2)	22
Exit option with Undergraduate Certificate (44 Credits)							**44**
III	MTC 3.1: Theory of Real Function (4) MTC 3.2: Group Theory I (4) MTC 3.3: PDE and Systems of ODE (3) MTC 3.3(P): PDE and Systems of ODE (1)	MTM 3: PDE and Systems of ODE (3) MTM 3 (P): PDE and Systems of ODE (1)	MDC 3: Intellectual Property Rights (4)	MTS 3: Graph Theory (2)			22
IV	MTC 4.1: Numerical Methods (3) MTC 4.1(P): Numerical Methods (1) MTC 4.2: Riemann Integration and Series of Functions (4) MTC 4.3: Group Theory II (4)	MTM 4: Linear Algebra (4)		MTS 4: Laplace and Fourier Transform (2)	AEC 3: Poetry, prose and Short Stories (2)	VAC 3: Work Ethics (2)	22
Exit option with Undergraduate Diploma (88 Credits)							**88**
V	MTC 5.1: Multivariant Calculus (4) MTC 5.2: Linear Algebra (4) MTC 5.3: Number Theory (4)	MTM 5.: Group Theory (4)		MTS 5: Project work (2)	AEC 4: Novel and Drama (2)	VAC 4: India through the ages (2)	22
VI	MTC 6.1: Complex Analysis (4) MTC 6.2: Ring Theory (4) MTC 6.3: Operation Research (4) MTC 6.4: Probability and Statistics (4)	MTM 6: Numerical Methods (3) MTM 6(P): Numerical Methods (1)		MTS 6: Project Work (2)			22
Exit option with Bachelor of Science, B.Sc Mathematics (132 Credits)-UG Degree							**132**

Semester	Major or Discipline Specific Core Paper (DSC) (4 credits each)	Interdisciplinary Minor Paper (IDM) (4 credits each)	Multidisciplinary course (MDC) (4 credits each)	Skill Enhancement courses (SEC) OR Internship/ Apprenticeship/Project/Community Outreach (2 credits each)	Research Project/ Dissertation (12 Credits) OR 3 Theory Papers (12 Credits)	Total Credits
VII	MTC 7.1: Metric Spaces (4) MTC 7.2: Calculus of Variations and Integral Equations (4) RM 7: Research Methodology (4)	MTM 7.1: Real Analysis (4) MTM 7.2: Discrete Mathematics (4)			Research Project/ Dissertation will start	20
VIII	MTC 8.1: Topology (4)	MTM 8.1: Probability and Statistics (4)			Research Project/Dissertation in major (12) **OR** MTM 8.2: Linear Programming and Theory of Games (4) MTC 8.2: Linear Programming and Theory of Games (4) MTC 8.3: Mechanics (4)	20
Bachelor of Science, B.Sc Mathematics (Honours) with Research (172 Credits)						**172**

DISCIPLINE SPECIFIC COURSES (DSC) (MAJOR COURSES)

SEMESTER	PAPER CODE	PAPER CODE (used)	TITLE OF THE PAPER	CREDITS
I	DSC 1	MTC 1.1 MTC 1.1(P)	Calculus Calculus	3 1
	DSC 2	MTC 1.2	Algebra	4
II	DSC 3	MTC 2.1	Real Analysis	4
	DSC 4	MTC 2.2 MTC 2.2 (P)	Differential Equations Differential Equations	3 1
III	DSC 5	MTC 3.1	Theory of Real Function	4
	DSC 6	MTC 3.2	Group Theory I	4
	DSC 7	MTC 3.3 MTC 3.3 (P)	PDE and systems of ODE PDE and systems of ODE	3 1
IV	DSC 8	MTC 4.1 MTC 4.1 (P)	Numerical Methods Numerical Methods	3 1
	DSC 9	MTC 4.2	Riemann Integration and series of Functions	4
	DSC 10	MTC 4.3	Group Theory II	4
V	DSC 11	MTC 5.1	Multivariant Calculus	4
	DSC 12	MTC 5.2	Linear Algebra	4
	DSC 13	MTC 5.3	Number Theory	4
VI	DSC 14	MTC 6.1	Complex Analysis	4
	DSC 15	MTC 6.2	Ring Theory	4
	DSC 16	MTC 6.3	Operation Research	4
	DSC 17	MTC 6.4	Probability and Statistics	4
VII	DSC 18	MTC 7.1	Metric Spaces	4
	DSC 19	MTC 7.2	Calculus of Variations and Integral Equations	4
		RM 7	Research Methodology	4
VIII	DSC 20	MTC 8.1	Topology	4
			2 Major Theory Papers in lieu of Research Project/Dissertation (For Honors Students not undertaking Research Projects)	
	DSC 21	MTC 8.2	Linear Programming and Theory of Games	4
	DSC 22	MTC 8.3	Mechanics	4

MULTI-DISCIPLINARY/INTRODUCTORY COURSES (MDC)

SEMESTER	PAPER CODE	TITLE OF THE PAPER	CREDITS
I	MDC 1	Environmental Studies	4
II	MDC 2	Programming using Python	4
III	MDC 3	Intellectual Property Rights (IPR)	4

INTER-DISCIPLINARY MINOR COURSES (IDM)

SEMESTER	PAPER CODE	PAPER CODE (used)	TITLE OF THE PAPER	CREDITS
I	IDM 1	MTM 1 MTM 1 (P)	Calculus Calculus	3 1
II	IDM 2	MTM 2 MTM 2 (P)	Differential Equation Differential Equation	3 1
III	IDM 3	MTM 3 MTM 3 (P)	PDE and Systems of ODE PDE and Systems of ODE	3 1
IV	IDM 4	MTM 4	Linear Algebra	4
V	IDM 5	MTM 5	Group Theory	4
VI	IDM 6	MTM 6 MTM 6 (P)	Numerical Methods Numerical Methods	4
VII	IDM 7	MTM 7.1	Real Analysis	4
	IDM 8	MTM 7.2	Discrete Mathematics	4
VIII	IDM 9	MTM 8.1	Probability and Statistics	4
			1 Minor Theory Papers in lieu of Research Project/Dissertation (For Honors Students not undertaking Research Projects)	
	IDM 10	MTM 8.2	Linear Programming and Theory of Games	4

SKILL ENHANCEMENT COURSES (SEC)

SEMESTER	PAPER CODE	PAPER CODE (used)	TITLE OF THE PAPER	CREDITS
I	SEC 1	MTS 1	Logic and Sets	2
II	SEC 2	MTS 2	LaTeX & HTML	2
III	SEC 3	MTS 3	Graph Theory	2
IV	SEC 4	MTS 4	Laplace and Fourier Transform	2

DISCIPLINE SPECIFIC COURSES (DSC)

NAME OF THE PAPER (CODE) : **CALCULUS (MTC 1.1)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Calculus**:

CO 1:	To aid the students in understanding the foundations of calculus.
CO 2:	To assist the students in the understanding of derivatives of hyperbolic and trigonometric functions.
CO 3:	To create an understanding of curve tracing and integration techniques.
CO 4:	To inculcate the students in understanding how to find the volume and surface of revolution.
CO 5:	To make the students aware of techniques of sketching conics and properties of conics.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Foundations of Calculus	The definition of the limit of a function, The definition of continuity of a function, the basic limit theorems. More examples of continuous functions, Proofs of the basic limit theorems, Composite functions and continuity, Bolzano's theorem for continuous functions, The intermediate-value theorem for continuous functions and examples.	**CSO 1.1:** to define the term limit of a function (K) **CSO 1.2:** to solve some functions to check its limit with the help of the definition. (U) **CSO 1.3:** to define the term continuity of a function. (K) **CSO 1.4:** to solve some functions to check its continuity with the help of the definition. (U) **CSO 1.5:** to state and prove basic limit theorems. (K/U) **CSO 1.6:** to define the term composite functions and continuity. (K) **CSO 1.7:** to state and prove Bolzano's theorem for continuous functions. (K/U) **CSO 1.8:** to state and prove the intermediate-value theorem for continuous function and examples. (K/U)	10	22	Not to be filled-in
UNIT 2 Derivatives of hyperbolic and trigonometric	Hyperbolic functions, higher order derivatives, Leibniz rule and its applications to problems of type $e^{(ax+b)}\sin x$, $e^{(ax+b)}\cos x$, $(\mathrm{ax}+\mathrm{b})^n\sin x$, $(\mathrm{ax}+\mathrm{b})^n\cos x$, concavity	**CSO 2.1:** to define hyperbolic functions and some properties. (K) **CSO 2.2:** to define higher order derivatives and solve some problems. (K/A) **CSO 2.3:** to explain Leibniz rule and its applications to problems. (U/A) **CSO 2.4:** to apply Leibniz rule	9	20	Not to be filled-in

	and inflection points, asymptotes.	to solve some problem types. (A) **CSO 2.5:** to define and explain concavity and inflection points. (U) **CSO 2.6:** to find concavity and inflection points. (U/A) **CSO 2.7:** to define and explain asymptotes. (K/U) **CSO 2.8:** to solve some problems to find asymptotes. (U)			
UNIT 3 Curve tracing and Integration techniques	Curve tracing in Cartesian coordinates, introduction to polar coordinates and curve tracing in polar coordinates of standard curves (cycloid, cardioid, other simple curves), Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n xdx$, $\int cos^n x\, dx$, $\int tan^n\, xdx$, $\int sec^n xdx$, $\int x^m (\log)^n\, dx$, $\int (sin^m\, x)cos^n\, x\, dx$	**CSO 3.1:** to define curve tracing (K) **CSO 3.2:** to define cartesian coordinates. (K) **CSO 3.3:** to explain curve tracing in cartesian coordinates. (U) **CSO 3.4:** to define polar coordinates (K) **CSO 3.5:** to explain curve tracing in polar coordinate of standard curves. (U) **CSO 3.6:** to tackle some problems on curve tracing. (A) **CSO 3.8:** to explain reduction formulae and derivatives. (U) **CSO 3.9:** to apply reduction formulae to some specific type of problems. (A)	10	22	Not to be filled-in
UNIT 4 **Volume and Surfaces of revolution**	Volumes by slicing disks and washer's methods, volumes by cylindrical shells, volumes by parametric equations, Parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution.	**CSO 4.1:** to explain volumes by slicing disks. (K/U) **CSO 4.2:** to solve problems to find the volume by slicing disks. (A) **CSO 4.3:** to define and explain Washer's method. (K/U) **CSO 4.4:** to apply Washer's method to find volume. (A) **CSO 4.5:** to explain Volume by cylindrical shells. (U) **CSO 4.6:** to solve problems to find volume by cylindrical shells. (A) **CSO 4.7:** to explain volume by parametric equations. (U) **CSO 4.8:** to solve problems to	8	18	Not to be filled-in

		find volume by parametric equations. (A) **CSO 4.9:** to explain Parameterizing a curve. (U) **CSO 4.10:** to define arc length and some problems to find arc length. (K/A) **CSO 4.11:** to explain arc length of parametric curves. (U) **CSO 4.12:** to solve problems to find area of surface of revolution. (A)			
UNIT 5 **Conic Section**	Techniques of sketching conics, reflection properties of conics, rotation of axes and second-degree equations, classification into conics using the discriminant, polar equations of conics.	**CSO 5.1:** to explain techniques of sketching conics and draw some sketch. (U) **CSO 5.2:** to explore and comprehend the reflection properties of conic sections, particularly focusing on the reflective behaviour of ellipses, hyperbolas, and parabolas across different axes. (U) **CSO 5.3:** to explain rotation of axes and second-degree equations and solve some problems. (U) **CSO 5.4:** to explain the classification into conics using the discriminant and solve some problems. (U) **CSO 5.5:** to explain polar equations of conics and solve some problems. (U)	8	18	Not to be filled-in

NAME OF THE PAPER (CODE) : CALCULUS (MTC 1.1) (Practical)
Number of Credit : 01
Number of Hours of Lecture : 30

List of Practical's (using any software)

1. Practical based on tracing curves (trigonometric functions, inverse function, exponential function, logarithmic function and hyperbolic function)
   a. Draw the graph of sinx, cosx, tanx, cotx, secx, cosecx.
   b. Draw the graph of $\sin^{-1} x, \cos^{-1} x, \tan^{-1} x, \cot^{-1} x, sex^{-1}x, \cos ec^{-1} x$.
   c. Draw the graph of sinhx, coshx, tanhx, cothx.
   d. Draw the graph of $\log_a x, a_x$.
   e. Draw the graph of cardioids and asteroid
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Practical based on integral and reduction formula, summation of the series, surface and volume.
4. Matrix operation (Addition, multiplication,inverse,transpose)
5. Practical based on successive differentiation.

   a. Find the nth derivative of the given function at a given point.
   b. Application of Leibnitz's theorem.
6. Evaluation of limits by L'Hospital's rule.
7. Application of reduction formula for integration.
8. Application of series using integration.
9. Application of volume revolution.
10. Matrix Operations: Addition, Multiplication, Inverse, Transpose, Determinant.

Suggested Readings:

1. G.B. Thomas and R.L. Finney, *Calculus, 9th Ed*., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, *Calculus, 3rd Ed.,* Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, *Calculus*, *7th Ed*., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. R. Courant and F. John, *Introduction to Calculus and Analysis (Volumes I & II),* Springer-Verlag, New York, Inc., 1989.
5. Tom. M. Apostol, *Calculus –Volume I and II, 2nd Ed.*, John Wiley and Sons, Inc, 1967

NAME OF THE PAPER (CODE) **: ALGEBRA (MTC1.2)**
Number of Credit **: 04**
Number of Hours of Lecture **: 60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Algebra:**

CO 1:	Students are exposed to solving polynomial equations, summation of an infinite series, matrices, and elementary number theory.
CO 2:	learn the different methods to solve polynomial equations.
CO 3:	understand the methods of the sum to infinity of a binomial, exponential, and logarithmic series.
CO 4:	find the Eigen values and Eigen vectors of a given square matrix.
CO 5:	acquire a basic knowledge of different types of numbers, a number of divisors of a positive integer.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Basic Algebra series:	Summation of series using Binomial - Exponential and Logarithmic series (Theorems without proofs) - Approximation using Binomial, Exponential and Logarithmic series - simple problems.	**CSO 1.1:** find the sum to infinity of the given binomial/exponential/logarithmic series. **(K)** **CSO 1.2:** carry out the calculations of approximate roots of the given polynomial equation. **(U)** **CSO 1.3:** demonstrate the knowledge of the relationship between roots and coefficients of the given equation. **(A)**	11	18	Not to be filled-in
UNIT 2 Systems of linear equations	Systems of linear equations, row reduction and echelon forms, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems.	**CSO 2.1:** Find the rank and type of solutions. (K) **CSO 2.2:** Determine of homogeneous and non-homogeneous system of linear equations. (U)	11	18	Not to be filled-in
UNIT 3 Basic Linear Algebra:	Introduction to vector space, vector equations, linear independence of vectors, Introduction to linear transformations, matrix of a linear transformation,	**CSO 3.1:** Learn about the concept of linear independence of vectors over a field, and the dimension of a vector space. (K) **CSO 3.2:** Basic concepts of linear transformations, dimension theorem, matrix representation of a linear	13	22	Not to be filled-in

	inverse of a matrix, characterizations of invertible matrices.	transformation, and the change of coordinate matrix. (A) **CSO 3.3:** Understand the basic concept of vector space, subspace, quotient space and linear combination of vectors, linear span and its results, basis and dimension of vector space and subspace. (U)			
UNIT 4 **Matrices**	Symmetric - Skew Symmetric, - Hermitian - Skew Hermitian - Orthogonal and Unitary Matrices - Eigen Values - Eigen Vectors – Cayley-Hamilton Theorem (without proof) - Similar Matrices - Diagonalization of a Matrix.	**CSO 4.1:** demonstrate the knowledge of matrices and calculate the Eigen values and Eigen vectors of a given square matrix. **(U)** **CSO 4.2:** Study about basic matrix definitions **(U)** **CSO 4.3:** Cayley Hamilton theorem application. **(A)**	12	20	Not to be filled-in
UNIT 5 **Theory of Number**	Prime Number - Composite Number - Decomposition of a Composite Number as a Product of Primes uniquely (without proof) - Divisors of a Positive Integer - Congruence Modulo n - Euler Function (without Proof) - Highest Power of a Prime Number p contained in n!- Fermat's and Wilson's Theorems (statements only) - simple problems.	**CSO 5.1:** discuss the basic number theory concepts. (K) **CSO 5.2:** Describe some important results in the theory of numbers including the prime number theorem, Chinese remainder theorem, Wilson's theorem and their consequences. (U) **CSO 5.3:** Describe number theoretic functions, modular arithmetic and their applications. (A)	13	22	Not to be filled-in

Suggested Readings:

1. P. Kandasamy, K. Thilagavathy, *Mathematics for B.Sc*. Vol-I, II, III & IV, S. Chand & Company Ltd, 2005.
2. S. Arumugam, *Algebra*, New Gamma Publishing House, Palayamkottai, 2003.
3. P. R. Vittal, V. Malini, *Algebra and Trigonometry*, Margham Publications, Chennai.
4. S. Sudha, *Algebra and Trigonometry*, Emerald Publishers, Chennai, 1998.
5. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph theory*, Pearson Education
6. David C. Lay, *Linear Algebra and its applications*, 3rd Ed., Pearson Education Asia, India, 2019.
7. Gilbert Strang, *Linear algebra and its application*, Pearson Education India, 2016.

NAME OF THE PAPER (CODE) : REAL ANALYSIS (MTC 2.1)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Real Analysis**:

CO 1:	To learn "Countability of sets and the real number system" and gaps in the rational numbers.
CO 2:	To acquire the knowledge of "Topology of real numbers" by learning completeness axiom and denseness in ℝ . The student shall be able to find limit points of set and define closed set with this concept.
CO 3:	The students shall aware of the "Sequence of real numbers" and its convergence. The idea of monotone sequence and its convergence theorem is also introduced.
CO 4:	To impart the knowledge of "Subsequence" to identify monotone subsequence and its convergence, divergence subsequence.
CO 5:	To help students understand "Infinite series and its convergence" by using various convergence test.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Countability of sets and the real number system	Rational numbers and its properties, gaps in the rational numbers, Review of algebraic and order properties of ℝ-neighbourhood of a point in ℝ, Idea of countable sets, uncountable sets and uncountability of ℝ. Bounded above sets, Bounded below sets, Bounded sets, Unbounded sets, Suprema and Infima	CSO 1.1: To understand the rational number system and its gap (K) CSO 1.2: To discuss the algebraic and order properties of ℝ (U) CSO 1.3: Defining neighbourhood of point (K) CSO 1.4: Theorems on neighbourhoods of a point (U) CSO 1.5 Finding neighbourhood of a point (A) CSO 1.6: To introduce the concept of countable and uncountable sets (K) CSO 1.7: Theorems on union of countable sets, infinite subsets of countable sets, uncountability of ℝ (U) CSO 1.8: Defining bounded sets, unbounded sets, (K) CSO 1.9: To find the upper bound and lower bound of sets (A) CSO 1.10: Defining suprema and infima of a set (K) CSO 1.11: To find suprema and infima of a set (A)	13	22	Not to be filled-in
UNIT 2 Topology of real numbers	The completeness property of ℝ, The Archimedean property, Density of rational and irrational numbers in	CSO 2.1: Describing the concept of completeness axiom (K) CSO 2.2: Theorems on completeness axiom (U) CSO 2.3: Describing the concept of Archimedean property of real	11	18	Not to be filled-in

	ℝ, Intervals. Limit points of a set, Isolated points, Illustration of Bolzano-Weierstrass theorem for bounded sets	numbers (K) CSO 2.4: Theorems based on Archimedean property of real numbers (U) CSO 2.5: To discuss denseness in ℝ (U) CSO 2.6: to understand the idea of intervals(K) CSO 2.7: to define limit point and isolated point of a set(K) CSO 2.8: Finding limit point and isolated point of a set (A) CSO 2.9: Illustration of Bolzano Weierstrass theorem for bounded sets (A)			
UNIT 3 Sequence of real numbers	Sequences, Bounded sequence, Convergent sequence, Limit of a sequence. Limit theorems, Monotone sequence, Monotone convergence theorem	CSO 3.1: To define sequence of real numbers (K) CSO 3.2: To define bounded sequence and unbounded sequence (K) CSO 3.3: To define limit of a sequence (K) CSO 3.4 To discuss the convergence of a sequence (U) CSO 3.5: Finding the limit of a sequence and determining its convergence (A) CSO 3.6: To describe the algebra of limits (K) CSO 3.7: Theorem on limits (U) CSO 3.8: To define monotone sequence (K) CSO 3.9: To discuss monotone convergence theorem (U) CSO 3.10: To determine monotone sequence (A)	12	20	Not to be filled-in
UNIT 4 Subsequence	Subsequence, Divergence criteria, Monotone subsequence theorem (statement only), Bolzano-Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion	CSO 4.1: Defining subsequence of a sequence (K) CSO 4.2: To discuss the convergence and divergence concept of subsequence (U) CSO 4.3: Discussing the divergence criteria of a subsequence (U) CSO 4.4: Solving problem based on convergence and divergence of sequence (A) CSO 4.5: To describe monotone subsequence theorem (K) CSO 4.6: To discuss Bolzano Weierstrass theorem for sequences (U) CSO 4.7: Defining Cauchy's sequence (K) CSO 4.8: Describing Cauchy's Convergence Criterion (K)	12	20	Not to be filled-in

		CSO 4.9: Determining Cauchy's sequence (A)			
UNIT 5 Infinite series and its convergence	Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: Comparison test, Ration test, Cauchy's nth root test, Integral test, Alternating series, Leibnitz's test, Absolute and conditional convergence	CSO 5.1: Defining infinite series (K) CSO 5.2: Discussing Cauchy's criterion of convergence of infinite series (U) CSO 5.3: Discussing some properties on infinite series (U) CSO 5.4: Defining Comparison test (K) CSO 5.5: Applying Comparison test on infinite series (A) CSO 5.6: Defining limit comparison test (K) CSO 5.7: Applying comparison test on infinite series (A) CSO 5.8: Defining ratio test (K) CSO 5.9: Applying ratio test on infinite series (A) CSO 5.10: Defining Cauchy's nth root test (K) CSO 5.11: Applying Cauchy's nth root test (A) CSO 5.12: Defining integral test (K) CSO 5.13: Applying integral test on infinite series (A) CSO 5.14: Introducing Alternate series (U) CSO 5.15: Testing convergence of infinite series (A) CSO 5.16: Defining Leibnitz's test (U) CSO 5.17: Testing convergence of alternate series by using Leibnitz's test (A) CSO 5.18: Discussing the convergence of absolute and conditional convergence (U)	12	20	Not to be filled-in

Suggested Readings:

1. R.G. Bartle and D.R. Sherbert, *Introduction to Real Analysis*, John Wiley and Sons, 2011.
2. A. Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, CRC Press.
3. W. Rudin - *Principles of Mathematical Analysis*, McGraw Hill Education, 1976.
4. S.K. Berberian, *A first Course in Real Analysis*, Springer Verlag, New York, 1994.
5. Terence Tao, *Analysis I*, Hindustan Book Agency, 2016.

NAME OF THE PAPER (CODE) : **DIFFERENTIAL EQUATION (MTC 2.2)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Differential Equation:**

CO 1:	the student will be able to know the various methods of solving the first-order higher degree differential equations.
CO 2:	the student will be able to carry out the different methods of solving the second order differential equations.
CO 3:	the student will be able to understand the concepts of total differential equations and solve the problems.
CO 4:	the student will be able to demonstrate knowledge of Laplace transform and its applications.
CO 5:	the student will be able to solve partial differential equations.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Differential Equation for first order**	Bernoulli Equation – Exact Differential Equations – Equations Reducible to Exact Equations – Equations of First order and Higher degree.	**CSO 1.1:** Formulate logical skills in the formation of differential equations (K) **CSO 1.2:** Solve first order non-linear differential equation and linear differential equations of higher order using various techniques. (U)	9	2 0	Not to be filled-in
UNIT 2 **Differential Equation for second order and higher or**	Method of Variation of Parameters – 2nd order Differential Equations with Constant Coefficients for finding the P. I's of the form e^{ax} V, where V is sin(mx) or cos(mx) or x^n – Equations reducible to Linear equations with constant coefficients.	**CSO 2.1:** Solving the parameter variables (K) **CSO 2.2:** Finding P.I for second order or higher order D.E (K) **CSO 2.3:** Varies method applying to solve Differential Equation. (U)	9	20	Not to be filled-in
UNIT 3 **Simultaneous Equations with Constant coefficients**	Total Differential Equations Simultaneous Total Differential Equations – Equations of the form dx/P = dy/Q = dz/R	**CSO 3.1:** Expose different techniques for finding solutions to differential equations and understand the topics of simultaneous and total differential equations (K) **CSO 3.2:** Finding first order differential equation using	9	20	Not to be filled-in

		by Cauhy metho**d.** (U)			
UNIT 4 General solution for the second order differential equations:	Particular integrals of second order differential equations with constant coefficients - Linear equations with variable coefficients – Method of Variation of Parameters	**CSO 4.1**: Find second order differential equation solution with constant coefficients. (K) **CSO 4.2:** Find the Method of Variation of Parameters (U) **CSO 4.3:** finding General terms solutions (A)	9	20	Not to be filled-in
UNIT 5 Mathematical modelling	Compartmental model-exponential growth and decay model [limited growth of population and limited growth with harvesting] equilibrium points, interpretation of the phase plane. Predatory prey model and its analysis, epidemic model of influenza and it's analysis.	**CSO 5.1:** Apply these techniques to solve and analyze various mathematical models. (K) **CSO 5.2:** Plotting of second order solution family of differential equation. (U) **CSO 5.3:** Plotting of third order solution family of differential equation. (A)	9	20	Not to be filled-in

NAME OF THE PAPER (CODE) : **DIFFERENTIAL EQUATION (MTC 2.2**) (Practical)
Number of Credit : **01**
Number of Hours of Lecture : **30**

List of Practicals (using any software):

1. Plotting of second order solution family of differential equation.
2. Plotting of third order solution family of differential equation.
3. Growth model (exponential case only).
4. Decay model (exponential case only).
5. Limited growth of population (with and without harvesting).
6. Predatory prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
7. Epidemic model of influenza (basic epidemic model, contagious for life disease with carriers).
8. Battle model (basic battle model, jungle warfare, long range weapons).

Suggested Readings:

1. M.D. Raisinghania, [2001] *Ordinary and Partial Differential Equations*, S. Chand and Co., New Delhi, 2014.
2. M.R. Spiegel, *Advanced Mathematics for Engineers and Scientists*, McGraw Hill Edition, New Delhi, 1971.
3. S.L Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, India, 2004.
4. S. Sudha [2003] *Differential Equations and Integral Transforms*, Emerald Publishers.
5. M.K. Venkataraman [1998] *Higher Engineering Mathematics*, III-B, National Publishing Co.
6. C.H. Edwards and D.E Penny, *Differential Equations and Boundary Value problems computing and Modeling*, Pearson Education India, 2005.
7. George F. Simmons, *Differential equation with applications and historical notes*, McGraw-Hill, 197

NAME OF THE PAPER (CODE) : **THEORY OF REAL FUNCTIONS (MTC 3.1)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Theory of Real Functions**:

CO 1:	To learn "Limit of functions" by introducing different limits such as infinite limit, limit at infinity, one sided limit and etc.
CO 2:	To help the students in the understanding of "Continuity" of functions with the help of different theorems based on this concept and solving problems. Further, the concept of uniform continuity is introduced.
CO 3:	To impart the knowledge of "Differentiability of functions" and extending the concept to prove Rolle's theorem, mean value theorem and Cauchy's mean value theorem.
CO 4:	To learn "Indeterminate forms" by applying L' Hospital's rule and find limit of function.
CO 5:	To help the students in the understanding of "Taylor's theorem and its application" and obtaining some infinite series with the help of Taylor's and Maclaurin's series.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Limit of functions	Limit of functions ($\varepsilon - \delta$ approach), sequential criterion for limits, divergence criteria, limit theorems, one sided limits, infinite limits, and limits at infinity	**CSO 1.1:** Defining limit by $\varepsilon - \delta$ approach (K) **CSO 1.2:** Defining left hand and right limit, limits at infinity and infinite limits (K) **CSO 1.3:** Finding left hand and right limit, limits at infinity and infinite limits (A) **CSO 1.4:** Discussing Algebra of limits (U) **CSO 1.5:** Proving sequential criterion of limit (U) **CSO 1.6:** Describing divergence criterion of limits (K) **CSO 1.7:** Discussing theorem on infinite limits (U)	11	18	Not to be filled-in
UNIT 2 Continuity and Uniform Continuity of functions	Continuous functions, sequential criterion of continuity and discontinuity, Algebra of continuous functions, Continuous functions on an interval, intermediate value theorem, Location of roots theorem, preservation of interval theorem, Uniform continuity,	**CSO 2.1:** Defining continuity of a function (K) **CSO 2.2:** To determine continuous functions (A) **CSO 2.3:** Proving sequential criterion for continuous function (U) **CSO 2.4:** Describing algebra of continuous function (K) **CSO 2.5:** Elaborating intermediate value theorem (U) **CSO 2.6:** Proving location of root theorem (U) **CSO 2.7:** Discussing intermediate value theorem and	13	22	Not to be filled-in

	Non-uniform continuity criteria, uniform, continuity theorem	preservation of interval theorem (U) **CSO 2.8:** Defining non uniform continuity criteria (K) **CSO 2.9:** To determine uniform continuous functions (A)			
UNIT 3 Differentiability of functions	Differentiability of a function at a point and in an interval, Caratheodory's theorem, Algebra of differentiable functions, Rolle's theorem, Mean value theorem, Cauchy's mean value theorem	**CSO 3.1:** To define differentiability of a function (K) **CSO 3.2:** To determine differentiable functions (A) **CSO 3.3:** Describing algebra of differentiability (K) **CSO 3.4** Proving Caratheodory's theorem which gives the relation between continuity and differentiability (U) **CSO 3.5:** Proving Rolle's theorem (U) **CSO 3.6:** Identifying functions which supports Rolle's theorem (K) **CSO 3.7:** Proving Mean value theorem (U) **CSO 3.8:** Identifying functions which supports Mean value theorem (K) **CSO 3.9:** Proving Cauchy's mean value theorem (U) **CSO 3.10:** Applying Cauchy's mean value theorem on functions (A)	12	20	Not to be filled-in
UNIT 4 Indeterminate forms	L' Hospital's rule, Intermediate value property of derivatives, Darboux's theorem, Application of mean value theorem to inequalities and approximation of polynomials, Taylor's theorem to inequalities.	**CSO 4.1:** Identifying the indeterminate forms (K) **CSO 4.2:** Finding limits of different functions using different indeterminate forms (A) **CSO 4.3:** Proving Darboux's theorem(U) **CSO 4.4:** Application of Lagrange's mean value theorem to inequalities and approximation of polynomials (A) **CSO 4.5:** Proving Taylor's theorem (U) **CSO 4.6:** Application of Taylor's theorem to inequalities (A) **CSO 4.7:** Describing sign of the derivative theorem (K) **CSO 4.8:** Proving Intermediate value property of derivatives (U)	13	22	Not to be filled-in
UNIT 5 Taylor's theorem and its	Taylor's theorem with Lagrange's form of remainder, Taylor's theorem	**CSO 5.1:** Elaborating Taylor's theorem (U) **CSO 5.2:** Describing Taylor's theorem with Lagrange's form of	11	18	Not to be filled-in

application	with Cauchy's form of remainder, Application of Taylor's, theorem to convex functions, Relative extrema, Interior extremum theorem, Taylor's series and Maclaurin's series expansion of exponential, trigonometry and logarithmic functions	remainder (K) **CSO 5.3:** Describing Taylor's theorem with Cauchy's form of remainder (K) **CSO 5.4:** Application of Taylor's theorem to convex functions (A) **CSO 5.5:** Defining Taylor's series and Maclaurin's series(K) **CSO 5.6:** Expansion of some infinite series such as exponential, logarithm, trigonometric etc using Taylor's series and Maclaurin's series (U) **CSO 5.7:** Proving interior exterior theorem (U) **CSO 5.8:** Defining relative minima, reative maxima (K) **CSO 5.9:** Finding relative minima and maxima of functions (A)			

Suggested Readings:

1. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. S. R. Ghorpade and B. V. Limaye, *A Course in Calculus and Real Analysis*, Springer, 2006.
3. K. A. Ross, *Elementary Analysis: The Theory of Calculus*, Springer, 2004.
4. A. Mattuck, *Introduction to Analysis*, Prentice Hall, 1999.

NAME OF THE PAPER (CODE) : **GROUP THEORY I (MTC 3.2)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Group Theory I**:

CO 1:	To provide a comprehensive understanding of Group Theory, focusing on the definition and examples of Groups.
CO 2:	To provide a comprehensive understanding of subgroups and Cyclic groups. Also explore techniques to identify and classify subgroups.
CO 3:	To enhance critical thinking skills by analyzing and interpreting Permutation structures and their implications for problem solving in diverse contexts. Also learn the concept of Cosets and Lagrange's theorem including its use in proving Fermat's little theorem.
CO 4:	To provide an in depth understanding of advanced topics in Group Theory, focusing on the External direct products, Normal subgroups and Factor groups.
CO 5:	To provide a comprehensive understanding of Group Homomorphism, Isomorphism and its properties, understand its First, Second and Third Theorem. Also learn about Symmetries of a Square and Dihedral groups.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 **Introduction to Groups**	Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups.	**CSO 1.1:** To define groups (K) **CSO 1.2:** Illustration of groups with examples. (U) **CSO 1.3:** to define Permutation Groups and Quaternion Groups (K) **CSO 1.4:** to Illustrate Permutation Groups and Quaternion Groups with matrices (U) **CSO 1.5:** to discuss the elementary properties of groups (K+U)	12	20	Not to be filled-in
UNIT 2 **Subgroups and Cyclic groups**	Subgroups and examples of subgroups, product of two subgroups, center of a group, centralizer, normalizer. Properties of cyclic groups, classification of subgroups of cyclic groups.	**CSO 2.1:** to define subgroups and understand with the help of examples (K+U) **CSO 2.2:** to define and prove that two subgroups of a group G is a product of subgroups of G (K+A) **CSO 2.3:** to define centralizer, normalizer and center of a group. (K) **CSO 2.4:** to prove that centralizer, normalizer and center of a group is a subgroup of a group (A)	12	20	Not to be filled-in

		CSO 2.5: to define cyclic groups (K) **CSO 2.6:** to learn the properties of a cyclic group (U) **CSO 2.7:** to classify subgroups of cyclic groups (U)			
UNIT 3 **Permutation Groups, Cosets and Lagrange's Theorem**	Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.	**CSO 3.1:** Define cycle permutation.(K) **CSO 3.2:** to Illustrate with examples (U) **CSO 3.3:** to find different powers of a cycle and its order. (A) **CSO 3.4:** to learn the properties of permutations (K) **CSO 3.5:** to define even and odd permutation. (K) **CSO 3.6:** to Illustrate with examples. (U) **CSO 3.7:** to define alternating group and to show that the set of all even permutation is a normal subgroup. (K+A) **CSO 3.8:** to define and understand cosets and its properties. (K+U) **CSO 3.9:** to state and prove Lagrange's theorem. (K+A) **CSO 3.10:** to state and prove Fermat's little theorem. (K+A)	12	20	Not to be filled-in
UNIT 4 **External direct products, Normal subgroups and Factor groups**	External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.	**CSO 4.1:** to define external direct product. (K) **CSO 4.2:** to prove that external direct product is a group (U+A) **CSO 4.3:** to define normal subgroups. Illustrate with an example. (K+U) **CSO 4.4:** to define Factor group. Illustrate Factor group with an example. (K+U) **CSO 4.5:** to Prove that every quotient group of a cyclic group is cyclic. (A) **CSO 4.6:** to Prove that a subgroup of a group G is normal in G iff the product of two right cosets is again a right coset of H in G.	12	20	Not to be filled-in

		(K+U) **CSO 4.7:** to state and prove Cauchy theorem for finite abelian group (K+A)			
UNIT 5 Group homomorphisms, isomorphisms and Some special groups	Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems,Symmetries of a square, Dihedral groups	**CSO 5.1:** to define group homomorphism. Illustrate with examples. (K+U) **CSO 5.2:** to understand the Properties of homomorphism. (U) **CSO 5.3:** to define group isomorphism. Illustrate with examples. (K+U) **CSO 5.4:** to understand the Properties of isomorphism. (U) **CSO 5.5:** to state and prove Cayley's theorem. (K+A) **CSO 5.6:** to state and prove First, Second and Third theorem of isomorphism. (K+A) **CSO 5.7:** To understand Symmetries of a square of how they form Group under composition (U) **CSO 5.8:** To learn about Dihedral Groups, understand its properties, representations and applications. (K+U+A)	12	20	Not to be filled-in

Suggested Readings:

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra*, 4th Ed., Narosa Publishing House, New Delhi, 1999.
4. Joseph J. Rotman, *An Introduction to the Theory of Groups*, 4th Ed., Springer Verlag, 1995.
5. I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.

NAME OF THE PAPER (CODE) : **PDE AND SYSTEMS OF ODE (MTC 3.3)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

Use of Scientific Calculator is allowed

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **PDE and Systems of ODE**:

CO 1:	To introduce the basic concepts of partial differential equations. To Construct, interpret geometrically, form and classify the first order PDE. To obtain the general solution of PDE.
CO 2:	To provide a comprehensive understanding of method of separation of variables for first order linear PDEs and the derivation, classification and, solution of second order PDEs.
CO 3:	To particularly focus more on the application of PDEs in solving Cauchy and boundary value problems related to wave propagation.
CO 4:	To equip students with the necessary skills and knowledge to tackle PDEs with non-homogeneous boundary conditions, focusing on practical applications in wave propagation and heat conduction
CO 5:	To provide a comprehensive understanding of systems of linear differential equations, and their solution methods, with a focus on practical applications and numerical techniques.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Introduction to Partial Differential Equations	Partial Differential Equations – Basic concepts and Definitions, Mathematical Problems. First-Order Equations: Classification, Construction and Geometrical Interpretation. Method of Characteristics for obtaining General Solution of Quasi Linear Equations. Canonical Forms of First-order Linear Equations.	**CSO 1.1:** to define PDE (K) **CSO 1.2:** to discuss basic concepts of partial differential equations. (U) **CSO 1.3:** to classify, Construct and give geometrical interpretation of first order PDE (U) **CSO 1.4:** to form PDE by eliminating constants (U) **CSO 1.5:** to find the general solution of first order linear PDE. (A) **CSO 1.6:** to explain the method of canonical form of first order linear equations (U) **CSO 1.7:** to Reduce the linear PDE to canonical form and obtain the general solution. (A)	9	20	Not to be filled-in
UNIT 2 Method of Separation of Variables and Classification of second	Method of Separation of Variables for solving first order partial differential equations. Derivation of Heat equation,	**CSO 2.1:** to explain Method of Separation of Variables (U) **CSO 2.2:** to apply Method of Separation of Variables to solve first order PDEs. (A) **CSO 2.3:** to explain and derive	9	20	Not to be filled-in

order linear equations	Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order Linear Equations to canonical forms.	Heat, Wave and Laplace Equation (U+A) **CSO 2.4:** to Classify second order linear equations hyperbolic, parabolic or elliptic (U) **CSO 2.5:** to explain the method of canonical form of second order PDE(U) **CSO 2.6:** to reduce second order Linear Equations to canonical forms (A) **CSO 2.7:** to explain Secant method and its derivative. (U)			
UNIT 3 Solving Cauchy problem and Boundary Value Problems	The Cauchy problem, the Cauchy-Kowaleewskaya theorem, Cauchy problem of an infinite string. Initial Boundary Value Problems, Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end.	**CSO 3.1:** to define Cauchy problem with problems (K+U) **CSO 3.2:** to give the statement for Cauchy-Kowaleewskaya theorem (K) **CSO 3.3:** to apply method of separation of variables to solve Initial Boundary Value Problems. (A) **CSO 3.4:** to explain Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end. (U) **CSO 3.5:** to solve various problems on Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end (A)	9	20	Not to be filled-in
UNIT 4 **Solving non-homogeneous equations with boundary conditions using separation of variables**	Equations with non-homogeneous boundary conditions, Non-Homogeneous Wave Equation. Method of separation of variables, Solving the Vibrating String Problem, Solving the Heat Conduction problem.	**CSO 4.1:** to derive the equations of non-homogeneous boundary conditions. (K+A) **CSO 4.2:** to Solve the non-homogeneous wave equation. (A) **CSO 4.3:** to apply method of separation of variables to derive vibrating string problem. (A) **CSO 4.4:** to solve the Vibrating String Problem (A) **CSO 4.5:** to derive the Heat Conduction problem by method of separation of variables (K+A) **CSO 4.6:** to solve by the method of heat conduction (A)	9	20	Not to be filled-in
UNIT 5 Systems of linear	Systems of linear differential equations, types of linear	**CSO 5.1:** to understand the concept of systems of linear differential equations (K+U)	9	20	Not to be filled-

differential equations	systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions, The method of successive approximations, the Euler method, the modified Euler method, The Runge-Kutta method.	**CSO 5.2:** to explain types of linear systems (U) **CSO 5.3:** to understand the concept of differential operators (U) **CSO 5.4:** to use the operator method to find the general solution of the given linear systems. (A) **CSO 5.5:** to understand the concept of basic theory of linear system in normal form (U) **CSO 5.6:** to illustrate with examples (U) **CSO 5.7:** to define homogeneous linear system. (K) **CSO 5.8:** to define non-homogeneous linear system (K) **CSO 5.9:** to find Solutions of homogeneous and non-homogeneous linear system. (A) **CSO 5.10:** to explain method of successive approximations, the Euler method, the modified Euler method, The Runge-Kutta method. (U) **CSO 5.11:** to apply the methods to systems of linear differential equations. (A)			in

NAME OF THE PAPER (CODE) : **PDE AND SYSTEMS OF ODE (MTC 3.3) (Practical)**
Number of Credit : **01**
Number of Hours of Lecture : **30**

List of Practicals (using any software)

(i) Solution of Cauchy problem for first order PDE.
(ii) Finding the characteristics for the first order PDE.
(iii) Plot the integral surfaces of a given first order PDE with initial data.
(iv) Solution of wave equation $\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$ for the following associated conditions

a) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x), x \in \mathbb{R}, t > 0$
b) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ u(0,t) = 0, x \in (0,\infty),\ t > 0$
c) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ u_x(0,t) = 0, x \in (0,\infty),\ t > 0$
d) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ u(0,t) = 0,\ u(l,t) = 0,\ 0 < x < l,\ t > 0$

(v) Solution of heat equation $\frac{\partial u}{\partial t} = K^2 \frac{\partial^2 u}{\partial x^2}$ for the following associated conditions

a) $u(x,0) = \phi(x),\ u(0,t) = a, u(l,t) = b,\ 0 < x < l,\ t > 0$
b) $u(x,0) = \phi(x),\ u(0,t) = a, ,\ x \in (0,\infty),\ t \geq 0$
c) $u(x,0) = \phi(x),\ u(0,t) = a, x \in \mathbb{R}, 0 < t < T$

Suggested Readings:

1. Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers*, 4th edition, Springer, Indian reprint, 2006.
2. S.L. Ross, *Differential equations,* 3rd Ed., John Wiley and Sons, India, 2004.
3. Martha L Abell and James P Braselton, *Differential equations with MATHEMATICA*, 3rd Ed., Elsevier Academic Press, 2004.
4. J Sinha Roy and S Padhy, *A course of Ordinary and Partial differential equation*, Prentice-Hall, New Delhi, 2012.
5. Martha L Abell, James P Braselton, *Differential equations with MATHEMATICA*, 3rd Ed., Elsevier Academic Press, 2004.
6. Robert C. McOwen, *Partial Differential Equations*, Pearson Education Inc., 2010.
7. T Amarnath, *An Elementary Course in Partial Differential Equations*, Narosa Publications, 2005.

NAME OF THE PAPER (CODE) : **NUMERICAL METHODS (MTC 4.1)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

Use of Scientific Calculator is allowed.

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Numerical Methods**:

CO 1:	To make the students aware of the numerical methods and basic concepts of algorithm, convergence and errors.
CO 2:	To aid the students in the understanding of transcendental and polynomial equations and help them to solve the equations by using different methods, and analyse its convergence.
CO 3:	To create an understanding among the students, the system of linear algebraic equations and how to solve it and analyse its convergence.
CO 4:	To inculcate and create interest among students in the understanding of interpolation.
CO 5:	To assist the students in the understanding of Numerical integration.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Introduction to Numerical Methods	Algorithms, Convergence, Errors: Relative, Absolute, Round off and Truncation	**CSO 1.1:** to define the term Algorithm (K) **CSO 1.2:** to construct an Algorithm for a sequence to find mean and standard deviation. (U) **CSO 1.3:** to apply the Algorithm to find mean and standard deviation. (A) **CSO 1.4:** to construct an Algorithm to find an integral of a function using trapezoidal rule. (U) **CSO 1.5:** to apply the Algorithm to find an integral. (A) **CSO 1.6:** to define the term convergence. (K) **CSO 1.7:** to understand the rate of convergence and order of convergence. (U) **CSO 1.8:** to evaluate rate of convergence and order of convergence of some functions. (A) **CSO 1.9:** to define the term error. (K) **CSO 1.10:** to write and define the different types of errors. (K) **CSO 1.11:** to find the value of the different errors by solving some questions. (A)	8	18	Not to be filled-in

UNIT 2 Transcendental and Polynomial Equations	Transcendental and Polynomial equations: Bisection method, Newton's method, Secant method, Rate of convergence of these methods	**CSO 2.1:** to define Transcendental equation. (K) **CSO 2.2:** to define polynomial equation. (K) **CSO 2.3:** to explain Bisection Method and its derivative. (U) **CSO 2.4:** to apply Bisection Method to solve some Transcendental and polynomial equations. (A) **CSO 2.5:** to explain Newton's method and its derivative. (U) **CSO 2.6:** to apply Newton's method to solve some Transcendental and polynomial equations. (A) **CSO 2.7:** to explain Secant method and its derivative. (U) **CSO 2.8:** to apply Secant method to solve some Transcendental and polynomial equations. (A) **CSO 2.9:** to analyse the rate of convergence for Newton's method. (A) **CSO 2.10:** to analyse the rate of convergence for Bisection method. (A) **CSO 2.11:** to analyse the rate of convergence for Secant method. (A)	9	20	Not to be filled-in
UNIT 3 System of Linear Algebraic Equations	System of linear algebraic equations: Gaussian Elimination and Gauss Jordon methods, Gauss Jacobi method, Gauss Seidel method and their convergence analysis	**CSO 3.1:** to define system of linear algebraic equation. (K) **CSO 3.2:** to explain Gaussian Elimination method and its derivative. (U) **CSO 3.3:** to apply Gaussian Elimination method to solve some system of linear algebraic equations. (A) **CSO 3.4:** to explain Gauss Jordon method and its derivative. (U) **CSO 3.5:** to apply Gauss Jordon method to solve some system of linear algebraic equations. (A) **CSO 3.6:** to explain Gauss Jacobi method and its derivative. (U) **CSO 3.7:** to apply Gauss Jacobi method to solve some system of linear algebraic equations. (A) **CSO 3.8:** to explain Gauss Seidel method and its derivative. (U) **CSO 3.9:** to apply Gauss Seidel method to solve some system of linear algebraic equations. (A) **CSO 3.10:** to analyse the rate of convergence for Gaussian	9	20	Not to be filled-in

		Elimination method. (A) **CSO 3.11:** to analyse the rate of convergence for Gauss Jordon method. (A) **CSO 12:** to analyse the rate of convergence for Gauss Jacobi method. (A) **CSO 3.13:** to analyse the rate of convergence for Gauss Seidel method. (A)			
UNIT 4 **Interpolation**	Interpolation: Lagrange and Newton's methods, Error bounds. Finite difference operators, Gregory forward and backward difference interpolation.	**CSO 4.1:** to define Interpolation. (K) **CSO 4.2:** to explain Lagrange method. (U) **CSO 4.3:** to apply Lagrange method to solve some questions. (A) **CSO 4.4:** to explain Newton's method. (U) **CSO 4.5:** to apply Newton's method to solve some questions. (A) **CSO 4.6:** to define error bound. (K) **CSO 4.7:** to analyse the error bound of some problems. (A) **CSO 4.8:** to define finite difference operators. (K) **CSO 4.9:** to solve problems using the finite difference operators. (A) **CSO 4.10:** to explain Gregory forward Interpolation. (U) **CSO 4.11:** to apply Gregory forward Interpolation to solve some problems. (A) **CSO 4.12:** to explain Backward difference Interpolation. (U) **CSO 4.13:** to apply Backward difference Interpolation to solve some problems. (A)	9	20	Not to be filled-in
UNIT 5 Numerical Integration	Numerical Integration: Trapezoidal rule, Simpson's $^{1}/_{3}$ rule, Simpsons $^{3}/_{8}$ rule, Boole's rule, Midpoint rule, Composite Trapezoidal rule, Composite Simpson's rule, Ordinary Differential Equations: Euler's method, Runge-Kutta	**CSO 5.1:** to define Numerical Integration. (K) **CSO 5.2:** to explain Trapezoidal rule. (U) **CSO 5.3:** to apply Trapezoidal rule to find the integration of some equations. (A) **CSO 5.4:** to explain Simpson's $1/3^{rd}$ rule. (U) **CSO 5.5:** to apply Simpson's $1/3^{rd}$ rule to find the integration of some equations. (A) **CSO 5.6:** to explain Simpson's $3/8^{th}$ rule. (U) **CSO 5.7:** to apply Simpson's $3/8^{th}$ rule to find the integration of some	10	22	Not to be filled-in

	Methods of orders two and four.	equations. (A) **CSO 5.8:** to explain Boole's rule. (U) **CSO 5.9:** to apply Boole's rule to find the integration of some equations. (A) **CSO 5.10:** to explain Midpoint rule. (U) **CSO 5.11:** to apply Midpoint rule to solve some equations. (A) **CSO 5.12:** to explain composite Trapezoidal rule. (U) **CSO 5.13:** to explain composite Simpson's rule. (U) **CSO 5.14:** to define ordinary Differential equation. (K) **CSO 5.15:** to explain Euler's method. (U) **CSO 5.16:** to explain Runge-Kutta methods of order two and four. (U) CSO 5.17: to apply Euler's method and Runge-Kutta methods to solve some problems.			

NAME OF THE PAPER (CODE) : NUMERICAL METHODS (MTC 4.1) (Practical)
Number of Credit : 01
Number of Hours of Lecture : 30

List of Practicals (using any software)

(i) Calculate the sum 1/1+1/2+1/3+1/4+…….+1/N
(ii) To find the absolute value of an integer.
(iii) Enter 100 integers into an array and sort them in an ascending order.
(iv) Bisection Method.
(v) Newton Raphson Method.
(v) Secant Method.
(vi) Regula Falsi Method.
(vii) LU decomposition Method.
(ix) Gauss-Jacobi Method.
(x) SOR Method or Gauss-Siedel Method.
(xi) Lagrange Interpolation or Newton Interpolation.
(xii) Simpson's rule.

Suggested Readings:

1. Brian Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation, 6th Ed*., New age International Publisher, India, 2007.
3. C.F. Gerald and P.O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India, 2008.
4. Uri M. Ascher and Chen Greif, *A First Course in Numerical Methods, 7th Ed.*, PHI Learning Private Limited, 2013.
5. John H. Mathews and Kurtis D. Fink, *Numerical Methods using Matlab, 4th Ed*., PHI Learning Private Limited, 2012.

NAME OF THE PAPER (CODE): RIEMANN INTEGRATION AND SERIES OF FUNCTIONS (MTC 4.2)

Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Riemann Integration and series of Functions:**

CO 1:	To understand the concept of Riemann integration.
CO 2:	To aid the students in understanding more about Riemann integration.
CO 3:	To create the students in understanding about improper integrals.
CO 4:	To inculcate and create interest among students in the understanding functions of analysis.
CO 5:	To assist the students in the understanding more on functions of analysis.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Riemann integration	Riemann integration-inequalities of upper and lower sums; Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions.	**CSO 1.1:** Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Fundamental theorems of integration. (K) **CSO 1.2:** Riemann integration- inequalities of upper and lower sums; Riemann conditions of integrability. (U) **CSO 1.3:** Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions. (A)	8	18	Not to be filled-in
UNIT 2 Riemann integration	Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals; Fundamental theorems of Calculus.	**CSO 2.1:** Intermediate Value theorem for Integrals; Fundamental theorems of Calculus. (K) **CSO 2.2:** definition and integrability of piecewise continuous and monotone functions. (K) **CSO 2.3:** Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; (U)	9	20	Not to be filled-in

UNIT 3 Improper integrals	Improper integrals; Convergence of Beta and Gamma functions.	**CSO 3.1:** Know about improper integrals including, beta and gamma functions. (K) **CSO 3.2:** finding few examples reg. convergent and divergent. (U)	9	20	Not to be filled-in
UNIT 4 **Functions of Analysis**	Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.	**CSO 4.1:** Learn about Cauchy criterion for uniform convergence and Weierstrass M-test for uniform convergence. (K) **CSO 4.2:** Know about the constraints for the inter-changeability of differentiability and integrability with infinite sum. (U)	9	20	Not to be filled-in
UNIT 5 Functions of Analysis	Limit superior and Limit inferior. Power series, radius of convergence, Cauchy Hadamard Theorem, Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem.	**CSO 5.1:** Approximate transcendental functions in terms of power series as well as, differentiation and integration of power series. (K) **CSO 5.2:** Cauchy Hadamard Theorem, Differentiation and integration of power series; Abel's Theorem (U)	10	22	Not to be filled-in

Suggested Readings:

1. K.A. Ross, *Elementary Analysis, The Theory of Calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
2. R.G. Bartle D.R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
3. Charles G. Denlinger, *Elements of Real Analysis*, Jones & Bartlett (Student Edition), 2011.
4. Bartle, Robert G., & Sherbert, Donald R. (2015). *Introduction to Real Analysis* (4th ed.). Wiley India Edition. Delhi.
5. Denlinger, Charles G. (2011). *Elements of Real Analysis*. Jones & Bartlett (Student Edition). First Indian Edition. Reprinted 2015.
6. Ghorpade, Sudhir R. & Limaye, B. V. (2006). *A Course in Calculus and Real Analysis*. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
7. Ross, Kenneth A. (2013). *Elementary Analysis: The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer.

NAME OF THE PAPER (CODE) : GROUP THEORY II (MTC 4.3)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Group Theory II**:

CO 1:	To provide an in depth understanding of advanced topics in Group Theory, focusing more on Automorphisms. Also see its various applications in real world problem.
CO 2:	To provide a comprehensive understanding of the properties of External Direct Products. Also learn its applications in Cryptography and Number theory.
CO 3:	To develop a solid understanding of group actions and how groups acts on sets and other mathematical structures. Also learn its applications in various mathematical contexts.
CO 4:	To provide an in depth understanding of Groups acting on themselves by conjugation, the class equations and its consequences, conjugacy in permutations and p-groups.
CO 5:	To provide a deep understanding of Sylow theorems. Also learn non-simplicity test to check whether a group is simple.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Introduction to Group Automorphism	Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.	**CSO 1.1:** To define Automorphisms (K) **CSO 1.2:** to illustrate with examples. (U) **CSO 1.3:** to define Inner automorphism (K) **CSO 1.4:** to Illustrate with examples (U) **CSO 1.5:** to discuss the Automorphism groups and to determine automorphisms groups of finite and infinite cyclic group. (K+U) **CSO 1.6:** to define factor groups and dicuss its applications (K+U+A) **CSO 1.7:** to define Commutator Subgroup and discuss its properties (K+U)	12	20	Not to be filled-in
UNIT 2 External Direct Products	Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finite abelian groups.	**CSO 2.1:** to discuss the properties of external direct product (U) **CSO 2.2:** to define group of units modulo n as an external direct product (K) **CSO 2.3:** to understand its properties and applications in Cryptography and Number	12	20	Not to be filled-in

		theory (K+U) **CSO 2.4:** to define and understand the properties of internal direct product (K+U) **CSO 2.5:** to understand the Fundamental Theorem of finite abelian groups and explore its implications for the classification of finite Abelian Groups (U+A)			
UNIT 3 **Group Actions and its Applications**	Group actions, stabilizers and kernels, permutation representation associated with a given group action, Applications of group actions: Generalized Cayley's theorem, Index theorem.	**CSO 3.1:** Define Group Actions and learn its properties (K+U) **CSO 3.2:** to define Stabilizers and Kernels of grouo action and to understand it with examples (K+U) **CSO 3.3:** to construct permutation representations associated with group actions (A) **CSO 3.4:** to state and prove Generalized Cayley's theorem and Index theorem. (K+A) **CSO 3.5:** to understand the applications of group actions through Generalized Cayley's theorem and Index theorem. (A)	12	20	Not to be filled-in
UNIT 4 **Class Equations, Conjugacy and p-Groups**	Groups acting on themselves by conjugation, class equation and consequences, conjugacy in S_n, *p*-groups.	**CSO 4.1:** to define conjugate class. (K) **CSO 4.2:** to illustrate with examples (U) **CSO 4.3:** to define class equations (K+U) **CSO 4.4:** to determine class equations and conjugacy classes for various Groups (A) **CSO 4.5:** to understand the concept of p-groups. (U) **CSO 4.6:** to apply the concept and techniques to group actions (A)	12	20	Not to be filled-in
UNIT 5 **Sylow Theorems, Simplicity and Non-Simplicity Tests**	Sylow's theorems and consequences, Cauchy's theorem, Simplicity of An for n ≥ 5, non-simplicity tests.	**CSO 5.1:** to define and discuss Sylow first, second, third theorem and its consequences (K+U) **CSO 5.2:** to state and prove Cauchy's theorem (K+A) **CSO 5.3:** to define Simple Groups (K) **CSO 5.4:** to discuss different non-simplicity tests (U)	12	20	Not to be filled-in

		CSO 5.5: to apply the tests to various problems to check non simplicity of a group (A)			

Suggested Readings:

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002**.**
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra,* 4th Ed., Narosa Publishing House, 1999.
4. David S. Dummit and Richard M. Foote*, Abstract Algebra*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
5. J.R. Durbin, *Modern Algebra*, John Wiley & Sons, New York Inc., 2000.
6. D. A. R. Wallace, *Groups, Rings and Fields*, Springer Verlag London Ltd., 1998.

NAME OF THE PAPER (CODE) : **MULTIVARIATE CALCULUS (MTC 5.1)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Multivariate Calculus**:

CO 1:	To make the students aware of the "Functions of several variables" by learning continuity and differentiability of two variables
CO 2:	To extend the "Functions of several variables" by introducing gradient, divergence, curl of vectors and extreme values
CO 3:	To establish an understanding among the students, the concept of "Multiple Integrals" by learning double integrals and triple integrals in cartesian and polar forms, cylindrical coordinate, spherical co-ordinate and changing of variables
CO 4:	To instruct and make interest among students in the understanding of "Vector Calculus" by introducing line integral, and using it to find work done and to determine path independent of a vector field.
CO 5:	To extend the concept of "Vector Calculus" to introduce Green's theorem, Stoke's theorem and Gauss's Divergence theorem

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Functions of several variables (I)	Functions of several variables, limit and continuity of functions of two variables, Partial differentiation, Total differentiability and differentiability, Sufficient condition for differentiability, Chain rule for one and two independent parameters.	**CSO 1.1:** To define explicit and implicit functions (K) **CSO 1.2:** To define explicit functions of two variables (K) **CSO 1.3:** To define the neighbourhood of a point of functions of two variables (K) **CSO 1.4:** To define the limit point of functions of two variables (K) **CSO 1.5:** To define the limit or double limit or simultaneous limit of functions of two variables (K) **CSO 1.6:** Determining the limit of functions of two variables (A) **CSO 1.7**: Discussing the condition of non-existence of limit (U) **CSO 1.8:** Describing the algebra of limits of functions of two variables (K) **CSO 1.9:** To define continuity of functions of two variables (K) **CSO 1.10:** Interpreting continuity of functions of two variables (U) **CSO 1.11:** To define partial derivatives of continuity of functions of two variables (K)	12	20	Not to be filled-in

		CSO 1.12: Determining the partial derivatives of continuity of functions of two variables (A) **CSO 1.13:** To define differentiability of functions of two variables (K) **CSO 1.14:** Identifying the functions of two variables which are differentiable. (K) **CSO 1.15:** Describing sufficient conditions for differentiability of functions of two variables (K) **CSO 1.16:** Stating Young's theorem and Schwarz's theorem (K) **CSO 1.17:** Applying Young's theorem and Schwarz's theorem in determining differentiability of functions of two variables (A) **CSO 1.18:** Describing Chain rule for one and two independent parameters. (K)			
UNIT 2 Functions of several variables (II)	Definition of vector field, Divergence and Curl, Directional derivatives, The gradient, Maximal and normal property of the gradient, Tangent planes, Extrema of functions of two variables, Method of Lagrange's multipliers, Constrained optimization problems.	**CSO 2.1:** To define scalar field and vector field (K) **CSO 2.2:** To define divergence and curl, directional derivatives, gradient (K) **CSO 2.3:** Determining divergence and curl, directional derivatives, gradient of functions of several variables (A) **CSO 2.4:** Discussing maximal and normal property of the gradient (U) **CSO 2.5:** To define tangent and normal planes of functions of several variables (K) **CSO 2.6:** Determining tangent and normal planes of functions of several variables (A) **CSO 2.7:** Identifying maxima and minima of functions of two variables (K) **CSO 2.8:** Discussing Lagrange's method of undetermined multipliers for several and independent variables multipliers (U)	12	20	Not to be filled-in
UNIT 3 Multiple Integrals	Double integration over rectangular region, Double integration over non rectangular region, Double integral over polar coordinate, Triple integrals, Change of variable in double and triple integrals, Triple integral over	**CSO 3.1:** To define double integration (K) **CSO 3.2:** Applying double integration over rectangular and non-rectangular region (A) **CSO 3.3:** Describing double integration over polar coordinate (K) **CSO 3.4** To define triple integrals (K) **CSO 3.5:** Discussing change of variables in double integration from rectangular to polar coordinate (U)	14	24	Not to be filled-in

	parallelepiped and solid regions, volume by triple integral, cylindrical and spherical coordinates.	**CSO 3.6:** Describing triple integrals over parallelepiped and solid regions (K) **CSO 3.7:** Describing volume by triple integrals using cylindrical and spherical coordinates (K) **CSO 3.8:** Discussing change of variables in triple integrals from rectangular to cylindrical coordinates (U) **CSO 3.9:** Discussing change of variables in triple integrals from rectangular spherical coordinates (U)			
UNIT 4 Vector Calculus (I)	Line integral, Application of line integrals: Mass and Work done, Fundamental theorem for line integrals, Conservative vector fields, Independence of path.	**CSO 4.1:** To define line integral of functions of several variables (K) **CSO 4.2:** Applying line integrals in determining mass and work done of functions of several variables (A) **CSO 4.3:** Discussing fundamental theorem for line integral (U) **CSO 4.4:** To define conservative vector fields (K) **CSO 4.5:** Identifying conservative vector fields of functions of several variables (K) **CSO 4.6:** Discussing Independence of path of functions of several variables (U)	10	16	Not to be filled-in
UNIT 5 Vector calculus (II)	Green's theorem, Surface integrals, Integrals over parametrically defined surfaces, Stoke's theorem, The divergence theorem.	**CSO 5.1:** Stating Green's theorem (K) **CSO 5.2:** Discussing Green's theorem over functions of several variables (U) **CSO 5.3:** To define **s**urface integrals over functions of several variables (K) **CSO 5.4:** Finding Surface integrals over functions of several variables (A) **CSO 5.5:** Stating Stoke's theorem (K) **CSO 5.6:** Discussing Stoke's theorem over functions of several variables (U) **CSO 5.7:** Stating Gauss's divergence theorem (K) **CSO 5.8:** Describing divergence theorem over functions of several variables (K)	12	20	Not to be filled-in

Suggested Readings:

1. G. B. Thomas and R. L. Finney, *Calculus, 9th Ed.*, Pearson Education, Delhi, 2005.
2. M. J. Strauss, G. L. Bradley and K. J. Smith, *Calculus, 3rd Ed.*, Dorling Kindersley (India) Pvt. Ltd., (Pearson Education), Delhi, 2007.

3. James Stewart, *Multivariate Calculus, Concepts and Contexts, 2nd Ed.*, Brooks/Cole, Thomson Learning, USA, 2001.
4. E. Marsden, A. J. Tromba and A. Weinstein, *Basic Multivariate calculus*, Springer (SIE), Indian reprint, 2005.

NAME OF THE PAPER (CODE) : LINEAR ALGEBRA (MTC 5.2)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Linear Algebra**:

CO 1:	To provide a comprehensive understanding of Vector Spaces and its subspaces, and methods to finding basis of a vector space.
CO 2:	To provide a comprehensive understanding of Linear Transformation and isomorphisms, the concept of rank and nullity of linear transformation, and learn techniques for computing them, including the use of Matrix representation.
CO 3:	To provide a comprehensive understanding of advanced concepts in linear algebra, focusing more on dual spaces. Also, learn about the minimal polynomial for a linear operator, such as its diagonalizability and its relationship with the characteristic polynomial.
CO 4:	To provide a comprehensive understanding of Inner Product Spaces, also learn techniques for constructing Orthonormal bases using Gram-Schmidt process.
CO 5:	To provide an in depth understanding of advanced topics in linear algebra, focusing more on Least Squares Approximation to check the orthogonality of vectors. Also, understand the spectral theorem for self-adjoint operators.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 **Vector Spaces**	Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.	**CSO 1.1:** to define vector spaces and understand the general properties of vector spaces (K+U) **CSO 1.2:** to define and understand subspaces and algebra of subspaces (K+U) **CSO 1.3:** to define Quotient spaces (K) **CSO 1.4:** to define and understand linear combination of vectors, linear span, linear dependence and independence of vectors. (K+U) **CSO 1.5:** to define basis and dimension of subspaces (K) **CSO 1.6:** to define basis and dimension of vector spaces (K)	12	20	Not to be filled-in
UNIT 2 **Linear**	Linear transformations, null	**CSO 2.1:** to define linear transformation and linear	12	20	Not to be

Transformations and Isomorphisms	space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms, Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.	operator (K) **CSO 2.2:** to define null space, range, rank and nullity of a linear transformation (K) **CSO 2.3:** to represent linear transformation in matrix form (U) **CSO 2.4:** to apply matrix representation of a linear transformation to find range and nullity of a linear transformation (A) **CSO 2.5:** to understand the concept of isomorphism theorem, invertible matrix and change of coordinate. (U)			filled-in
UNIT 3 **Linear Transformations, Eigenvalues and Eigenvectors, Elementary canonical forms**	Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators, Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem. The minimal polynomial for a linear operator.	**CSO 3.1:** to define dual space, dual basis and double dual (K) **CSO 3.2:** to understand transpose of a linear transformation and its matrix in the dual basis (U) **CSO 3.3:** to define annihilators (K) **CSO 3.4:** to define Eigen value, Eigen vector and Eigen spaces of a linear operator (K) **CSO 3.5:** to understand diagonalizability and check whether a matrix is diagonalizable (U) **CSO 3.6:** to understand the concept of invariant subspaces (U) **CSO 3.7:** to state and prove Cayley-Hamilton theorem (K+A) **CSO 3.8:** to define and understand the concept of characteristic polynomial and minimal polynomial (K+U)	12	20	Not to be filled-in
UNIT 4 **Inner Product Spaces and Operators on Inner Product Spaces**	Inner product spaces and norms, Gram-Schmidt orthogonalization process, orthogonal complements, Bessel's inequality, the adjoint of a linear operator.	**CSO 4.1:** to define and understand Inner Product and Inner product space with examples (K+U) **CSO 4.2:** to define Norms and prove theorems related to norms such as Cauchy-Schwartz inequality theorem, , triangle theorem, Pythagoras theorem (U+A) **CSO 4.3:** to understand Gram Schmidt Orthogonalization Process (U)	12	20	Not to be filled-in

		CSO 4.4: to understand orthogonal complements (U) **CSO 4.5:** to understand Bessel's inequality, the adjoint of a linear operator. (U)			
UNIT 5 Orthogonality	Least Squares Approximation, minimal solutions to systems of linear equations, Normal and self-adjoint operators, Orthogonal projections and Spectral theorem.	**CSO 5.1:** to learn least square approximation and apply it. (K+A) **CSO 5.2:** to understand the minimal solution to system of linear equations and solve.(U+A) **CSO 5.3:** to define normal and self-adjoint operators (K) **CSO 5.4:** to understand the Orthogonal projections and Spectral theorem. (U+A)	12	20	Not to be filled-in

Suggested Readings:

1. John B. Fraleigh, *A First Course in Abstract Algebra, 7th Ed*., Pearson, 2002.
2. M. Artin, *Abstract Algebra, 2nd Ed*., Pearson, 2011.
3. Stephen H. Friedberg, Arnold J. Insel & Lawrence E. Spence, *Linear Algebra, 4th Ed*., Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
4. Joseph A. Gallian, *Contemporary Abstract Algebra, 4th Ed.*, Narosa Publishing House, New Delhi, 1999.
5. S. Lang, *Introduction to Linear Algebra, 2nd Ed*., Springer, 2005.
6. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
7. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
8. Kenneth Hoffman, *Ray Alden Kunze*, *Linear Algebra, 2nd Ed*., Prentice-Hall of India Pvt. Ltd., 1971.
9. D.A.R. Wallace, *Groups, Rings and Fields*, Springer Verlag London Ltd., 1998.

NAME OF THE PAPER (CODE) : NUMBER THEORY (MTC 5.3)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Number Theory**:

CO 1:	To create an understanding of the concepts of Number Theory.
CO 2:	To assist the students in understanding Number Theoretic functions and formulas.
CO 3:	To create an understanding of Integer functions and Euler's theorem.
CO 4:	To inculcate the students in understanding order, roots and congruences.
CO 5:	To make the students familiar with cryptography.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Exploring Number Theory	Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson's theorem.	**CSO 1.1:** to define linear Diophantine equation with appropriate examples. (K/U) **CSO 1.2:** to define prime counting function with examples. (K/U) **CSO 1.3:** to state prime number theorem. (K) **CSO 1.4:** to define Goldbach conjecture with examples. (K/U) **CSO 1.5:** to define and explain linear congruences and workout some problems. (K/U/A) **CSO 1.6:** to define complete set of residues with examples. (K/U) **CSO 1.7:** to state and proof Chinese Remainder theorem. (K/U) **CSO 1.8:** to tackle some questions based on Chinese remainder theorem. (A) **CSO 1.9:** to state and proof Fermat's little theorem. (K/U) **CSO 1.10**: to solve some problems based on Fermat's little theorem. (A) **CSO 1.11:** to state and proof wilson's theorem. (K/U)	13	22	Not to be filled-in
UNIT 2 Number Theoretic	Number theoretic functions, sum and number of divisors,	**CSO 2.1:** to define and explain Number theoretic functions. (K/U)	12	20	Not to be filled-

Functions and Formulas	totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula.	**CSO 2.2:** to workout some problems based on number theoretic functions. (A) **CSO 2.3:** to explain sum and number of divisors with appropriate examples. (K/U) **CSO 2.4:** to define total multiplicative functions and workout some functions. (K/A) **CSO 2.5:** to define Dirichlet product. (K) **CSO 2.6:** to write down the properties of the Dirichlet product. (K) **CSO 2.7:** to define and explain Mobius inversion formula with examples. (K/U)			in
UNIT 3 **Integer Functions and Euler's Theorem**	The greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.	**CSO 3.1:** to define and explain the greatest integer function and workout some problems. (K/U/A) **CSO 3.2:** to define Euler's phi-function and workout some problems. (K/A) **CSO 3.3:** to state and prove Euler's theorem. (K/U) **CSO 3.4:** to define reduced set of residues with examples. (K/U) **CSO 3.5:** to write down some properties of Euler's phi-function and explain it. (K/U) **CSO 3.6:** to workout some problems with the help of the properties of Euler's phi-function. (A)	12	20	Not to be filled-in
UNIT 4 **Order, Roots and Congruences**	Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli.	**CSO 4.1:** to define order of an integer modulo n with examples. (K/U) **CSO 4.2:** to define primitive roots for primes and workout some problems. (K/A) **CSO 4.3:** to explain composite numbers having primitive roots and solve some problems based on it. (U/A) **CSO 4.4:** to state Euler's criterion and prove it. (K/U) **CSO 4.5:** to define Legendre symbol and its properties with some problem solutions. (K/U/A) **CSO 4.6:** to define quadratic reciprocity with appropriate	12	20	Not to be filled-in

		examples. (K/U) **CSO 4.7:** to explain quadratic congruences with composite moduli and workout problems based on it. (K/U/A)			
UNIT 5 **Cryptography And non-linear Diophantine equation**	Public key encryption, RSA encryption and decryption, the equation x2 + y2= z2, Fermat's Last theorem.	**CSO 5.1:** to define and explain Public key encryption with examples. (K/U) **CSO 5.2:** to define and explain RSA encryption and decryption and workout problems based on it. (K/U/A) **CSO 5.3:** to explain the equation x2 + y2= z2. (U) **CSO 5.4:** to state and prove Fermat's Last theorem. (U)	11	18	Not to be filled-in

Suggested Readings:
1. David M. Burton, *Elementary Number Theory*, *6th Ed.*, Tata McGraw-Hill, Indian reprint, 2007.
2. Neville Robbins, *Beginning Number Theory, 2nd Ed*., Narosa Publishing House Pvt. Ltd., Delhi, 2007.

NAME OF THE PAPER (CODE) **: COMPLEX ANALYSIS (MTC 6.1)**
Number of Credit **: 04**
Number of Hours of Lecture **: 60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Complex Analysis**:

CO 1:	To make the students in understanding "Analytic functions" by introducing basic concepts of complex systems and C-R equations limits, derivatives and properties of complex planes.
CO 2:	To make the students understand by Discussing "Complex Integration" through Cauchy's theorem, Cauchy's integral theorem, contour integral and also expansion of series by Taylor's and, Laurent's series
CO 3:	To make the students in understanding "Singularities and Calculus of Residue" Zeros, singularities, residue at a pole and infinity, conformal and bilinear transformation, fixed points, critical points, cross ratio. Prove of Cauchy's residue theorem and Jordan's lemma.
CO 4:	To make the students in understanding "Meromomorphic functions and Analytic Continuation" Poles and Zeros of meromorphic functions, prove of Mittag-Leffler's theorem, the principle of argument. Prove of Rouche's theorem with examples. Prove of fundamental theorem of algebra. The power series methods of analytic continuation and schwarz reflection of principle.
CO 5:	To make the students in understanding "Uniform Convergence of a Sequence and Series" by applying Weierstrass's-M test. To make students understand infinite product and its convergence with some examples. Defining Gamma function and its properties and canonical product.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	Los
UNIT 1 Analytic functions	Functions of complex variables, Continuity and Differentiability, Analytic functions, Conjugate functions, Harmonic functions, Cauchy Riemann Equation (Cartesian and polar of form) Construction of Analytic functions, Milne Thompson method, Stereographic projection and the spherical representation of the extended complex plane	**CSO 1.1:** To define limit of a function of complex variables, and its continuity and differentiability (K) **CSO 1.2:** Defining Analytic functions (K) **CSO 1.3:** To define conjugate and harmonic function (K) **CSO 1.4:** Discussing the condition of Laplace equation for the function to be a harmonic (U) **CSO 1.5:** Proving Cauchy-Riemann equation on Cartesian and polar of form (U) **CSO 1.6:** Determining analytic functions based on Cauchy-Riemann equation (A) **CSO 1.7:** Constructing Analytic function by Milne's	12	20	Not to be filled-in

		Thompson's method (A) **CSO 1.8:** Finding the analytic function $f(z) = u + iv$ when u or v is given (A) **CSO 1.9:** Describing the Stereographic projection and the spherical representation of the extended complex plane (K)			
UNIT 2 Complex Integration	Complex line integral, Cauchy's theorem, Cauchy's integral formula, Contour integrals and its examples, Cauchy's inequality, Morera's theorem, Poisson integral formula for a circle, Liouville's theorem, Power series, Taylor's series, Laurent's series, Fundamental theorem of algebra, Maximum modulus principle, Schwarz Lemma	**CSO 2.1:** To define line integral in complex variable (K) **CSO 2.2:** Statement and proof of Cauchy's theorem (U) **CSO 2.3:** Solving contour integral using Cauchy's theorem (A) **CSO 2.4:** Statement and proof of Cauchy's integral formula (U) **CSO 2.5:** Solving contour based on Cauchy's integral formula (A) **CSO 2.6:** Describing Cauchy's inequality (K) **CSO 2.7:** Describing Morera's theorem (K) **CSO 2.8:** Describing Poisson integral formula for a circle (K) **CSO 2.9:** Discuss Liouville's theorem (U) **CSO 2.10:** To define power series (K) **CSO 2.11:** Applying Taylor's and Laurent's series formula to obtain some series of complex variable (A) **CSO 2.12:** Discussing Fundamental theorem of algebra (U) **CSO 2.13:** Describing Maximum modulus principle (A) **CSO 2.14:** Proving Schwarz's Lemma (U)	12	20	Not to be filled-in
UNIT 3 Singularities and Calculus of residue	Zeros and singularities, Residue at a pole and infinity, Cauchy's residue theorem, Jordan's lemma, Evaluation of definite integrals using residue, Conformal and bilinear transformation, Fixed points, Critical points, Cross ratio	**CSO 3.1:** Defining the term zero (K) **CSO 3.2:** Finding zeros of $f(z)$ (A) **CSO 3.3:** Defining the term singularity and its types (K) **CSO 3.4:** Finding singularities and determining its type on $f(z)$ (A) **CSO 3.5:** Defining residue at a pole and residue at infinity (K) **CSO 3.6:** Proving Cauchy's residue theorem (U)	12	20	Not to be filled-in

	"%d"	**CSO 3.7:** Finding residue at pole of f(z) and at infinity (A) **CSO 3.8:** Applying Cauchy's residue theorem to solve definite integral (A) **CSO 3.9:** To define conformal transformation (K) **CSO 3.10:** Finding region of w −plane under the transformation type $w = z + \beta$; $w = ze^{\frac{i\pi}{4}}$; $w = 2z$; $w = 1/z$ (A) **CSO 3.11:** Studying conformal property (U) **CSO 3.12:** Defining bilinear transformation, fixed point, cross ratio (K) **CSO 3.13:** Determining bilinear transformation (A) **CSO 3.14:** Proving preservance of cross ratio theorem (U)			
UNIT 4 Meromorphic functions and Analytic Continuation	Poles and zeros of meromorphic functions, Mittag-Leffler's theorem, Principle of argument, Rouche's theorem, Examples, Analytic continuation, Power series methods of analytic continuation, Examples, Schwarz refection principle.	**CSO 4.1:** To define the term meromorphic function and entire function (K) **CSO 4.2:** Describing Mittag-Leffler's theorem (K) **CSO 4.3:** Application of Mittag-Leffler's theorem (A) **CSO 4.4:** Stating and proving **p**rinciple of argument and Rouche's theorem (U) **CSO 4.5:** Describing number of Poles and zeros of meromorphic function (K) **CSO 4.6:** Applying Rouche's theorem to find roots of $f(z)$ (A) **CSO 4.7:** Defining the term analytic continuation and it examples (K) **CSO 4.8:** Discussing analytic continuation by means of power series (U) **CSO 4.9:** Solving problems based on **a**nalytic continuation by means of power series (A) **CSO 4.10:** Deriving Schwarz refection principle (A)	12	20	Not to be filled-in
UNIT 5 Uniform Convergence of sequence and series	Uniform convergence of sequence and series, Weierstrass's M test, Examples, Infinite products, Convergence of infinite product,	**CSO 5.1:** Defining Uniform convergence of complex sequence and series (K) **CSO 5.2:** Discussing necessary and sufficient condition for complex sequence and series to be uniformly convergent (U)	12	20	Not to be filled-in

	Examples, Weierstrass's product theorem, Gamma function and its properties, Canonical product.	**CSO 5.3:** Describing Weierstrass's M test (K) **CSO 5.4:** Solving problems on uniform convergent of sequence and series of complex variable (A) **CSO 5.5:** Defining infinite product and convergence of infinite product (K) **CSO 5.6:** Discussing general principle of convergence of infinite product (U) **CSO 5.7:** Solving problems on convergence of infinite product (A) **CSO 5.8:** Defining gamma function (K) **CSO 5.9:** Discussing the properties of gamma function (U) **CSO 5.10:** Defining canonical product (K) **CSO 5.11:** Applications of canonical product (A)			

Suggested Readings:

1. S. Kumaresan, *Topology of Metric Spaces, 2^{nd} Ed.*, Narosa Publishing House, 2011
2. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill, 2004.
3. James Ward Brown and Ruel V. Churchill, *Complex Variable and Applications, 8^{th} Ed.*, McGraw Hill International Edition, 2009.
4. Satish Shirali and Harikishan L. Vasudeva, *Metric Spaces*, Springer Verlag, London, 2006.
5. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, 2^{nd} Ed., 2011.

NAME OF THE PAPER (CODE) : RING THEORY (MTC 6.2)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Ring Theory**:

CO 1:	To provide a comprehensive understanding of Rings, including their definitions, properties and its characteristics.
CO 2:	To possess the knowledge and concept of ideals, factor ring, prime ideal, maximal ideal and operations on a ring.
CO 3:	To provide a comprehensive understanding of Ring homomorphisms and Isomorphism. Also learn to construct field of quotients.
CO 4:	To provide a comprehensive understanding of Polynomial rings. Also learn about tests for irreducibility for polynomial rings.
CO 5:	To understand the concept of Unique factorization domain, and explore Divisibility in integral domains and Euclidean domains.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Introduction to Rings and Characteristic of Rings**	Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring.	**CSO 1.1:** to define Rings and illustrate with examples (K+U) **CSO 1.2:** to discuss the properties of Rings (U) **CSO 1.3:** to define Subrings and see various examples of Subring of a ring. (K+A) **CSO 1.4:** to define Units and Zero Divisors (K) **CSO 1.5:** to define Integral Domain and discuss its properties and examples. (K+U) **CSO 1.6:** to define Field and prove that every field is an Integral Domain but not the converse. (K+A) **CSO 1.7:** to define Characteristic of a ring (K) **CSO 1.8:** to determine the characteristic of a ring. (A)	12	20	Not to be filled-in
UNIT 2 **Ideals**	Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.	**CSO 2.1:** to define right Ideal, left Ideal and Ideal. (K) **CSO 2.2:** to illustrate with examples (U) **CSO 2.3:** to define Factor rings (K) **CSO 2.4:** to discuss various operations on Ideals (U)	12	20	Not to be filled-in

		CSO 2.5: to define Prime Ideals and Maximal Ideals (K) **CSO 2.6:** to discuss and determine various properties and theorems of Prime Ideal and maximal Ideal. (U+A)			
UNIT 3 **Ring Homomorphisms and Isomorphisms**	Ring homomorphisms, properties of ring homomorphisms, Isomorphism theorems I, II and III, field of quotients.	**CSO 3.1:** to define Ring homomorphism (K) **CSO 3.2:** to discuss the properties of ring homomorphisms (U) **CSO 3.3:** to state and prove first isomorphism theorem (K+A) **CSO 3.4:** to state and prove second isomorphism theorem (K+A) **CSO 3.5:** to state and prove third isomorphism theorem (K+A) **CSO 3.6:** to define field of quotients (K)	12	20	Not to be filled-in
UNIT 4 **Polynomial Rings**	Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion.	**CSO 4.1:** to define Polynomial rings (K) **CSO 4.2:** to discuss polynomial rings over commutative rings (U) **CSO 4.3:** to state and prove division algorithm theorem and discuss its consequences (K+A+U) **CSO 4.4:** to define Principal Ideal and Principal Ideal Domain (PID) (K) **CSO 4.5:** to discuss the properties of PID and determine whether the polynomial rings is a PID. (U+A) **CSO 4.6:** to define irreducible polynomial and reducible polynomial (K) **CSO 4.7:** to discuss reducibility tests, irreducibility tests, Eisenstein criterion and apply it. (U+A)	12	20	Not to be filled-in
UNIT 5 **Unique Factorization and Euclidean Domains**	Unique factorization in Z[x]. Divisibility in integral domains, irreducibles, primes, unique factorization domains, Euclidean domains.	**CSO 5.1:** to define irreducible element. (K) **CSO 5.2:** to define Prime element (K) **CSO 5.3:** to illustrate with examples to understand irreducible and prime element (U) **CSO 5.4:** to define Euclidean	12	20	Not to be filled-in

		Domain and Unique factorization Domain (K) **CSO 5.5:** to discuss Unique factorization in Z[x] **CSO 5.6:** to explain Divisibility in integral domains (U)			

Suggested Readings:

1. John B. Fraleigh, *A First Course in Abstract Algebra, 7th Ed*., Pearson, 2002.
2. M. Artin, *Abstract Algebra, 2nd Ed*., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra, 4th Ed*., Narosa Publishing House, 1999.
4. Stephen H. Friedberg, Arnold J. Insel & Lawrence E. Spence, *Linear Algebra, 4th Ed*., Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
5. S. Lang, *Introduction to Linear Algebra, 2nd Ed*., Springer, 2005.
6. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
7. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
8. Kenneth Hoffman & Ray Alden Kunze, *Linear Algebra, 2nd Ed.*, Prentice-Hall of India Pvt. Ltd., 1971.
9. S.H. Friedberg, A.L. Insel and L.E. Spence, *Linear Algebra*, Prentice Hall of India Pvt. Ltd., 2004.

NAME OF THE PAPER (CODE) : **OPERATION RESEARCH** (**MTC 6.3**)
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Operation Research:**

CO 1:	To make the students in understanding assignment problems and algorithm, optimum solutions and unbalanced assignment problems.
CO 2:	To make the students in understanding Game theory, maximin and minimax principle, domination property and graphical method. Problems based on all the above.
CO 3:	To make the students in understanding Queueing theory and its system and characteristics, its symbols and Notations, and problems-based solutions
CO 4:	To make the students in understanding multi-channel Queueing Models problems
CO 5:	To make the students in understanding inventory control and types of inventories and cost. EOQ and production problems with and without shortages and EOQ with price breaks.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Assignment Problems	Assignment Problems – Assignment algorithm – optimum solutions – Unbalanced Assignment Problems.	**CSO 1.1:** Find mini cost value from Assignment Problems (K) **CSO 1.2:** Discussed about balance and unbalanced problem. (U) **CSO 1.3:** application of algorithm. (A)	12	20	Not to be filled-in
UNIT 2 Game Theory	Game Theory – Two-person zero sum game – The Maximin – Minimax principle – problems - Solution of 2 x 2 rectangular Games – Domination Property – (2 x n) and (m x 2) graphical method – Problems.	**CSO 2.1:** Identify the importance of stocks the reasons for holding stock in an organization, determine the optimal order quantity for models. M. (K) **CSO 2.2:** Apply game theory concepts to articulate real-world situations by identifying, analyzing and practicing strategic decisions. (K) **CSO 2.3:** Solution of 2 x 2 rectangular Games (U) **CSO 2.4:** Domination Property – (2 x n) and (m x 2) graphical method – Problems. (A)	12	20	Not to be filled-in
UNIT 3 Queueing Theory	Queueing Theory – Introduction – Queueing system – Characteristics of Queueing system – Symbols and Notations	**CSO 3.1:** Classifications of queues Problems in (M/M/1) (∞/FIFO) (K) **CSO 3.2:** Introduction – Queueing system – (U) **CSO 3.3:** Expanding the varies	12	20	Not to be filled-in

	– Classifications of queues – Problems in (M/M/1) : (∞/FIFO)	model. (A)			
UNIT 4 **Multi-Channel Queueing Models**	Multi-Channel Queueing Models - Problems in (M/M/1):(N/FIFO); (M/M/C) : (∞/FIFO); (M/M/C) : (N/FIFO) Models.	**CSO 4.1: :** Apply and extend queueing models to analyze real world systems (K) **CSO 4.2:** Problems in (M/M/1):(N/FIFO); (M/M/C) : (∞/FIFO); (M/M/C) : (N/FIFO) Models. (U)	12	20	Not to be filled-in
UNIT 5 Inventory control	Inventory control – Types of inventories – Inventory costs – EOQ Problem with no shortages – Production problem with no shortages – EOQ with shortages – Production problem with shortages – EOQ with price breaks.	**CSO 5.1: :** Explain the various costs related to inventory system. (K) **CSO 5.2:** Production problem with shortages – EOQ with price breaks. (U) **CSO 5.3:** Production problem with no shortages (A)	12	22	Not to be filled-in

Suggested Readings:

1. Kanti Swarup, P. K. Gupta, *Operations Research*, Man Mohan S. Chand & Sons Education Publications, New Delhi, 12th Revised edition, 2003.
2. Prem Kumar Gupta, D. S. Hira, *Operations Research*, S. Chand & Company Ltd, Ram Nagar, New Delhi, 2014.
3. S. Dharani Venkata Krishnan, *Operations Research Principles and Problems*, Keerthi publishing house PVT Ltd., 1994.
4. Hamdy Taha, *Operations Research: An Introduction*, Pearson Education Inc.
5. Pradeep Prabhakar Pai, *Operations Research: Principles and Practice*, Oxford Higher Education, Oxford University press.
6. Ravindran Phillips and Solberg, *Operations Research: Principles and Practice*, Wiley India Edition.
7. P Mariappan, *Operations Research*, Pearson.
8. A M Natarajan, P Balasubramani, A Tamilarasi, *Operations Research*, Pearson Education Inc.
9. H N Wagner, *Operations Research*, Prentice hall.
10. Ronald Rardin, *Optimization in Operations Research*, Pearson Education Inc.
11. R. Paneerselvam, *Operations Research*, Prentice Hall of India Pvt. Ltd.
12. N D Vohra, *Quantitative Techniques in Management*, Tata McGraw-Hill.

NAME OF THE PAPER (CODE) : PROBABILITY AND STATISTICS (MTC 6.4)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Probability and Statistics:**

CO 1:	To help the students in understanding Sample space, probability axioms, real random variables, cumulative distribution function, probability mass function, mathematical expectation, moments and moment generating function, characteristic function and problem-based solutions.
CO 2:	To help the students in understanding discrete and continuous distributions and its properties, joint density functions, marginal and conditional distributions and problem-based solutions.
CO 3:	To help the students in understanding expectation of functions of two variables, conditional expectations, independent random variables, Bivariate normal distribution, correlation coefficient, joint moment generating function and calculation of covariance, linear regression for two variables and problem-based solutions.
CO 4:	To help the students in understanding Chebyshev's inequality, statement and interpretation of law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance and problem-based solutions.
CO 5:	To help the students in understanding Markov Chains, Chapman-Kolmogorov equations, classification of states.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Probability**	Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function.	**CSO 1.1:** Learn about probability density and moment generating functions. (K) **CSO1.2:** knowning moments, moment generating function, characteristic function. (U) **CSO 1.3:** Leaning Basic probability properties. (A)	12	20	Not to be filled-in
UNIT 2 Discrete Probability distributions	Discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential. Joint cumulative distribution function and its properties, joint	**CSO 2.1:** Know about various univariate distributions such as, Binomial, geometric and Poisson distributions. (K) **CSO 2.2:** Learn about distributions to study the joint behavior of two random variables. (K) **CSO 2.3:** Joint cumulative	13	22	Not to be filled-in

	probability density functions, marginal and conditional distributions.	distribution function and its properties, joint probability density functions, marginal and conditional distributions. (U)			
UNIT 3 Mathematical Expectation	Expectation of function of two random variables, conditional expectations, independent random variables. Bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.	**CSO 3.1:** Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression. (K) **CSO 3.2:** Expectation of function of two random variables, conditional expectations, independent random variables. (U)	13	22	Not to be filled-in
UNIT 4 Continuous Probability distributions	Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance.	**CSO 4.1:** Understand central limit theorem, which helps to understand the remarkable fact that: the empirical frequencies of so many natural populations, exhibit a bell-shaped curve, i.e., a normal distribution. (K) **CSO 4.2:** Spealing the definition law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance. (U)	12	20	Not to be filled-in
UNIT 5 Stochastic Probability	Markov Chains, Chapman-Kolmogorov equations, classification of states.	**CSO 5.1:** Find stochastic matrices values (K) **CSO 5.2:** Finding its classification of states (U) **CSO 5.3:**Scecking Markov Chains, Chapman-Kolmogorov equations. (A)	10	16	Not to be filled-in

Suggested Readings:

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

NAME OF THE PAPER (CODE) : **METRIC SPACE (MTC 7.1)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Metric Space**:

CO 1:	By introducing "Basic Notations on Metric Spaces", the students shall enable to identify whether a given function is a metric or not, open or not, closed or not in the given metric space.
CO 2:	To learn the concept of "Continuity" in metric space with the help of sequential criterion and also continuity in closed and open sets. Further, the idea of continuity is extended to discuss uniform continuity.
CO 3:	To understand "Connectedness" and connected subsets of ℝ, path connectedness, local connectedness, problem-based solutions and prove of Intermediate value theorem.
CO 4:	Understanding "Compactness" and their properties through continuous functions on compact spaces, characterisation of compact metric spaces, locally compact spaces and problem-based solutions.
CO 5:	To discuss "Complete Metric Space" by introducing Cauchy sequence, sequence and its convergence with examples, and also prove of Cantor's Intersection Theorem and Baire's Category Theorem.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Basic Notations on Metric Spaces	Definition and examples of metric spaces, Sequences in Metric Spaces, Open and closed balls, Neighbourhood, Open set, Interior of a set, Limit point of a set, Closed set, Subspaces, dense sets and Separable spaces.	**CSO 1.1:** Defining metric function and metric space (K) **CSO 1.2:** Discussing the examples of metric spaces using metric such as usual metric, discrete metric, Euclidean metric etc. (U) **CSO 1.3:** Defining open ball and closed ball (K) **CSO 1.4:** Defining neighbourhood of a point (K) **CSO 1.5:** Defining open sets (K) **CSO 1.6:** Proving theorems on open (U) **CSO 1.7:** Defining interior point, exterior point, frontier point (K) **CSO 1.8:** Describing the Properties of interior, exterior and frontier sets (K) **CSO 1.9:** Defining limit point, Derived set, Closed set, Closure of a set (K) **CSO 1.10:** Finding limit point,	12	20	Not to be filled-in

		Derived set and Closure of a set (A) **CSO 1.11:** Describing properties of closure of a set (K) **CSO 1.12:** Defining subspace, dense sets and separable space (K) **CSO 1.13:** Proving theorem on subspace of a metric space (U) **CSO 1.14:** Solving examples on everywhere dense, dense in itself and nowhere dense sets (A)			
UNIT 2 Continuity	Continuous mappings, sequential criterion and other characterization of continuity, Uniform continuity, Homeomorphism, Contraction mapping, Banach fixed point theorem.	**CSO 2.1:** Defining continuity of a function in metric space (K) **CSO 2.2:** Discussing sequential criterion for continuous function in metric space (U) **CSO 2.3:** Examining continuous functions using sequential criterion method (A) **CSO 2.4:** Describing theorems on open and closed sets of continuous functions (K) **CSO 2.5:** Elaborating equivalent definitions of continuity (U) **CSO 2.6:** Defining uniform continuity (K) **CSO 2.7:** Proving theorems on uniform continuity on a metric space (U) **CSO 2.8:** Defining homeomorphism and contraction mapping (K) **CSO 2.9:** Elaborating Banach fixed point theorem (U)	13	22	Not to be filled-in
UNIT 3 Connectedness	Connectedness, Connected subsets of R, Examples, Path connectedness, local connectedness, Intermediate value theorem.	**CSO 3.1:** Defining separated sets, connectedness and disconnectedness of metric space (X, d) (K) **CSO 3.2:** Examining connected and disconnected sets (A) **CSO 3.3:** Discussing theorems based on connectedness and disconnectedness (U) **CSO 3.4:** Describing continuous image in view of connectedness (K) **CSO 3.5:** To define local connectedness and path	11	18	Not to be filled-in

		connectedness (K) **CSO 3.6:** Applications of local connectedness and path connectedness (A) **CSO 3.7:** Proving Intermediate value theorem (U)			
UNIT 4 Compactness	Compact spaces and their properties, Continuous functions on compact spaces, Characterisation of compact metric spaces, Locally compact spaces.	**CSO 4.1:** Define open cover, open subcover, finite subcover and compactness (K) **CSO 4.2:** Illustration of sets which are compact (A) **CSO 4.3:** Describing theorems on compactness (K) **CSO 4.4:** Discussing continuous image in view of compactness (U) **CSO 4.5:** To define relatively compact, sequentially compact, totally bounded sets (K) **CSO 4.6:** Elaborating that a metric space is sequentially compact iff the space has Bolzano-Weierstrass property (U) **CSO 4.7:** Elaborating that every compact metric space is sequentially compact (U) **CSO 4.8:** Discussing that a metric space is sequentially compact iff the space is complete and totally bounded (U) **CSO 4.9:** Define locally compact (K)	12	20	Not to be filled-in
UNIT 5 Complete metric spaces	Sequences in metric space, Cauchy Sequences, Complete metric spaces, Examples, Cantor's Intersection Theorem, Baire Category Theorem	**CSO 5.1:** To define sequence in metric space (K) **CSO 5.2:** Discussing convergence of sequence in metric space (U) **CSO 5.3:** To define Cauchy's sequence (K) **CSO 5.4:** Discussing how Cauchy's sequence converges. (U) **CSO 5.5:** Determining convergent sequence in metric space (A) **CSO 5.6:** To define complete metric space (K) **CSO 5.7:** Constructing Cauchy's sequence on ℓ_∞ and ℓ_p space to show that the spaces are complete metric space under distance function 'd' (A) **CSO 5.8:** Discussing examples	12	20	Not to be filled-in

		on complete metric space (U) **CSO 5.9:** To define diameter of a set (K) **CSO 5.10:** Describing Cantor's intersection theorem by constructing a sequence (x_n) in closed set F_n in the metric space (X, d) and showing that (X, d) is a complete metric space (K) **CSO 5.11:** Proving Baire Category Theorem (U)			

Suggested Readings:

1. S. Kumaresan, *Topology of Metric Spaces, 2nd Ed.*, Narosa Publishing House, 2011
2. Satish Shirali and Harikishan L. Vasudeva, *Metric Spaces*, Springer Verlag, London, 2006.
3. R. R. Goldberg, *Methods of Real Analysis*, John Wiley & Sons, 1976.
4. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Tata McGraw-Hill, 2013.

NAME OF THE PAPER (CODE) : **CALCULUS OF VARIATIONS AND INTEGRAL EQUATIONS (MTC 7.2)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Calculus of Variations and Integral Equations**:

CO 1:	To learn solving "Volterra Integral Equations" of first and second kind by methods of successive substitution and successive approximation, by finding iterated kernels/resolvent
CO 2:	To learn "Fredholm integral equations" of first and second kind by methods of successive approximation and successive substitution, by finding iterated kernels/resolvent
CO 3:	To impart the concept "Introduction to Calculus of Variation" by discussing of functionals and variation functionals
CO 4:	To let the students aware of "Functionals and its examples" by discussing functionals in first and higher order derivatives
CO 5:	To provide a comprehensive understanding of "Variational problems" in moving boundary, Transversality condition and solving variation problems of ordinary and partial differential equation

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Volterra Integral Equations	Introduction on linear integral equations-Volterra, Initial value problems reduced to Volterra integral equation, Volterra integral equation of the first kind, Solution of Volterra integral equation of second kind by methods of successive substitution and successive approximation, Volterra integral equation with iterated kernels/Resolvent Kernels	**CSO 1.1:** To define integral equation and kernel of integral equation (K) **CSO 1.2:** To define Volterra integral equation of first and second kind (K) **CSO 1.3:** To solve problems on reducing the initial value problems to Volterra integral equation (U) **CSO 1.4:** To discuss the solutions of Volterra integral equation by successive substitution and successive approximation (U) **CSO 1.5** To discuss the solution of Volterra integral equation of first kind (U) **CSO 1.6:** To describe how Volterra integral equation of first kind can be transformed to Volterra integral equation of second kind (K) **CSO 1.7:** To discuss reducing an integral equation to Volterra integral equation of second kind	12	20	Not to be filled-in

		and solving by Laplace method (U) **CSO 1.8:** Applying method of Iterated/Resolvent Kernel to solve the Volterra integral equation (A)			
UNIT 2 Fredholm Integral Equations	Introduction on Fredholm Integral equations, Boundary Value Problems reduced to Fredholm integral equations, Solution of Fredholm integral equations of second kind by methods of successive approximation and successive substitution, Fredholm integral equation with Iterated Kernels/Resolvent kernels, Fredholm's first, second and third theorem, Integral equations with degenerate kernels, Integral equation with symmetric kernel	**CSO 2.1: To define** Fredholm Integral equations of first and second kind (K) **CSO 2.2:** Solving problems to reduce boundary value problems to Fredholm integral equations (A) **CSO 2.3:** To discuss the solution of Fredholm integral equations by methods of successive approximation and successive substitution (U) **CSO 2.4:** To define resolvent/Iterated kernel (K) **CSO 2.5:** Solving Fredholm integral equation by finding resolvent kernel (A) **CSO 2.6:** Discussing Fredholm's first, second and third theorem (U) **CSO 2.7:** To define degenerate kernel (K) **CSO 2.8:** To define symmetric kernel (K) **CSO 2.9:** Describing Fredholm integral equation with symmetric kernel (K) **CSO 2.10:** Solving Fredholm integral equation by finding degenerate kernel (A)	14	24	Not to be filled-in
UNIT 3 Introduction to Calculus of Variation	Variation of a functional and its properties, Variational problems with fixed boundaries, Euler's equation, Fundamental lemma of calculus of variation, Functional in the form of integrals, Problems of finding shortest distance and minimum surface of resolution, Brachistochrone problem.	**CSO 3.1:**. To define functional and variation of a functional (K) **CSO 3.2:**. To discuss Euler's equation (U) **CSO 3.3:** Finding extremals of the functionals using Euler's equation (A) **CSO 3.4:** To describe fundamental lemma of calculus of variations which invokes from Euler-Lagrange's equation (K) **CSO 3.5:** Discussing Brachistochrone problem to find shortest time (U) **CSO 3.6:** Solving problem to find shortest distance (A)	12	20	Not to be filled-in
UNIT 4 Functionals and its examples	Functionals depending on several unknown functions and their first order derivatives, Functional involving	**CSO 4.1:** To describe functionals involving first order and higher order derivatives (K) **CSO 4.2:** To discuss variation problems involving several	12	20	Not to be filled-in

	higher derivatives, Euler Poisson equation, Examples, Functionals dependent on several independent variables, Ostrogradaskey equation, Variational problems in parametric form, Isoperimetric problem, Geodesic problem.	unknown functions (U) **CSO 4.3:** To find the extremal of several unknown functions (A) **CSO 4.4:** To discuss parametric form of variation functionals (U) **CSO 4.5:** To solve isoperimetric problems (A) **CSO 4.6:** To discuss variation problems involving more independent (U) **CSO 4.7:** To discuss Euler Poisson equation (K) **CSO 4.8:** To elaborate Euler-Ostrogradsky equation (K)			
UNIT 5 Variational Problems	Variational problem with moving boundaries, Moving boundary problem with more than one dependent variables, Transversality condition, Examples, Variational method of solving ordinary differential equation and partial differential equation by Rayleigh Ritz method.	**CSO 5.1:** Discussing variational problem with both the end points moving on two vertical lines (U) **CSO 5.2:** Discussing variational problem with one end points fixed and other end point moving on a vertical line (U) **CSO 5.3:** Discussing variational problem with one end points fixed and other moving on a certain curve (U) **CSO 5.4:** To find the Transversality condition for functionals (A) **CSO 5.5:** To define Rayleigh Ritz method (K) **CSO 5.6:** To describe **v**ariational method of solving ordinary differential equation by Rayleigh Ritz method (K) **CSO 5.7:** Solving ordinary differential equation to obtain approximate solution by Rayleigh Ritz method (A) **CSO 5.8:** Solving Laplace equation, Poisson equation of partial differential equation by Rayleigh Ritz method (A)	10	16	Not to be filled-in

Suggested Readings:

1. R. P. Kanwal, *Linear Integral Equations*, Theory and Techniques, Birkhauser, 1924.
2. J. M. Gelfand and S. V. Fomin, *Calculus of Variations*, Prentice Hall, New Jersey, 1963.
3. L. Elsgolts, *Differential Equations and the Calculus of Variations*, MIR Publishers, 1970.
4. A. S. Gupta, *Calculus of Variations with Applications*, PHI Learning, 2015.

NAME OF THE PAPER (CODE) : **RESEARCH METHODOLOGY (RM)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

Use of Calculator is allowed.

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Research Methodology**:

CO 1:	Understanding "Introduction to research methodology" by learning the objectives of research, types, approaches, significance, methods, process, Criteria of good research, Research problem and techniques
CO 2:	Understanding the need for "Research Design" through sampling design, features, basic principle, criteria, characteristics and types of design.
CO 3:	Understanding about "Data collection" by collection through different methods, and processing of data.
CO 4:	Understanding the "Statistics in Research" by learning measures of central data like mean median, mode, measures of dispersion like range, Quartile deviation, Mean deviation, Standard deviation, Karl Pearson's coefficient of correlation, Regression analysis, Association in case of attributes.
CO 5:	Understanding "Testing of Hypothesis" through basic concepts and procedure of testing of hypothesis

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Introduction to research methodology	Objectives of research, Types of research, Research approaches, Significance of research, Research and scientific methods, Research process, Criteria of good research, Research problem: Selecting the research problem, Necessity of defining the research problem, Techniques involved in defining a problem.	**CSO 1.1:** To introduce objectives of research and types of research (K) **CSO 1.2:** Discussing research approach and the significance of research (U) **CSO 1.3:** To discuss on methods of research (U) **CSO 1.4:** Describing scientific methods (K) **CSO 1.5:** Discussing the steps of research or research process (U) **CSO 1.6:** Discussing the criteria of good research (U) **CSO 1.7:** To define research problem (K) **CSO 1.8:** Examining the importance of defining a research problem (A) **CSO 1.9:** Identifying the research problem (K) **CSO 1.10:** Examining the techniques involved in defining	12	20	Not to be filled-in

		a research problem (A)			
UNIT 2 Research Design	Need for research design, Features of good design, Different research designs, Basic principle of experimental designs, Sampling Design: Criteria of selecting a sampling procedure, Characteristics of a good sample design, Different types of, sample design, How to select a random sample?	**CSO 2.1:** To describe the need for research design (K) **CSO 2.2:** Introducing different research designs (K) **CSO 2.3:** Discussing the basic principle of experimental designs (U) **CSO 2.4:** To define sample design (K) **CSO 2.5:** To examine the criteria of selecting a sampling procedure (A) **CSO 2.6:** Characteristics of a good sample design (K) **CSO 2.7:** Discussing different types of sample designs (U) **CSO 2.8:** Identifying how to select a random sample? (K)	12	20	Not to be filled-in
UNIT 3 Data Collection	Collection of primary data, Observation method, Interview method, Collection of data through questionnaires, Collection of data through schedules, Difference between questionnaires and schedules, Collection of secondary data, Other methods, of data collection: Depth interviews, content analysis, pantry audits, consumer panels. Processing of data: Editing, Coding, Classification, Tabulation.	**CSO 3.1:**. To define the concept of data collection (K) **CSO 3.2:**. Classifying the types of data collection into primary and secondary data (U) **CSO 3.3:**. Describing the methods of primary data collection such as Observation method, Interview method, questionnaires, schedules (K) **CSO 3.4** To differentiate questionnaires and schedules (U) **CSO 3.5:** Describing about secondary data collection (K) **CSO 3.6:** Determining other methods of data collection such as Depth interviews, content analysis, pantry audits, consumer panels (A) **CSO 3.7:** To define data processing (K) **CSO 3.8:** Explaining the steps of Processing of data such as editing, coding, classification, tabulation (U)	11	18	Not to be filled-in
UNIT 4 Statistics in Research	Measures of central tendency: Mean, Median, Mode. Measures of dispersion: Range, Quartile deviation, Mean, deviation, Standard deviation, Karl Pearson's coefficient of correlation,	**CSO 4.1:** To define mean, mode, median (K) **CSO 4.2:** Determining mean, mode, median (A) **CSO 4.3:** To elaborate range, quartile deviation, mean deviation, standard deviation (U) **CSO 4.4:** To determine range, quartile deviation, mean deviation, standard deviation	11	18	Not to be filled-in

	Regression analysis, Association in case of attributes.	(A) **CSO 4.5:** To define Karl Pearson's coefficient of correlation (K) **CSO 4.6:** Finding Karl Pearson's coefficient of correlation (A) **CSO 4.7:** Discussing regression analysis (U) **CSO 4.8:** Discussing association of attributes (U)			
UNIT 5 Testing of Hypothesis	What is a hypothesis? Characteristics of a hypothesis, Basic concepts concerning testing of hypothesis: Null, and Alternate hypothesis, Type I and II error, level of significance, Level of confidence, Decision rule, Two tailed and One tailed test, Hypothesis testing for means, Hypothesis testing for difference between means, Hypothesis testing of proportions, Hypothesis testing, for difference between proportions, Hypothesis testing about a variance or standard deviation, Hypothesis testing for difference, between two variances or standard deviations	**CSO 5.1:** Defining the term hypothesis (K) **CSO 5.2:** Characteristics of a hypothesis (U) **CSO 5.3:** Identifying null and alternate hypothesis (K) **CSO 5.4:** Identifying type I and II error (K) **CSO 5.5:** To define level of significance, level of confidence, decision rule, two tailed and one tailed test (K) **CSO 5.6:** Elaborating the steps of testing of hypothesis (U) **CSO 5.7:** To calculate testing of Hypothesis for means and difference between means (A) **CSO 5.8:** To calculate testing of Hypothesis for proportions and difference between proportions (A) **CSO 5.9:** To calculate testing of hypothesis about a variance or standard deviation and difference between two standard deviation (A)	14	24	Not to be filled-in

Suggested Readings:

1. C. R. Kothari, *Research Methodology: Methods and Techniques*, New Age International, 2004.
2. R. Kumar, *Research Methodology*, SAGE Publication Ltd., New Delhi, 4th Ed., 2014.
3. John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, SAGE Publications, 2018.

NAME OF THE PAPER (CODE) **: TOPOLOGY (MTC 8.1)**
Number of Credit **: 04**
Number of Hours of Lecture **: 60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Topology**:

CO 1:	To learn the definition of "Topological spaces" and its concepts with examples.
CO 2:	Understanding "Countability and Separation Axioms", such as separable spaces and separability, Lindeloff space, T_0 , T_1, T_2, T_3, T_4 spaces, regular spaces, normal space with some basic results.
CO 3:	To acquire the idea of "Compactness" by introducing sequentially, locally compact spaces, one point compactification, finite product of compact spaces with examples and some basic results.
CO 4:	To understand "Connectedness" with examples and some basic results, and also what is local path connectedness and Hausdorff spaces.
CO 5:	To understand the "Product topological space and Metrization theorem" by introducing projection mapping, Tychonoff spaces, metrizability, Urysohn's lemma, and Tietze's extension theorem.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Topological Spaces	Definition and examples of Topological spaces, Intersection and Union of topologies, Closed sets, Neighbourhood, Base, Limit point, Adherent points, Derived sets, closure, Interior, Exterior and Frontier of a set, Relation between Closure, Interior and frontier sets, subspace topology, product topology, quotient topology and quotient space.	**CSO 1.1:** Defining topological space (K) **CSO 1.2:** Discussing examples on topological space (U) **CSO 1.3:** Discussing properties on Intersection and Union of topologies (U) **CSO 1.4:** Defining neighbourhood and open sets (K) **CSO 1.5:** Determining neighbourhood of a point (A) **CSO 1.6:** Defining base, limit point, Adherent points, Derived sets, closure and closed sets (K) **CSO 1.7:** Finding base, limit point, Adherent points, Derived sets, closure of a set (A) **CSO 1.8:** Describing the intersection and union of closed sets and open sets (K) **CSO 1.9:** Defining Interior, Exterior and Frontier of a set (K) **CSO 1.10:** Discussing the properties of Interior and	12	20	Not to be filled-in

		Exterior of a set (U) **CSO 1.11:** Discussing the Relation between Closure, Interior and frontier sets (U) **CSO 1.12:** Defining subspace topology, relative topology, product topology, quotient topology (K) **CSO 1.13:** Finding base for the product topology and solving examples on subspace topology, relative topology (A) **CSO 1.14:** Defining quotient space (K) **CSO 1.15:** Proving the equivalence theorem of quotient space with closed mapping and open mapping (U)			
UNIT 2 Countability and Separation Axioms	First countable spaces, Second countable spaces, Separable spaces and Separability, Lindeloff space, T_0 , T_1, T_2, T_3, T_4 spaces, Regular spaces, Normal space.	**CSO 2.1:** Defining First countable spaces, Second countable spaces, and Separable spaces with examples (K) **CSO 2.2:** Discussing first countability on discrete and metric space, subspace of first countable space is also countable, co-countable topology is not first countable (U) **CSO 2.3:** Describing that every second countable space is first countable space, second countable space is hereditary, open continuous image of second countable space is second countable (K) **CSO 2.4:** Discussing some theorems on separable spaces such as every second countable space is separable , countable space is hereditarily separable, metric space is separable iff the space is second countable. (U) **CSO 2.5:** Defining Lindelof space (K) **CSO 2.6:** Deriving that every second countable space is a Lindeloff space, metric space is Lindeloff iff the space is second countable (A) **CSO 2.7:** Constructing example that Lindeloff space is not a hereditary property (A) **CSO 2.8:** Defining T_0 , T_1, T_2, T_3, T_4 spaces (K)	13	22	Not to be filled-in

		CSO 2.9: Discussing examples and theorem on T_0 , T_1, T_2, T_3, T_4 spaces (U)			
UNIT 3 Compactness	Compact spaces, compact and sequentially compact spaces, locally compact spaces, One point compactification, finite product of compact spaces	**CSO 3.1:** to define open cover, finite subcover and compact set (K) **CSO 3.2:** Describing theorem such as compact subset of a Hausdorff space is closed, theorem on compact subspace, closed subsets of compact sets are compact (K) **CSO 3.3:** Constructing examples of closed space which is not Hausdorff (A) **CSO 3.4:** Proving finite intersection property of a compact topological space (U) **CSO 3.5:** Discussing compactness in $\mathbb{R}$ (U) **CSO 3.6:** To define sequential compact (K) **CSO 3.7:** Elaborating on theorems such as continuous image of a sequentially compact set is compact, compactness is a topological invariant (U) **CSO 3.8:** To define locally compact (K) **CSO 3.9:** Proving that every compact topological space is locally compact, every closed subspace of a locally compact space is locally compact (U) **CSO 3.10:** To define compact topological space (K) **CSO 3.11:** Elaborating that the space (X^*, τ^*) is a compactification of the space (X, τ) (U) **CSO 3.12:** To define one point compactification or Alexandroff compactification (K) **CSO 3.13:** To discuss that the space (X^*, τ^*) has properties that satisfies one point compactification (U)	11	18	Not to be filled-in
UNIT 4 Connectedness	Connected spaces, generation of connected sets, components, path connected spaces, local connectedness,	**CSO 4.1:** To define separated sets, connected sets, disconnected sets (K) **CSO 4.2:** Classifying connected and disconnected sets (A)	11	18	Not to be filled-in

	local path connectedness, Hausdorff spaces.	**CSO 4.3:** Discussing theorems on connected and disconnected sets(U) **CSO 4.4:** Describing on continuity and connectedness (K) **CSO 4.5:** To define components, local connectedness, path connectedness, local path connectedness (K) **CSO 4.6:** Constructing examples on space which is connected but not locally connected and locally connected but not connected (A) **CSO 4.7:** Discussing theorems on components and locally connectedness (U)			
UNIT 5 Product topological space and Metrization theorem	Product topological space, Projections mappings, Tychonoff theorem (Finite product only), Tychonoff spaces, Urysohn's Lemma, Metrizability, Metrizability theorem, Tietze's extension theorem	**CSO 5.1:** To define product topology and product topological space (K) **CSO 5.2:** Determining base and sub base for product topology (A) **CSO 5.3:** Discussing theorem on product topology (U) **CSO 5.4:** To define projection mapping (K) **CSO 5.5:** Describing that projection mapping is continuous (K) **CSO 5.6:** To define Tychonoff topology (K) **CSO 5.7:** Describing Urysohn's Lemma (K) **CSO 5.8:** To define metrizable (K) **CSO 5.9:** Discussing Urysohn's Metrizability theorem (U) **CSO 5.10:** Constructing metrizability of spaces such as $(\mathbb{R}, U)$, $[0,1]$ etc. (A) **CSO 5.11:** Proving Tietze's extension theorem (U)	13	22	Not to be filled-in

Suggested Readings:

1. J. R. Munkres, *Topology: A First Course*, Prentice Hall of India Ltd., New Delhi, 2000.
2. M. A. Armstrong, *Basic Topology*, Springer International Ed., 2005.
3. J. L. Kelley, *General Topology*, Springer Verlag, Newyork, 1990.
4. J. N. Sharma and J. P. Chauhan, *Topology*, Krishna Prakashan Media (P) Ltd., 48^{th} Ed. Meerut, 2018.

2 Major Theory Papers in lieu of Research Project/Dissertation
(For Honors Students not undertaking Research Projects)

NAME OF THE PAPER (CODE) : LINEAR PROGRAMMING AND THEORY OF GAMES (MTC 8.2)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Linear Programming and Theory of Games:**

CO 1:	To help the students to understand simplex algorithm, M method algorithm and solving the problems.
CO 2:	To help the students to understand Relation of dual and primal problems using corresponding algorithms.
CO 3:	To help the students to understand types of Transportation problems (T.p) and algorithms.
CO 4:	To help the students to understand Hungarian methods for solving assignment problem and algorithms.
CO 5:	To help the students to understand type of game theory for example two person sum of game with pure and mixed strategies, Graphical solution , linear programming etc..

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Linear Programming**	Introduction to linear programming problem, Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.	**CSO 1.1:** Find simplex table (K) **CSO 1.2:** Find BIG-M table (K) **CSO 1.3:** Find two face method tabulate.(K) **CSO 1.4:** study for algorithm simplex. (A)	13	22	Not to be filled-in
UNIT 2 **Linear Programming**	Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.	**CSO 2.1:** Tabulate duality simplex (K) **CSO 2.2:** studying relation between dual to primal relation (U) **CSO 2.3:** clarity of economic interpretation of the dual. (U)	11	18	Not to be filled-in
UNIT 3 **Transportation problem**	Transportation problem and its mathematical formulation, northwest-corner method least cost method and Vogel approximation method for determination of starting basic solution.	**CSO 3.1:**Find mini cost from TP (K) **CSO 3.2:** check mathematical formulation (U) **CSO 3.3:** study NWC,LCM, VAM for determination of starting	12	20	Not to be filled-in

		basic solution. (U)			
UNIT 4 **Assignment problem**	Algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.	**CSO 4.1:** Study about TP Algorithm. (A) **CSO 4.2:** Solve assignment problem using by TP (U) **CSO 4.3:** Hungarian method for solving assignment problem. (K)	12	20	Not to be filled-in
UNIT 5 **Game theory**	Game theory: formulation of two-person zero sum games, solving two-person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.	**CSO 5.1**: How to apply two person zero sum game. (K) **CSO 5.2:** Tablate mixed strategies players. (U) **CSO 5.3:** Draw graphical solution**.** (A) **CSO 5.4:** Finding linear programming solution of games. (U)	12	20	Not to be filled-in

Suggested Readings:

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows*, 2nd Ed., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, *Introduction to Operations Research*, 9th Ed., Tata McGraw Hill, Singapore, 2009.
3. Hamdy A. Taha, *Operations Research, An Introduction*, 8th Ed., Prentice-Hall India, 2006.
4. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.

NAME OF THE PAPER (CODE) : **MECHANICS (MTC 8.3)**
Number of Credit : **04**
Number of Hours of Lecture : **60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Mechanics**:

CO 1:	To aid the students in understanding the concepts of Structural Mechanics.
CO 2:	To assist the students in understanding laws and different types of Frictional forces.
CO 3:	To create an understanding of the concepts in Geometry and Structural Analysis.
CO 4:	To inculcate the students in understanding Energy Conservation and Dynamics.
CO 5:	To make the students familiar with particle Dynamics and reference frames.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Structural Mechanics	Moment of a force about a point and an axis, couple and couple moment, Moment of a couple about a line, resultant of a force system, distributed force system, free body diagram, free body involving interior sections, general equations of equilibrium, two-point equivalent loading, problems arising from structures, static indeterminacy.	**CSO 1.1:** to define the term moment of a force about a point with examples and some problem solutions. (K/U/A) **CSO 1.2:** to define moment of a force about an axis with examples and solve some problems based on it. (K/U/A) **CSO 1.3:** to define the term couple and couple moment with examples. (K/U) **CSO 1.4:** to define moment of a couple about a line with examples and solve some problems based on it. (K/U/A) **CSO 1.5:** to define resultant of a force system with some examples. (K/U) **CSO 1.6:** to define and explain distributed force system with examples and tackle some problems based on it. (K/U/A) **CSO 1.7:** to explain and define free body diagram with examples. (K/U) **CSO 1.8:** to tackle some problems based on free body diagram involving interior sections. (U/A) **CSO 1.9:** to write down and explain the general equations of equilibrium. (K/A)	13	22	Not to be filled-in

		CSO 1.10: to solve some problems based on two-point equivalent loadings. (U/A) **CSO 1.11:** to solve some problems arising from structure and static indeterminacy. (U/A)			
UNIT 2 **Frictional Forces**	Laws of Coulomb friction, application to simple and complex surface contact friction problems, transmission of power through belts, screw jack, wedge, first moment of an area and the centroid, other centers.	**CSO 2.1:** to define and explain Law of Coulomb friction with prove. (K/U) **CSO 2.2:** to apply coulomb friction to solve simple and complex surface contact friction problems. (A/U) **CSO 2.3:** to define and explain the transmission of powers through belts, scew jack, wedge and tackle some problems based on all of it. (K/A/U) **CSO 2.4:** to define first moment. (K) **CSO 2.5:** to solve some problems to find the first moment of an area, the centroid and other centers. (A)	11	18	Not to be filled-in
UNIT 3 **Concepts in Geometry and Structural Analysis**	Theorem of Pappus-Guldinus, second moments and the product of area of a plane area, transfer theorems, relation between second moments and products of area, polar moment of area, principal axes.	**CSO 3.1:** to state and prove Theorem of Pappus-Guldinus (K/U) **CSO 3.2:** to define the term second moment. (K) **CSO 3.3:** to explain the product of area of a plane area and tackle some problems based on it. (U/A) **CSO 3.4:** to state and prove transfer theorems. (K/A) **CSO 3.5:** to explain the relation between second moment and product of area. (K/U) **CSO 3.6:** to define polar moment of area and workout problems based on it. (K/A) **CSO 3.8:** to explain principal axes and workout problems based on it. (U/A)	12	20	Not to be filled-in
UNIT 4 **Energy Conservation and Dynamics**	Conservative force field, conservation for mechanical energy, work energy equation, kinetic energy and work kinetic energy expression based on center of mass,	**CSO 4.1:** to define Conservative force field with examples. (K/U) **CSO 4.2:** to define conservation for mechanical energy with examples. (K/U) **CSO 4.3:** to explain work energy equation and workout problems. (U/A)	12	20	Not to be filled-in

	moment of momentum equation for a single particle and a system of particles, translation and rotation of rigid bodies.	**CSO 4.4:** to define kinetic energy. (K) **CSO 4.5:** to define work kinetic energy expression based on center of mass and workout problems based on it. (K/U/A) **CSO 4.6:** to define moment of momentum equation for a single particle and a system of particles and solve some problems based on it. (K/A/U) **CSO 4.7:** to define and explain translation and rotation of rigid bodies with examples. (K/U)			
UNIT 5 **Particle Dynamics And Reference Frames**	Chasles' theorem, general relationship between time derivatives of a vector for different references, relationship between velocities of a particle for different references, acceleration of particle for different references.	**CSO 5.1:** to state and prove Chasles' theorem. (K/U) **CSO 5.2:** to explain the general relationship between time derivatives of a vector for different references with prove and examples. (U) **CSO 5.3:** to explain the relationship between velocities of a particle for different references with prove and examples. (U) **CSO 5.4:** to explain the acceleration of particle for different references with prove and example. (U)	12	20	Not to be filled-in

Suggested Readings:

1. I.H. Shames and G. Krishna Mohan Rao, *Engineering Mechanics: Statics and Dynamics*, (4th Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.

2. R.C. Hibbeler and Ashok Gupta, *Engineering Mechanics: Statics and Dynamics*, 11th Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi.

MINOR PAPERS

NAME OF THE PAPER (CODE) : CALCULUS (MTM 1)
Number of Credit : 03
Number of Hours of Lecture : 45

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Calculus**:

CO 1:	To aid the students in understanding the foundations of calculus.
CO 2:	To assist the students in the understanding of derivatives of hyperbolic and trigonometric functions.
CO 3:	To create an understanding of Analytical geometry.
CO 4:	To inculcate the students in understanding Analytical techniques.
CO 5:	To make the students aware of the applications of double and triple integration.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Foundations of Calculus	Definition of the limit of a function ($\varepsilon-\delta$) form. Continuity- Types of discontinuities, Properties of continuous functions on a closed interval. Differentiability, Differentiability implies continuity- converse not true. Rolle's Theorem. Evaluation of limits by L'Hospital's rule.	**CSO 1.1:** to define the term limit of a function (K) **CSO 1.2:** to solve some functions to check its limit with the help of the definition. (U) **CSO 1.3:** to define the term continuity of a function. (K) **CSO 1.4:** to solve some functions to check its continuity with the help of the definition. (U) **CSO 1.5:** to write and discuss the types of discontinuity. (K/U) **CSO 1.6:** to write and discuss the properties of continuous functions on a closed interval. (K/U) **CSO 1.7:** to define and discuss differentiability and solve some problems based on the definition. (K/U/A) **CSO 1.8:** to state and prove Differentiability implies continuity- converse not true. (K/U) **CSO 1.9:** to state Rolle's Theorem and apply it to solve some problems. (K/A) **CSO 1.10:** to explain L'Hospital's rule and apply it to solve some problems. (U/A)	9	20	Not to be fille d-in
UNIT 2 Differentiation	Hyperbolic functions. Identities and its derivatives. Inverse hyperbolic functions.	**CSO 2.1:** to define hyperbolic functions and some properties. (K) **CSO 2.2:** to find the derivatives of the hyperbolic functions and inverse hyperbolic functions. (A/U)	9	20	Not to be fille d-in

	Derivatives, Higher order derivatives. Leibnitz's theorem and its applications. Differentiation of homogenous functions. Total derivative, Differentiation of implicit and composite functions.	**CSO 2.3:** to define higher order derivatives and solve some problems. (K/A) **CSO 2.4:** to explain Leibniz rule and its applications to problems. (U/A) **CSO 2.5:** to apply Leibnitz rule to solve some problem types. (A) **CSO 2.6:** to explain Differentiation of homogenous functions and solve some questions based on it. (U/A) **CSO 2.7:** to define implicit and composite function. (K) **CSO 2.8:** to differentiate implicit and composite functions.			
UNIT 3 Analytical Geometry	Sub tangent and sub normal. Polar coordinate angles between the tangents. Slope of the tangent. Length of arc. Evolutes. Asymptotes. Methods of finding asymptotes of Algebraic curves.	**CSO 3.1:** to define sub tangent and sub normal (K) **CSO 3.2:** to solve some problems to find sub tangent and sub normal. (A) **CSO 3.3:** to explain Polar coordinate angles between the tangents and how to find the angle. (U) **CSO 3.4:** to define slope of the tangent and find the slope of the tangent by solving some problems. (K/A) **CSO 3.5:** to define length of arc and find the length of arc by solving some problems. (K/A) **CSO 3.6:** to define evolutes and asymptotes. (K) **CSO 3.8:** to apply the methods of finding asymptotes of algebraic curves on some problems. (U/A)	9	20	Not to be fille d-in
UNIT 4 Analytical Techniques	Volumes and surfaces of revolution. Reduction formula. Beta and Gama functions. Properties and problems.	**CSO 4.1:** to explain volumes and surface of revolution. (U) **CSO 4.2:** to solve problems to find the volume and surface of revolution. (A) **CSO 4.3:** to explain reduction formulae and solve some problems using the formulae. (U/A) **CSO 4.4:** to define beta and gamma function. (A) **CSO 4.5:** to write down the properties of beta and gamma function and explain them. (U) **CSO 4.6:** to solve problems based on beta and gama functions. (A) **CSO 4.7:** to explain volume by parametric equations. (U) **CSO 4.8:** to solve problems to find	9	20	Not to be fille d-in
UNIT 5 Double	Double integrals. Change of order of integration. Triple integrals. Applications to area.	**CSO 5.1:** to explain double integrals and solve some problems based on it. (U/A) **CSO 5.2:** to explain change of order of integration and solve some	9	20	Not to be fille d-in

Triple Integrati	Surface Area and Volume.	problems based on it. (U/A) **CSO 5.3:** to explain triple integration and solve some problems based on it. (U) **CSO 5.4:** to explain the applications of double and triple integration to find area and volume respectively. (U) **CSO 5.5:** to apply double and triple integration to find surface area and volume to solve some problems. (U)			

NAME OF THE PAPER (CODE) **: CALCULUS (MTM 1) (Practical)**
Number of Credit **: 01**
Number of Hours of Lecture **: 30**

List of Practical's (using any software)

1. Practical based on tracing curves (trigonometric functions, inverse function, exponential function, logarithmic function and hyperbolic function)
    a. Draw the graph of sinx,cosx,tanx,cotx,secx,cosecx.
    b. Draw the graph of $\sin^{-1}x, \cos^{-1}x, \tan^{-1}x, \cot^{-1}x, sex^{-1}x, \cos ec^{-1}x$.
    c. Draw the graph of sinhx, coshx, tanhx, cothx.
    d. Draw the graph of $\log_a x, a_x$.
    e. Draw the graph of cardioids and asteroid.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Practical based on integral and reduction formula, summation of the series, surface and volume.
4. Practical based on successive differentiation.
    a. Find the nth derivative of the given function at a given point.
    b. Application of Leibnitz's theorem.
5. Evaluation of limits by L'Hospital's rule.
6. Application of reduction formula for integration.
7. Application of series using integration.
8. Application of volume revolution.

Suggested Readings:

1. K.C.Maity, R.Ghosh, *Differential Calculus (7th Edition)*, New Central Book Agency, 2004.
2. K.C.Maity, R.Ghosh, *Integral Calculus (7th Edition)*, New Central Book Agency, 2004.
3. Tom. M. Apostol, *Calculus –Volume I and II.*

NAME OF THE PAPER (CODE) : **DIFFERENTIAL EQUATIONS (MTM 2)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Differential equation**:

CO 1:	To introduce and understand the concept of Differential Equations.
CO 2:	To learn the different methods to solve first order ODEs, and how to reduce to exact equations and linear equations.
CO 3:	To introduce second order ODEs and using Abel's formula to find other linear independent solutions.
CO 4:	To learn the different methods to solve different types of second order ODEs.
CO 5:	To understand mathematical modelling and apply these techniques to solve and analyze various mathematical models.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 **Introduction to Differential Equations**	Differential Equation, Solutions of first order ODEs, Homogeneous Equations, Total differential, Exact Equations.	**CSO 1.1:** Understanding the concept of Differential Equation (DE). (U) **CSO 1.2:** Define Differential Equation and classify different types of Differential Equations (K) **CSO 1.3:** Discuss various types of solutions (K) **CSO 1.4:** Define Homogeneous functions and Homogeneous equations (K) **CSO 1.5:** Solve the homogeneous equations using method of separation of variables. (A) **CSO 1.6:** Define Total Differential and Exact equations (K) **CSO 1.7:** Criteria to check exactness and Solve Exact equations (A)	8	18	Not to be filled-in
UNIT 2	Solution methods for first order ODEs,	**CSO 2.1:** Solve by the method of exact differential equations.	8	18	Not to be

Approaches to First order ODEs and special equations	Reducible to Exact Equations, Integrating factors, Linear first order ODE, Reducible to linear equations, Bernoulli's Equation.	(A) **CSO 2.2:** Define Integrating Factor (K) **CSO 2.3:** How to apply integrating factor to Non-exact equations and solve. (U+A) **CSO 2.4:** Define Linear DE of first order (K) **CSO 2.5:** Solve the linear differential equation (A) **CSO 2.6:** Reducing the DE to linear DE and solve (K+A) **CSO 2.7:** Define Bernoulli's DE (K) **CSO 2.8:** Solve by the method of Bernoulli's equation (A)			filled-in
UNIT 3 **Introduction to Second Order ODE**	Introduction to Second order ODEs, Properties of solutions of second order homogeneous ODEs, Abel's formula to find the other linear independent solution, Abel's Formula-Demonstration with examples.	**CSO 3.1:** Understanding higher order linear DE (U) **CSO 3.2:** to discuss properties of solutions for second order homogeneous ODEs (K) **CSO 3.3:** to define Linear dependence and independence, understand with examples (K+U) **CSO 3.4:** Define Wronskian and it"s properties (K) **CSO 3.5:** Discuss the criterion for the linearly independent solutions (U) **CSO 3.5:** to explain Abel's formula to find other linear independent solution. (U+A) **CSO 3.6:** to demonstrate Abel's Formula with examples. (A)	9	20	Not to be filled-in
UNIT 4 **Types of second order ODE and Non-homogeneous ODEs**	Second order ODE's with constant coefficients, Euler-Cauchy equation, Non-homogeneous ODEs-Variation of parameters, Method of undetermined coefficients, Demonstration of Method of undetermined coefficients.	**CSO 4.1:** Discuss various cases for second order linear DE with constant coefficients. (K+U) **CSO 4.2:** Define Particular Integrals and methods to find a particular integrals for some cases (K+U) **CSO 4.3:** Define Cauchy-Euler equation (K) **CSO 4.4:** Solve by the method of Euler's Cauchy equation **CSO 4.5:** to apply and demonstrate Variation of	10	22	Not to be filled-in

		parameters, Method of undetermined coefficients to non-homogeneous ODEs (A)			
UNIT 5 **Mathematical modelling**	Mathematical modelling: Compartmental model-exponential growth and decay model, limited growth of population and limited growth with harvesting, equilibrium points, interpretation of the phase plane, predatory prey model and its analysis, epidemic model of influenza and its analysis.	**CSO 5.1:** Define compartment model (K) **CSO 5.2:** Define balance law (K) **CSO 5.3:** Concept of exponential growth and decay model. (U) **CSO 5.4:** Make model assumptions (K) **CSO 5.5:** Formulate differential equation of exponential growth decay model and solve. (A) **CSO 5.6:** Solve for limited growth of population and limited growth with harvesting (A) **CSO 5.7:** Define equilibrium points. (K) **CSO 5.8:** Find the equilibrium points of the given system of equation. (U) **CSO 5.9:** Define interpretation of phase plane. (K) **CSO 5.10:** Obtain and sketch the phase plane curves and draw the direction vector for trajectories. (U) **CSO 5.11:** Make Model assumptions, departmental diagram and word equations for predatory prey model, epidemic model. (K) **CSO 5.12:** Formulate differential equation for predatory prey model and epidemic model, solve and discuss its analysis. (U+A)	10	22	Not to be filled-in

NAME OF THE PAPER (CODE) : DIFFERENTIAL EQUATIONS (MTM 2) (Practical)
Number of Credit : 01
Number of Hours of Lecture : 30

List of Practicals (using any software):

1. Plotting of second order solution family of differential equation.
2. Plotting of third order solution family of differential equation.
3. Growth model (exponential case only).
4. Decay model(exponential case only).
5. Limited growth of population (with and without harvesting).
6. Predatory prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
7. Epidemic model of influenza (basic epidemic model,contagious for life disease with carriers).
8. Battle model (basic battle model,jungle warfare,long range weapons).

Suggested Readings:

1. Shepley L. Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, 1984.
2. Belinda Barnes and Glenn R. Fulford, *Mathematical Modelling with Case Studies, A Differential Equations Approach using Maple and Matlab, 2nd Ed.*, Taylor and Francis group, 2009.
3. Martha Labell, James P Braselton, *Differential Equations with Mathematica, 3rd Ed.*, Elsevier Academic Press, 2004.
4. C.H. Edwards and D.E. Penney, *Differential Equations and Boundary Value Problems: Computing and Modeling*, Pearson Education, 2005.
5. George F. Simmons, *Differential equation with applications and historical notes*, McGraw Hill, 1991.

NAME OF THE PAPER (CODE) : **PDE AND SYSTEMS OF ODE (MTM 3)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

COURSE OBJECTIVES (COs)
The following are the Course Objectives (COs) for the paper **PDE and Systems of ODE**:

CO 1:	To introduce the basic concepts of partial differential equations. To Construct, interpret geometrically, form and classify the first order PDE. To obtain the general solution of PDE.
CO 2:	To provide a comprehensive understanding of method of separation of variables for first order linear PDEs and the derivation, classification and, solution of second order PDEs.
CO 3:	To particularly focus more on the application of PDEs in solving Cauchy and boundary value problems related to wave propagation.
CO 4:	To equip students with the necessary skills and knowledge to tackle PDEs with non-homogeneous boundary conditions, focusing on practical applications in wave propagation and heat conduction
CO 5:	To provide a comprehensive understanding of systems of linear differential equations, and their solution methods, with a focus on practical applications and numerical techniques.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Introduction to Partial Differential Equations	Partial Differential Equations – Basic concepts and Definitions, Mathematical Problems. First-Order Equations: Classification, Construction and Geometrical Interpretation. Method of Characteristics for obtaining General Solution of Quasi Linear Equations. Canonical Forms of First-order Linear Equations.	**CSO 1.1:** to define PDE (K) **CSO 1.2:** to discuss basic concepts of partial differential equations. (U) **CSO 1.3:** to classify, Construct and give geometrical interpretation of first order PDE (U) **CSO 1.4:** to form PDE by eliminating constants (U) **CSO 1.5:** to find the general solution of first order linear PDE. (A) **CSO 1.6:** to explain the method of canonical form of first order linear equations (U) **CSO 1.7:** to Reduce the linear PDE to canonical form and obtain the general solution. (A)	9	20	Not to be filled-in
UNIT 2 Method of Separation of Variables and Classification of second	Method of Separation of Variables for solving first order partial differential equations. Derivation of Heat equation,	**CSO 2.1:** to explain Method of Separation of Variables (U) **CSO 2.2:** to apply Method of Separation of Variables to solve first order PDEs. (A) **CSO 2.3:** to explain and derive	9	20	Not to be filled-in

order linear equations	Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order Linear Equations to canonical forms.	Heat, Wave and Laplace Equation (U+A) **CSO 2.4:** to Classify second order linear equations hyperbolic, parabolic or elliptic (U) **CSO 2.5:** to explain the method of canonical form of second order PDE(U) **CSO 2.6:** to reduce second order Linear Equations to canonical forms (A) **CSO 2.7:** to explain Secant method and its derivative. (U)			
UNIT 3 Solving Cauchy problem and Boundary Value Problems	The Cauchy problem, the Cauchy-Kowaleewskaya theorem, Cauchy problem of an infinite string. Initial Boundary Value Problems, Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end.	**CSO 3.1:** to define Cauchy problem with problems (K+U) **CSO 3.2:** to give the statement for Cauchy-Kowaleewskaya theorem (K) **CSO 3.3:** to apply method of separation of variables to solve Initial Boundary Value Problems. (A) **CSO 3.4:** to explain Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end. (U) **CSO 3.5:** to solve various problems on Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end (A)	9	20	Not to be filled-in
UNIT 4 Solving non-homogeneous equations with boundary conditions using separation of variables	Equations with non-homogeneous boundary conditions, Non-Homogeneous Wave Equation. Method of separation of variables, Solving the Vibrating String Problem, Solving the Heat Conduction problem.	**CSO 4.1:** to derive the equations of non-homogeneous boundary conditions. (K+A) **CSO 4.2:** to Solve the non-homogeneous wave equation. (A) **CSO 4.3:** to apply method of separation of variables to derive vibrating string problem.(A) **CSO 4.4:** to solve the Vibrating String Problem (A) **CSO 4.5:** to derive the Heat Conduction problem by method of separation of variables (K+A) **CSO 4.6:** to solve by the method of heat conduction (A)	9	20	Not to be filled-in
UNIT 5 Systems of linear	Systems of linear differential equations, types of linear	**CSO 5.1:** to understand the concept of systems of linear differential equations (K+U)	9	20	Not to be filled-

differential equations	systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions, The method of successive approximations, the Euler method, the modified Euler method, The Runge-Kutta method.	**CSO 5.2:** to explain types of linear systems (U) **CSO 5.3:** to understand the concept of differential operators (U) **CSO 5.4:** to use the operator method to find the general solution of the given linear systems. (A) **CSO 5.5:** to understand the concept of basic theory of linear system in normal form (U) **CSO 5.6:** to illustrate with examples (U) **CSO 5.7:** to define homogeneous linear system. (K) **CSO 5.8:** to define non-homogeneous linear system (K) **CSO 5.9:** to find Solutions of homogeneous and non-homogeneous linear system. (A) **CSO 5.10:** to explain method of successive approximations, the Euler method, the modified Euler method, The Runge-Kutta method. (U) **CSO 5.11:** to apply the methods to systems of linear differential equations. (A)			in

NAME OF THE PAPER (CODE) **: PDE AND SYSTEMS OF ODE (MTM 3) (Practical)**
Number of Credit **: 01**
Number of Hours of Lecture **: 30**

List of Practicals (using any software)

(i) Solution of Cauchy problem for first order PDE.
(ii) Finding the characteristics for the first order PDE.
(iii) Plot the integral surfaces of a given first order PDE with initial data.
(iv) Solution of wave equation $\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$ for the following associated conditions

e) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x), x \in \mathbb{R}, t > 0$
f) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ u(0,t) = 0, x \in (0,\infty),\ t > 0$
g) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ u_x(0,t) = 0, x \in (0,\infty),\ t > 0$
h) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ u(0,t) = 0,\ u(l,t) = 0,\ 0 < x < l,\ t > 0$

(v) Solution of heat equation $\frac{\partial u}{\partial t} = K^2 \frac{\partial^2 u}{\partial x^2}$ for the following associated conditions

a) $u(x,0) = \phi(x),\ u(0,t) = a, u(l,t) = b,\ 0 < x < l,\ t > 0$
b) $u(x,0) = \phi(x),\ u(0,t) = a, ,\ x \in (0,\infty),\ t \geq 0$
c) $u(x,0) = \phi(x),\ u(0,t) = a, x \in \mathbb{R}, 0 < t < T$

Suggested Readings:

1. Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers, 4th edition*, Springer, Indian reprint, 2006.
2. S.L. Ross, *Differential equations, 3rd Ed.*, John Wiley and Sons, India, 2004.
3. Martha L Abell, James P Braselton, *Differential equations with MATHEMATICA, 3rd Ed*., Elsevier Academic Press, 2004.

NAME OF THE PAPER (CODE) **: LINEAR ALGEBRA (MTM 4)**
Number of Credit **: 04**
Number of Hours of Lecture **: 60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **LINEAR ALGEBRA**:

CO 1:	To develop a thorough understanding of system of linear equations and their representation using Augmented matrices, enabling them to interpret and analyze the real world problems in mathematical framework.
CO 2:	To provide a comprehensive understanding of matrices and its properties, determinant calculation, Cramer's rule, Rank of matrix, Characteristics roots and eigenvectors, diagonalization, Jordan blocks and Jordan form.
CO 3:	To provide a comprehensive understanding of Vector Spaces, and methods to finding basis of a vector space.
CO 4:	To provide a comprehensive understanding of Linear Transformation, the concept of rank and nullity of linear transformation, and learn techniques for computing them, including the use of Matrix representation.
CO 5:	To provide a comprehensive understanding of Inner Product Spaces, also learn techniques for constructing Orthonormal bases using Gram-Schmidt process.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Introduction to System of linear equations**	System of linear equations, Augmented matrix, Gaussian elimination with back substitution, Gauss Jordan elimination, Solving homogeneous system of linear equation.	**CSO 1.1:** to understand the system of linear equations (U) **CSO 1.2:** to define and understand with examples systems of linear equations and Augmented matrix. (K+U) **CSO 1.3:** to understand Gauss Jordan elimination (U) **CSO 1.4:** to solve systems of linear equations using Gauss Jordan elimination (A) **CSO 1.5:** to define and understand homogeneous system of linear equation with examples (U) **CSO 1.6:** to solve homogeneous system of linear equations. (A)	10	16	Not to be filled-in
UNIT 2 **Matrices**	Matrices, Elementary properties of matrices, Determinant of a square matrix, Properties of determinants, Cramer's rule, Rank of matrix, Characteristics roots, characteristics value and vectors of square matrix, Cayley Hamilton theorem, Diagonalization, Jordan blocks and Jordan form.	**CSO 2.1:** to understand matrices and its elementary properties (U) **CSO 2.2:** to explain on how to find determinant of matrix (A) **CSO 2.3:** to explain properties of determinants and apply them. (U+A) **CSO 2.4:** to define Cramer's rule (K) **CSO 2.5:** to apply Cramer's rule (A) **CSO 2.6:** to define rank of a matrix and find the rank of a matrix (K+A) **CSO 2.7:** to define Characteristics roots and eigenvectors (K) **CSO 2.8:** to find the Characteristics roots and eigenvectors of a matrix (A) **CSO 2.9:** to state and prove Cayley Hamilton theorem (K+A) **CSO 2.10:** to define diagonalization of a matrix and understand if a matrix is diagonalizable (K+U) **CSO 2.11:** to understand Jordan blocks and Jordan form (U)	14	24	Not to be filled-in

UNIT 3 **Vector Spaces**	Vector Spaces, General Properties of vector spaces, addition and scalar multiplication of vectors, internal and external composition, null space, vector subspace, linear combination of vectors, linear span linear dependence and independence of vector, Basis, Dimension, Finding basis of a vector space.	**CSO 3.1:** to define vector spaces and understand the general properties of vector spaces (K+U) **CSO 3.2:** to define and understand addition and scalar multiplication of vectors with examples (K+U) **CSO 3.3:** to define null space (K) **CSO 3.4:** to define and understand linear combination of vectors, linear span, linear dependence and independence of vectors. (K+U) **CSO 3.5:** to define basis and dimension (K) **CSO 3.6:** to find the basis of a vector space (A)	12	20	Not to be filled-in
UNIT 4 **Linear Transformation**	Linear transformation, Linear operators, Properties of linear transformation, Algebra of linear operators, Range and null space of linear transformations, Rank and nullity of linear transformation, Rank nullity theorem.	**CSO 4.1:** to define linear transformation and linear operators (K) **CSO 4.2:** to discuss the properties of linear transformation (U) **CSO 4.3:** to understand the range and nullspace of linear transformation. (U) **CSO 4.4:** to understand rank and nullity of linear transformation (U) **CSO 4.5:** to state and prove Rank nullity theorem. (K+A) **CSO 4.6:** to find the rank and nullity of a linear transformation (A)	12	20	Not to be filled-in
UNIT 5 **Inner Product Spaces**	Inner product, Length, Orthogonal vectors, Triangle inequality, Cauchy-Schwarz inequality, Orthonormal (Orthogonal Basis), Gram Schmidt Process.	**CSO 5.1:** to define and understand Inner Product and Inner product space with examples (K+U) **CSO 5.2:** to define Orthogonal vectors (K) **CSO 5.3:** to determine Orthogonal vectors in an Inner Product Space (A) **CSO 5.4:** to understand Triangle inequality and Cauchy-Schwarz inequality. (U) **CSO 5.5:** to define Orthonormal vectors (K) **CSO 5.6:** to understand Gram Schmidt Process (U) **CSO 5.7:** to apply the Gram Schmidt Process to find orthonormal bases (A)	12	20	Not to be filled-in

Suggested Readings:
1. K. Hoffman and R. Kunze, *Linear Algebra*, Prentice Hall, 1972.
2. I. N. Herstein, *Topics in Algebra*, Wiley Eastern, 1987.
3. N. Jacobson, *Basic Algebra, Vols. I & II*, Hindustan Pub. Co., 1984.
4. J. N. Sharma and A. R. Vasista, *Linear Algebra*, Krishna Prakashan Mandir, Meerut.
5. Stephen H. Friedberg et al., *Linear Algebra*, Prentice Hall of India Pvt. Ltd., 4th Ed., 2007.

NAME OF THE PAPER (CODE) : GROUP THEORY (MTM 5)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Group Theory**:

CO 1:	To provide a comprehensive understanding of Group Theory, focusing on the definition and examples of Groups.
CO 2:	To provide a comprehensive understanding of subgroups and Cyclic groups. Also explore techniques to identify and classify subgroups.
CO 3:	To enhance critical thinking skills by analyzing and interpreting Permutation structures and their implications for problem solving in diverse contexts. Also learn the concept of Cosets and Lagrange's theorem including its use in proving Fermat's little theorem.
CO 4:	To provide an in depth understanding of advanced topics in Group Theory, focusing on the External direct products, Normal subgroups and Factor groups.
CO 5:	To provide a comprehensive understanding of Group Homomorphism, Isomorphism and its properties, understand its First, Second and Third Theorem. Also learn about Symmetries of a Square and Dihedral groups.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Introduction to Groups	Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups.	**CSO 1.1:** To define groups(K) **CSO 1.2:** Illustration of groups with examples. (U) **CSO 1.3:** to define Permutation Groups and Quaternion Groups (K) **CSO 1.4:** to Illustrate Permutation Groups and Quaternion Groups with matrices (U) **CSO 1.5:** to discuss the elementary properties of groups (K+U)	11	18	Not to be filled-in
UNIT 2 Subgroups and Cyclic groups	Subgroups and examples of subgroups, product of two subgroups,	**CSO 2.1:** to define subgroups and understand with the help of examples (K+U)	12	20	Not to be filled-in

	center of a group, centralizer, normalizer. Properties of cyclic groups, classification of subgroups of cyclic groups.	**CSO 2.2:** to define and prove that two subgroups of a group G is a product of subgroups of G (K+A) **CSO 2.3:** to define centralizer, normalizer and center of a group. (K) **CSO 2.4:** to prove that centralizer, normalizer and center of a group is a subgroup of a group (A) **CSO 2.5:** to define cyclic groups (K) **CSO 2.6:** to learn the properties of a cyclic group (U) **CSO 2.7:** to classify subgroups of cyclic groups (U)			
UNIT 3 Permutation Groups, Cosets and Lagrange's Theorem	Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.	**CSO 3.1:** Define cycle permutation.(K) **CSO 3.2:** to Illustrate with examples (U) **CSO 3.3:** to find different powers of a cycle and its order. (A) **CSO 3.4:** to learn the properties of permutations (K) **CSO 3.5:** to define even and odd permutation. (K) **CSO 3.6:** to Illustrate with examples. (U) **CSO 3.7:** to define alternating group and to show that the set of all even permutation is a normal subgroup. (K+A) **CSO 3.8:** to define and understand cosets and its properties. (K+U) **CSO 3.9:** to state and prove Lagrange's theorem. (K+A) **CSO 3.10:** to state and prove Fermat's little theorem. (K+A)	12	20	Not to be filled-in
UNIT 4 External direct products, Normal subgroups and Factor groups	External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.	**CSO 4.1:** to define external direct product. (K) **CSO 4.2:** to prove that external direct product is a group (U+A) **CSO 4.3:** to define normal subgroups. Illustrate with an example. (K+U) **CSO 4.4:** to define Factor	12	20	Not to be filled-in

		group. Illustrate Factor group with an example. (K+U) **CSO 4.5:** to Prove that every quotient group of a cyclic group is cyclic. (A) **CSO 4.6:** to Prove that a subgroup of a group G is normal in G iff the product of two right cosets is again a right coset of H in G. (K+U) **CSO 4.7:** to state and prove Cauchy theorem for finite abelian group (K+A)			
UNIT 5 Group homomorphisms, isomorphisms and Some special groups	Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems,Symmetries of a square, Dihedral groups	**CSO 5.1:** to define group homomorphism. Illustrate with examples. (K+U) **CSO 5.2:** to understand the Properties of homomorphism. (U) **CSO 5.3:** to define group isomorphism. Illustrate with examples. (K+U) **CSO 5.4:** to understand the Properties of isomorphism. (U) **CSO 5.5:** to state and prove Cayley's theorem. (K+A) **CSO 5.6:** to state and prove First, Second and Third theorem of isomorphism. (K+A) **CSO 5.7:** To understand Symmetries of a square of how they form Group under composition (U) **CSO 5.8:** To learn about Dihedral Groups, understand its properties, representations and applications. (K+U+A)	13	22	Not to be filled-in

Suggested Readings:

1. John B. Fraleigh, *A First Course in Abstract Algebra, 7th Ed.*, Pearson, 2002.
2. M. Artin, *Abstract Algebra, 2nd Ed*., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra, 4th Ed*., Narosa Publishing House, New Delhi, 1999.
4. Joseph J. Rotman, *An Introduction to the Theory of Groups, 4th Ed*., Springer Verlag, 1995.
5. I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.

NAME OF THE PAPER (CODE) : **NUMERICAL METHODS (MTM 6)**
Number of Credit : **03**
Number of Hours of Lecture : **45**

Use of Scientific Calculator is allowed.

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Numerical Methods**:

CO 1:	To make the students aware of the numerical methods and basic concepts of algorithm, convergence and errors.
CO 2:	To aid the students in the understanding of transcendental and polynomial equations and help them to solve the equations by using different methods, and analyse its convergence.
CO 3:	To create an understanding among the students, the system of linear algebraic equations and how to solve it and analyse its convergence.
CO 4:	To inculcate and create interest among students in the understanding of interpolation.
CO 5:	To assist the students in the understanding of Numerical integration.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Introduction to Numerical Methods**	Algorithms, Convergence, Errors: Relative, Absolute, Round off and Truncation	**CSO 1.1:** to define the term Algorithm (K) **CSO 1.2:** to construct an Algorithm for a sequence to find mean and standard deviation. (U) **CSO 1.3:** to apply the Algorithm to find mean and standard deviation. (A) **CSO 1.4:** to construct an Algorithm to find an integral of a function using trapezoidal rule. (U) **CSO 1.5:** to apply the Algorithm to find an integral. (A) **CSO 1.6:** to define the term convergence. (K) **CSO 1.7:** to understand the rate of convergence and order of convergence. (U) **CSO 1.8:** to evaluate rate of convergence and order of convergence of some functions. (A) **CSO 1.9:** to define the term error. (K) **CSO 1.10:** to write and define the different types of errors. (K) **CSO 1.11:** to find the value of the different errors by solving some questions. (A)	8	18	Not to be filled-in
UNIT 2 **Transcendental and Polynomial**	Transcendental and Polynomial equations:	**CSO 2.1:** to define Transcendental equation. (K) **CSO 2.2:** to define polynomial	9	20	Not to be filled-

Equations	Bisection method, Newton's method, Secant method, Rate of convergence of these methods	equation. (K) **CSO 2.3:** to explain Bisection Method and its derivative. (U) **CSO 2.4:** to apply Bisection Method to solve some Transcendental and polynomial equations. (A) **CSO 2.5:** to explain Newton's method and its derivative. (U) **CSO 2.6:** to apply Newton's method to solve some Transcendental and polynomial equations. (A) **CSO 2.7:** to explain Secant method and its derivative. (U) **CSO 2.8:** to apply Secant method to solve some Transcendental and polynomial equations. (A) **CSO 2.9:** to analyse the rate of convergence for Newton's method. (A) **CSO 2.10:** to analyse the rate of convergence for Bisection method. (A) **CSO 2.11:** to analyse the rate of convergence for Secant method. (A)			in
UNIT 3 **System of Linear Algebraic Equations**	System of linear algebraic equations: Gaussian Elimination and Gauss Jordon methods, Gauss Jacobi method, Gauss Seidel method and their convergence analysis	**CSO 3.1:** to define system of linear algebraic equation. (K) **CSO 3.2:** to explain Gaussian Elimination method and its derivative. (U) **CSO 3.3:** to apply Gaussian Elimination method to solve some system of linear algebraic equations. (A) **CSO 3.4:** to explain Gauss Jordon method and its derivative. (U) **CSO 3.5:** to apply Gauss Jordon method to solve some system of linear algebraic equations. (A) **CSO 3.6:** to explain Gauss Jacobi method and its derivative. (U) **CSO 3.7:** to apply Gauss Jacobi method to solve some system of linear algebraic equations. (A) **CSO 3.8:** to explain Gauss Seidel method and its derivative. (U) **CSO 3.9:** to apply Gauss Seidel method to solve some system of linear algebraic equations. (A) **CSO 3.10:** to analyse the rate of convergence for Gaussian Elimination method. (A) **CSO 3.11:** to analyse the rate of convergence for Gauss Jordon method. (A) **CSO 12:** to analyse the rate of convergence for Gauss Jacobi method.	9	20	Not to be filled-in

		(A) **CSO 3.13:** to analyse the rate of convergence for Gauss Seidel method. (A)			
UNIT 4 Interpolation	Interpolation: Lagrange and Newton's methods, Error bounds. Finite difference operators, Gregory forward and backward difference interpolation.	**CSO 4.1:** to define Interpolation. (K) **CSO 4.2:** to explain Lagrange method. (U) **CSO 4.3:** to apply Lagrange method to solve some questions. (A) **CSO 4.4:** to explain Newton's method. (U) **CSO 4.5:** to apply Newton's method to solve some questions. (A) **CSO 4.6:** to define error bound. (K) **CSO 4.7:** to analyse the error bound of some problems. (A) **CSO 4.8:** to define finite difference operators. (K) **CSO 4.9:** to solve problems using the finite difference operators. (A) **CSO 4.10:** to explain Gregory forward Interpolation. (U) **CSO 4.11:** to apply Gregory forward Interpolation to solve some problems. (A) **CSO 4.12:** to explain Backward difference Interpolation. (U) **CSO 4.13:** to apply Backward difference Interpolation to solve some problems. (A)	9	20	Not to be filled-in
UNIT 5 Numerical Integration	Numerical Integration: Trapezoidal rule, Simpson's $^1/_3$ rule, Simpsons $^3/_8$ rule, Boole's rule, Midpoint rule, Composite Trapezoidal rule, Composite Simpson's rule, Ordinary Differential Equations: Euler's method, Runge-Kutta Methods of orders two and four.	**CSO 5.1:** to define Numerical Integration. (K) **CSO 5.2:** to explain Trapezoidal rule. (U) **CSO 5.3:** to apply Trapezoidal rule to find the integration of some equations. (A) **CSO 5.4:** to explain Simpson's 1/3rd rule. (U) **CSO 5.5:** to apply Simpson's 1/3rd rule to find the integration of some equations. (A) **CSO 5.6:** to explain Simpson's 3/8th rule. (U) **CSO 5.7:** to apply Simpson's 3/8th rule to find the integration of some equations. (A) **CSO 5.8:** to explain Boole's rule. (U) **CSO 5.9:** to apply Boole's rule to find the integration of some equations. (A) **CSO 5.10:** to explain Midpoint rule. (U) **CSO 5.11:** to apply Midpoint rule to solve some equations. (A) **CSO 5.12:** to explain composite Trapezoidal rule. (U)	10	22	Not to be filled-in

		CSO 5.13: to explain composite Simpson's rule. (U) **CSO 5.14:** to define ordinary Differential equation. (K) **CSO 5.15:** to explain Euler's method. (U) **CSO 5.16:** to explain Runge-Kutta methods of order two and four. (U) CSO 5.17: to apply Euler's method and Runge-Kutta methods to solve some problems.			

NAME OF THE PAPER (CODE) : NUMERICAL METHODS (MTM 6) (Practical)
Number of Credit : 01
Number of Hours of Lecture : 30

List of Practicals (using any software)

(i) Calculate the sum 1/1+1/2+1/3+1/4+…….+1/N
(ii) To find the absolute value of an integer.
(iii) Enter 100 integers into an array and sort them in an ascending order.
(iv) Bisection Method.
(v) Newton Raphson Method.
(v) Secant Method.
(vi) Regula Falsi Method.
(vii) LU decomposition Method.
(ix) Gauss-Jacobi Method.
(x) SOR Method or Gauss-Siedel Method.
(xi) Lagrange Interpolation or Newton Interpolation.
(xii) Simpson's rule.

Suggested Readings:

1. Brian Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation, 6th Ed*., New age International Publisher, India, 2007.
3. C.F. Gerald and P.O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India, 2008.
4. Uri M. Ascher and Chen Greif, *A First Course in Numerical Methods, 7th Ed*., PHI Learning Private Limited, 2013.
5. John H. Mathews and Kurtis D. Fink, *Numerical Methods using Matlab, 4th Ed*., PHI Learning Private Limited, 2012.

NAME OF THE PAPER (CODE) **: REAL ANALYSIS (MTM 7.1)**
Number of Credit **: 04**
Number of Hours of Lecture **: 60**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Real Analysis**:

CO 1:	To learn "Countability of sets and the real number system" and gaps in the rational numbers.
CO 2:	To acquire the knowledge of "Topology of real numbers" by learning completeness axiom and denseness in ℝ . The student shall be able to find limit points of set and define closed set with this concept.
CO 3:	The students shall aware of the "Sequence of real numbers" and its convergence. The idea of monotone sequence and its convergence theorem is also introduced.
CO 4:	To impart the knowledge of "Subsequence" to identify monotone subsequence and its convergence, divergence subsequence.
CO 5:	To help students understand "Infinite series and its convergence" by using various convergence test.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 Countability of sets and the real number system	Rational numbers and its properties, gaps in the rational numbers, Review of algebraic and order properties of ℝ- neighbourhood of a point in ℝ, Idea of countable sets, uncountable sets and uncountability of ℝ. Bounded above sets, Bounded below sets, Bounded sets, Unbounded sets, Suprema and Infima	**CSO 1.1:** To understand the rational number system and its gap (K) **CSO 1.2:** To discuss the algebraic and order properties of ℝ (U) **CSO 1.3:** Defining neighbourhood of point (K) **CSO 1.4:** Theorems on neighbourhoods of a point (U) **CSO 1.5** Finding neighbourhood of a point (A) **CSO 1.6:** To introduce the concept of countable and uncountable sets (K) **CSO 1.7:** Theorems on union of countable sets, infinite subsets of countable sets, uncountability of ℝ (U) **CSO 1.8:** Defining bounded sets, unbounded sets, (K) **CSO 1.9:** To find the upper bound and lower bound of sets (A) **CSO 1.10:** Defining suprema and infima of a set (K) **CSO 1.11:** To find suprema and infima of a set (A)	13	22	Not to be filled-in

UNIT 2 Topology of real numbers	The completeness property of ℝ, The Archimedean property, Density of rational and irrational numbers in ℝ, Intervals. Limit points of a set, Isolated points, Illustration of Bolzano-Weierstrass theorem for bounded sets	**CSO 2.1:** Describing the concept of completeness axiom (K) **CSO 2.2:** Theorems on completeness axiom (U) **CSO 2.3:** Describing the concept of Archimedean property of real numbers (K) **CSO 2.4:** Theorems based on Archimedean property of real numbers (U) **CSO 2.5:** To discuss denseness in ℝ (U) **CSO 2.6:** to understand the idea of intervals(K) **CSO 2.7:** to define limit point and isolated point of a set(K) **CSO 2.8:** Finding limit point and isolated point of a set (A) **CSO 2.9:** Illustration of Bolzano Weierstrass theorem for bounded sets (A)	11	18	Not to be filled-in
UNIT 3 Sequence of real numbers	Sequences, Bounded sequence, Convergent sequence, Limit of a sequence. Limit theorems, Monotone sequence, Monotone convergence theorem	**CSO 3.1:**. To define sequence of real numbers (K) **CSO 3.2:**. To define bounded sequence and unbounded sequence (K) **CSO 3.3:**. To define limit of a sequence (K) **CSO 3.4** To discuss the convergence of a sequence (U) **CSO 3.5:** Finding the limit of a sequence and determining its convergence (A) **CSO 3.6:** To describe the algebra of limits (K) **CSO 3.7:** Theorem on limits (U) **CSO 3.8:** To define monotone sequence (K) **CSO 3.9:** To discuss monotone convergence theorem (U) **CSO 3.10:** To determine monotone sequence (A)	12	20	Not to be filled-in
UNIT 4 Subsequence	Subsequence, Divergence criteria, Monotone subsequence theorem (statement only), Bolzano-Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion	**CSO 4.1:** Defining subsequence of a sequence (K) **CSO 4.2:** To discuss the convergence and divergence concept of subsequence (U) **CSO 4.3:** Discussing the divergence criteria of a subsequence (U) **CSO 4.4:** Solving problem based on convergence and divergence of sequence (A) **CSO 4.5:** To describe monotone	12	20	Not to be filled-in

		subsequence theorem (K) **CSO 4.6:** To discuss Bolzano Weierstrass theorem for sequences (U) **CSO 4.7:** Defining Cauchy's sequence (K) **CSO 4.8:** Describing Cauchy's Convergence Criterion (K) **CSO 4.9:** Determining Cauchy's sequence (A)			
UNIT 5 Infinite series and its convergence	Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: Comparision test, Ration test, Cauchy's nth root test, Integral test, Alternating series, Leibnitz's test, Absolute and conditional convergence	**CSO 5.1:** Defining infinite series (K) **CSO 5.2:** Discussing Cauchy's criterion of convergence of infinite series (U) **CSO 5.3:** Discussing **s**ome properties on infinite series (U) **CSO 5.4:** Defining Comparison test (K) **CSO 5.5:** Applying Comparison test on infinite series (A) **CSO 5.6:** Defining limit comparison test (K) **CSO 5.7:** Applying comparison test on infinite series (A) **CSO 5.8:** Defining ratio test (K) **CSO 5.9:** Applying ratio test on infinite series (A) **CSO 5.10:** Defining Cauchy's nth root test (K) **CSO 5.11:** Applying Cauchy's nth root test (A) **CSO 5.12:** Defining integral test (K) **CSO 5.13:** Applying integral test on infinite series (A) **CSO 5.14:** Introducing Alternate series (U) **CSO 5.15:** Testing convergence of infinite series (A) **CSO 5.16:** Defining Leibnitz's test (U) **CSO 5.17:** Testing convergence of alternate series by using Leibnitz's test (A) **CSO 5.18:** Discussing the convergence of absolute and conditional convergence (U)	12	20	Not to be filled-in

Suggested Readings:

1. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis, 3rd Ed.*, John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Gerald G. Bilodeau, Paul R. Thie, G. E. Keough, *An Introduction to Analysis, 2nd Ed.*, Jones & Bartlett, 2020.

3. Brian S. Thomson, Andrew M. Bruckner and Judith B. Bruckner, *Elementary Real Analysis*, Prentice Hall, 2001.
4. S. K. Berberian, *A First Course in Real Analysis*, Springer Verlag, New York, 1994.

NAME OF THE PAPER (CODE) : DISCRETE MATHEMATICS (MTM 7.2)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Discrete Mathematics**:

CO 1:	To create an understanding of the concept of Logic.
CO 2:	To assist the students in understanding Lattices.
CO 3:	To aid students in understanding Boolean algebra.
CO 4:	To inculcate the students in understanding Graph theory and how it works.
CO 5:	To make the students familiar with Graph Algorithms.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Logic	Statements, truth value and truth table, logical connectives, logical equivalence, tautologies and contradictions, arguments, propositional logic, applications of propositional logic to everyday reasoning, predicate, quantifiers, applications of predicate logic to everyday reasoning	**CSO 1.1:** to define statement and types of statements with examples. (K/U) **CSO 1.2:** to define truth value and truth table with examples. (K/U) **CSO 1.3:** to workout problems based on truth table. (A) **CSO 1.4:** to explain logical connectives with examples. (K/U) **CSO 1.5:** to define and explain logical equivalence and solve some problems based on it. (K/U/A) **CSO 1.6:** to define tautologies and contradictions with examples. (K/U) **CSO 1.7:** to define an argument with an example. (K/U) **CSO 1.8:** to define propositional logic and apply it to solve problems to everyday reasoning. (K/U/A) **CSO 1.9:** to define predicates and quantifiers with examples. (K/U) **CSO 1.10**: to apply predicate logic to everyday reasoning problems. (A)	13	22	Not to be filled-in
UNIT 2 Lattices	Partial order relations, lattices - definitions, examples, properties of lattices, properties of complete lattice, bounded lattice,	**CSO 2.1:** to define and explain partial order relations with examples. (K/U) **CSO 2.2:** to define lattices with examples. (K/U) **CSO 2.3:** to write down and explain the properties of lattices.	11	18	Not to be filled-in

	complemented lattice and distributive lattices.	(K/U) **CSO 2.4:** to define and explain the properties of complete lattice. (K/U) **CSO 2.5:** to define and explain bounded lattices. (K/U) **CSO 2.6:** to define and explain complemented lattice and distributive lattices with examples. (K/U) **CSO 2.7:** to workout problems based on all the above. (A)			
UNIT 3 Boolean algebra	Boolean algebras - Boolean sub algebra, basic properties Boolean homomorphism, Boolean algebra as lattices, Boolean expressions and Boolean functions, sum of product, product of sum, min term, max term, minimization of Boolean functions, Karnaugh map method.	**CSO 3.1:** to define Boolean algebras and sub algebra with examples. (K/U) **CSO 3.2:** to write down the basic properties of Boolean homomorphism and example it with examples. (K/U) **CSO 3.3:** to explain about Boolean algebra as lattices and workout problems. (U/A) **CSO 3.4:** to define Boolean expressions and Boolean functions with examples. (K/U) **CSO 3.5:** to explain sum of product and product of sum with examples and workout problems. (K/U/A) **CSO 3.6:** to define mid term and max term with examples. (K/U) **CSO 3.7:** to define minimization of Boolean functions and workout problems. (K/A) **CSO 3.8:** to explain Karnaugh map method and solve some problem based on it. (U/A)	12	20	Not to be filled-in
UNIT 4 **Graph Theory**	Basic concepts, definitions and examples, degree of vertex, sub graphs, complete graph, connected graph, walk, path, cycles, matrix representation of graph, adjacency matrix, incidence matrix, path matrix.	**CSO 4.1:** to define graph with examples. (K/U) **CSO 4.2:** to define degree of a vertex and solve some problems based on it. (K/A) **CSO 4.3:** to define sub graph, complete graph and connected graph with examples. (K/U) **CSO 4.4:** to define walk, path and cycles with examples. (K/U) **CSO 4.5:** to explain matrix representation of graph with examples. (K/U) **CSO 4.6:** to define and explain adjacency matrix, incidence matrix and path matrix with examples. (K/U) **CSO 4.7:** to tackle problems based on all the above topics. (A)	12	20	Not to be filled-in

UNIT 5 Graph Algorithms	Warshall's algorithm, planar graph, Eulerian path, tournament and Hamiltonian path. Directed graphs, in degree and out degree of a vertex, weighted undirected graphs, Dijkstra's algorithm.	**CSO 5.1:** to define and explain Warshall's algorithm and tackle problems based on it. (K/U/A) **CSO 5.2:** to define planar graph and solve problems based on it. (K/A) **CSO 5.3:** to define and explain Eulerian path, tournament and Hamiltonian path and workout problems based on all three topics. (K/U/A) **CSO 5.4:** to define directed graph, in degree and out degree of a vertex and tackle problems based on it. (K/U/A) **CSO 5.5:** to define weighted undirected graphs with examples and tackle problems based on it. (K/U/A) **CSO 5.6:** to define and explain Dijkstra's algorithm and workout problems based on it. (K/U/A)	12	20	Not to be filled-in

Suggested Readings:

1. C.T. Liu, *Elements of Discrete Mathematics*, Tata Mcgraw-Hill Pub. Co. ltd., 2000.
2. J. P. Tremblay & R. Manohar, *Discrete Mathematical Structures with Appl. to Computer Science*, McGraw – Hill Book Co., 1977.
3. J. Truss, *Discrete Mathematics for Computer Scientists*, Pearson Education, 3rd Ed., 2002.
4. R. Johnsonbaugh, *Discrete Mathematics*, Pearson Education Asia, 5th ed., 2003.
5. T. Veerarajan, *Discrete Mathematics with Graph Theory and Combinatorics*, Tata McGraw – Hill Pub. Co. ltd, 2007.

NAME OF THE PAPER (CODE) : PROBABILITY AND STATISTICS (MTC 6.4)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Probability and Statistics:**

CO 1:	To help the students in understanding Sample space, probability axioms, real random variables, cumulative distribution function, probability mass function, mathematical expectation, moments and moment generating function, characteristic function and problem-based solutions.
CO 2:	To help the students in understanding discrete and continuous distributions and its properties, joint density functions, marginal and conditional distributions and problem-based solutions.
CO 3:	To help the students in understanding expectation of functions of two variables, conditional expectations, independent random variables, Bivariate normal distribution, correlation coefficient, joint moment generating function and calculation of covariance, linear regression for two variables and problem-based solutions.
CO 4:	To help the students in understanding Chebyshev's inequality, statement and interpretation of law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance and problem-based solutions.
CO 5:	To help the students in understanding Markov Chains, Chapman-Kolmogorov equations, classification of states.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	**Unit Contents**	**Course Specific Objective (CSOs)**	**Lecture Hours**	**Marks**	**LOs**
UNIT 1 **Probability**	Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function.	**CSO 1.1:** Learn about probability density and moment generating functions. (K) **CSO1.2:** knowning moments, moment generating function, characteristic function. (U) **CSO 1.3:** Leaning Basic probability properties. (A)	12	20	Not to be filled-in
UNIT 2 **Discrete Probability distributions**	Discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential. Joint cumulative distribution function and its	**CSO 2.1:** Know about various univariate distributions such as, Binomial, geometric and Poisson distributions. (K) **CSO 2.2:** Learn about distributions to study the joint behavior of two random variables. (K)	13	22	Not to be filled-in

	properties, joint probability density functions, marginal and conditional distributions.	**CSO 2.3:** Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions. (U)			
UNIT 3 Mathematical Expectation	Expectation of function of two random variables, conditional expectations, independent random variables. Bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.	**CSO 3.1:** Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression. (K) **CSO 3.2:** Expectation of function of two random variables, conditional expectations, independent random variables. (U)	13	22	Not to be filled-in
UNIT 4 Continuous Probability distributions	Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance.	**CSO 4.1:** Understand central limit theorem, which helps to understand the remarkable fact that: the empirical frequencies of so many natural populations, exhibit a bell-shaped curve, i.e., a normal distribution. (K) **CSO 4.2:** Spealing the definition law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance. (U)	12	20	Not to be filled-in
UNIT 5 Stochastic Probability	Markov Chains, Chapman-Kolmogorov equations, classification of states.	**CSO 5.1:** Find stochastic matrices values (K) **CSO 5.2:** Finding its classification of states (U) **CSO 5.3:**Scecking Markov Chains, Chapman-Kolmogorov equations. (A)	10	16	Not to be filled-in

Suggested Readings:

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

1 Minor Theory Papers in lieu of Research Project/Dissertation
(For Honors Students not undertaking Research Projects)

NAME OF THE PAPER (CODE) : LINEAR PROGRAMMING AND THEORY OF GAMES (MTC 8.2)
Number of Credit : 04
Number of Hours of Lecture : 60

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Linear Programming and Theory of Games:**

CO 1:	To help the students to understand simplex algorithm, M method algorithm and solving the problems.
CO 2:	To help the students to understand Relation of dual and primal problems using corresponding algorithms.
CO 3:	To help the students to understand types of Transportation problems (T.p) and algorithms.
CO 4:	To help the students to understand Hungarian methods for solving assignment problem and algorithms.
CO 5:	To help the students to understand type of game theory for example two person sum of game with pure and mixed strategies, Graphical solution, linear programming etc..

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 **Linear Programming**	Introduction to linear programming problem, Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.	**CSO 1.1:** Find simplex table (K) **CSO 1.2:** Find BIG-M table (K) **CSO 1.3:** Find two face method tabulate.(K) **CSO 1.4:** study for algorithm simplex. (A)	13	22	Not to be filled-in
UNIT 2 **Linear Programming**	Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.	**CSO 2.1:** Tabulate duality simplex (K) **CSO 2.2:** studying relation between dual to primal relation (U) **CSO 2.3:** clarity of economic interpretation of the dual. (U)	11	18	Not to be filled-in
UNIT 3 **Transportation problem**	Transportation problem and its mathematical formulation, northwest-corner method least cost method and Vogel approximation method	**CSO 3.1:**Find mini cost from TP (K) **CSO 3.2:** check mathematical formulation (U) **CSO 3.3:** study	12	20	Not to be filled-in

	for determination of starting basic solution.	NWC,LCM, VAM for determination of starting basic solution. (U)			
UNIT 4 **Assignment problem**	Algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.	**CSO 4.1:** Study about TP Algorithm. (A) **CSO 4.2:** Solve assignment problem using by TP (U) **CSO 4.3:** Hungarian method for solving assignment problem. (K)	12	20	Not to be filled-in
UNIT 5 **Game theory**	Game theory: formulation of two-person zero sum games, solving two-person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.	**CSO 5.1**: How to apply two person zero sum game. (K) **CSO 5.2:** Tablate mixed strategies players. (U) **CSO 5.3:** Draw graphical solution**.** (A) **CSO 5.4:** Finding linear programming solution of games. (U)	12	20	Not to be filled-in

Suggested Readings:

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows, 2nd Ed*., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, *Introduction to Operations Research, 9th Ed.*, Tata McGraw Hill, Singapore, 2009.
3. Hamdy A. Taha, Operations Research, *An Introduction, 8th Ed*., Prentice-Hall India, 2006.
4. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.

SKILL ENHANCEMENT COURSES (SEC)

NAME OF THE PAPER (CODE) : LOGIC AND SETS (MTS 1)
Number of Credit : 02
Number of Hours of Lecture : 30

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Logic and Sets**:

CO 1:	To create an understanding of the foundations of Logic.
CO 2:	To assist the students in understanding the basic concept of Set theory.
CO 3:	To aid students in understanding Set theory and its relations.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Logic	Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, Quantifiers, Binding variables and Negations.	**CSO 1.1:** to define propositions with examples. (K/U) **CSO 1.2:** to define truth value and truth table with examples. (K/U) **CSO 1.3:** to workout problems based on truth table. (A) **CSO 1.4:** to define negation, conjunction and disjunction. (K) **CSO 1.5:** to define Implications and biconditional propositions. (K) **CSO 1.6:** to define contra positive and inverse Propositions with examples. (K/U) **CSO 1.7:** to define and write down the precedence of logical operators. (K) **CSO 1.8:** to define logical equivalences and apply it to solve problems. (K/A) **CSO 1.9:** to define predicates and quantifiers with examples. (K/U) **CSO 1.10**: to define binding variables and Negations. (K)	11	19	Not to be filled-in
UNIT 2 Set Theory	Sets, subsets, Set operations and the laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting	**CSO 2.1:** to define sets and subsets with examples. (K/U) **CSO 2.2:** to explain the set operations. (U) **CSO 2.3:** to write down and explain the laws of set theory and venn diagrams with	8	12	Not to be filled-in

	principle. Empty set, properties of empty set. Standard set operations	examples. (K/U) **CSO 2.4:** to tackle some problems based on the set theory and venn diagrams. (U/A) **CSO 2.5:** to write down the examples of finite and infinite sets. (K) **CSO 2.6:** to explain Finite sets and counting principle with examples. (U) **CSO 2.7:** to define empty set. (K) **CSO 2.8:** to write down and explain the properties of empty set. (K/U) **CSO 2.9:** to write down and explain Standard set operations. (K/U)			
UNIT 3 Set Theory and Relations	Classes of sets. Power set of a set. Difference and Symmetric difference of two sets. Set identities, Generalized union and intersections. Relation: Product set, Composition of relations, Types of relations, Partitions, Equivalence Relations with example of congruence modulo relation, Partial ordering relations, n-array relations.	**CSO 3.1:** to define the classes of sets with examples. (K/U) **CSO 3.2:** to define power set of a set with examples. (K/U) **CSO 3.3:** to define and explain Difference and Symmetric difference of two sets and tackle problems based on it. (U/A) **CSO 3.4:** to define set identities and workout problems based on it. (K/A) **CSO 3.5:** to explain Generalized union and intersections and workout problems. (K/U/A) **CSO 3.6:** to define relations and its types with examples. (K/U) **CSO 3.7:** to define Product set and Composition of relations with examples. (K/U) **CSO 3.8:** to define partitions with examples. (K/U) **CSO 3.9:** to define and explain Equivalence Relations with example of congruence modulo relation. (K/U) **CSO 3.10:** to define Partial ordering relations and n-array relations and workout problems based on them. (K/U/A)	11	19	Not to be filled-in

Suggested Readings:

1. R.P. Grimaldi, *Discrete Mathematics and Combinatorial Mathematics,* Pearson Education, 1998.
2. P.R. Halmos, *Naive Set Theory*, Springer, 1974.

3. E. Kamke, *Theory of Sets*, Dover Publishers, 1950.
4. G.F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill, 1963.

NAME OF THE PAPER (CODE)	**: LaTeX & HTML (MTS 2) (Practical)**
Number of Credit	**: 02**
Number of Hours of Lecture	**: 30**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **LaTeX and HTML**:

CO 1:	To discuss "Introduction to LaTeX" by typesetting a simple document, adding basic information to a document, Environments, Footnotes etc.
CO 2:	Understanding the "Mathematical Typesetting in LaTeX" like Subscript/ Superscript, Fractions, Roots, Ellipsis, Mathematical Symbols, Arrays, Delimiters, Multiline formulas, Spacing and changing style in math mode in different math environment
CO 3:	Understanding "Beamer Presentation and HTML "in LaTeX like Simple pictures using PS Tricks, Plotting of functions, Beamer presentation and Creating simple web pages, Images and links, Design of web pages in HTML

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	Los
UNIT 1 Introduction to LaTeX	Getting Started with LaTeX, Introduction to TeX and LaTeX, typesetting a simple document, Adding basic information to a document, Environments, Footnotes, Sectioning and displayed material.	**CSO 1.1:** To introduce typesetting a simple document in latex (K) **CSO 1.2:** Discussing on sectioning documents, sub-sectioning, adding footnotes on document (U) **CSO 1.3:** Introducing Bibliography in document (K) **CSO 1.4:** Write a document in latex involving two sections, two sub-sections, and a footnote with two bibliography (K)	9	15	Not to be filled-in
UNIT 2 Mathematical Typesetting in LaTeX	Mathematical Typesetting with LaTeX Accents and symbols, Mathematical Typesetting (Elementary and Advanced): Subscript/ Superscript, Fractions, Roots, Ellipsis, Mathematical Symbols, Arrays, Delimiters, Multiline formulas, Spacing and changing style in math mode.	**CSO 2.1:** Introducing mathematical typesetting in LaTeX (K) **CSO 2.2:** Writing LaTeX code in equation environment involving Subscript/ Superscript, Fractions, Roots, delimiters (K) **CSO 2.3:** Writing LaTeX code in align environment involving Subscript/ Superscript, Fractions, Roots, delimiters (K) **CSO 2.4:** Writing LaTeX code in multline environment involving Subscript/ Superscript, Fractions, Roots,	12	20	Not to be filled-in

		delimiters (K) **CSO 2.5:** Writing LaTeX code in split environment involving Subscript/ Superscript, Fractions, Roots, delimiters (K) **CSO 2.6:** Creating arrays in LaTeX (U) **CSO 2.7:** Creating table in LaTeX (U) **CSO 2.8:** Using case environment in LaTeX (A)			
UNIT 3 Beamer Presentation and HTML	Graphics and Beamer Presentation in LaTeX, Graphics in LaTeX, Simple pictures using PS Tricks, Plotting of functions, Beamer presentation. HTML basics, Creating simple web, pages, Images and links, Design of web pages.	**CSO 3.1:** Writing presentation using beamer class (K) **CSO 3.2:** To insert a picture in Latex document (A) **CSO 3.3:** Introducing HTML (K) **CSO 3.4:** Creating simple web pages in HTML (U) **CSO 3.5:** Inserting image on the webpage in HTML (A) **CSO 3.6:** Inserting hyperlinks on web page in HTML (A)	9	15	Not to be filled-in

Suggested Readings:

1. Bindner, Donald & Erickson, Martin., *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*, CRC Press, Taylor & Francis Group, LLC. 2011.
2. Lamport, Leslie, *LaTeX: A Document Preparation System, User's Guide and Reference Manual 2nd ed.*, Pearson Education, Indian Reprint, 1994.

Practical/Lab work to be performed in Computer Lab.
Practicals:
[1] Chapter 9 (Exercises 4 to 10), Chapter 10 (Exercises 1 to 4 and 6 to 9), Chapter 11 (Exercises 1, 3, 4, and 5), and Chapter 15 (Exercises 5, 6 and 8 to 11).

NAME OF THE PAPER (CODE) : **GRAPH THEORY (MTS 3)**
Number of Credit : **02**
Number of Hours of Lecture : **30**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Graph Theory**:

CO 1:	To create an understanding of the basic concepts of graph and its properties.
CO 2:	To assist the students in understanding graph connectivity.
CO 3:	To aid students in understanding how to solve the shortest path problems.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 Graphs	Definition, examples and basic properties of graphs, pseudo graphs, complete graphs. Bi-partite graphs, weighted graph, Isomorphism of graphs, adjacency matrix and incidence matrix.	**CSO 1.1:** to define graph with examples. (K/U) **CSO 1.2:** to write and explain the basic properties of graphs. (K/U) **CSO 1.3:** to define pseudo graph and complete graph with examples. (K/U) **CSO 1.4:** to define Bi-partite graphs and weighted graphs with examples. (K/U) **CSO 1.5:** to workout problems based on Bi-partite and weighted graphs. (A) **CSO 1.6:** to define isomorphism graphs with examples. (K/U) **CSO 1.7:** to define and explain adjacency matrix and incidence matrix. (K) **CSO 1.8:** to apply adjacency matrix and incidence matrix and workout problems. (A)	11	19	Not to be filled-in
UNIT 2 Connectivity	Connected graph and digraph, paths, circuits and cycles, Eulerian circuits, Hamiltonian cycles.	**CSO 2.1:** to define connected graph and digraph with examples. (K/U) **CSO 2.2:** to tackle some problems based on digraph. (A) **CSO 2.3:** to define paths, circuits and cycles with examples. (K/U) **CSO 2.4:** to define Eulerian circuits and workout problems based on it. (U/A) **CSO 2.5:** to define Hamiltonian cycles and tackle	8	12	Not to be filled-in

		problems based on it. (K/A)			
UNIT 3 Shortest Path Problems	The travelling salesman's problem. Shortest path, Dijkstra's algorithm, Floyd-Warshall algorithm.	**CSO 3.1:** to explain the travelling salesman's problem and workout problems based on it. (K/U/A) **CSO 3.2:** to define shortest path with examples. (K/U) **CSO 3.3:** to define and explain Dijkstra's algorithm and tackle problems based on it. (K/U/A) **CSO 3.4:** to define and explain Floyd-Warshall algorithm and workout problems based on it. (K/U/A)	11	19	Not to be filled-in

Suggested Readings:
1. B.A. Davey and H.A. Priestley, *Introduction to Lattices and Order*, Cambridge University Press, Cambridge, 1990.
2. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory*, *2nd Edition*, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
3. Rudolf Lidl and Gunter Pilz, *Applied Abstract Algebra, 2nd Ed*., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

NAME OF THE PAPER (CODE) : **LAPLACE AND FOURIER TRANSFORM** (**MTS 4**)
Number of Credit : **02**
Number of Hours of Lecture : **30**

COURSE OBJECTIVES (COs)

The following are the Course Objectives (COs) for the paper **Laplace and Fourier Transform**:

CO 1:	To aid the students in understanding the Laplace transform, its existence and some elementary functions, Functions of exponential order, Shifting theorems, change of scale property.
CO 2:	To aid the students in understanding inverse Laplace transform, Null function, linearity property, change of scale property, inverse Laplace transforms of derivatives & integrals, Division by powers of p, Beta function, Convolution theorem.
CO 3:	To aid the students in understanding the Fourier transforms & inversion theorem.

COURSE SPECIFIC OBJECTIVES (CSOs)

Unit & Title	Unit Contents	Course Specific Objective (CSOs)	Lecture Hours	Marks	LOs
UNIT 1 The Laplace Transform	The Laplace Transform Definition, Existence of Laplace Transforms, Functions of exponential order, Laplace Transform of some , elementary functions, Shifting theorems, change of scale property. Laplace Transform of the derivative of F(t), nth derivative of F(t), Laplace transform of integrals, Multiplication by powers of t & division by t, Periodic function, Beta and Gamma function.	**CSO 1.1:** List the Laplace transforms of some standard functions, understand conditions for its existence. (U) **CSO 1.2:** Find the Laplace Transforms of functions and implement it in Convolution theorem and Heaviside theorem. (A)	10	17	Not to be filled-in
UNIT 2 Inverse Laplace Transform	Null function (definition only), linearity property, First and second translation theorems, Change of scale property, Use of partial fractions, Inverse Laplace transforms of derivatives & integrals, Division by powers of p, Beta function, Convolution theorem.	**CSO 2.1:** Learning The inverse Laplace transformation. (K) **CSO 2.2:** How to apply convolution theorem in Laplace transformation (U) **CSO 2.3:** Concept applying in Differential Equation.(A)	10	17	Not to be filled-in
UNIT 3 Fourier Transform	Fourier transforms, inversion theorem, Fourier sine and cosine transform, inversion formula for sine and cosine transform, - linear properties, shifting properties, modulation theorem	**CSO 3.1:** Understand the basic concepts of Fourier Transforms, Fourier Sine and Cosine Transforms. (U) **CSO 3.2**: How to understanding the shifting property (U)	10	17	Not to be filled-in

Suggested Readings:

1. Baidyanath Patra, *An Introduction to Integral Transforms*, Prentice Hall, 2009.
2. J.K. Goyal, K.P.Gupta, *Integral Transforms*, *16th edition*, K.K. Mittal for Prakashan, 2013.
3. Erwin Kreyszig, *Advanced Engineering Mathematics, 8th edition*, Authorized reprint by Wiley Dreamtech India.