SYLLABUS FOR FOUR YEAR UG PROGRAMME
(Honours, Honours with Research and 3 Year Multi-Disciplinary Course)
IN
MATHEMATICS

Under National Education Policy (NEP)

Effective from 2023-2024

West Bengal State University
Barasat
Kolkata-700126
West Bengal

Structure of the 4-year Undergraduate Programme (Honours)

Table1: Semester-wise and Course category-wise distribution of credits

SEM	Major (DSC)	Minor	MDC	AEC	SEC	VAC	Internship	Total Credits
I	DS-1(5)	MA-1(5) MB-1(5)	MD-1 (3)	AE-1 (3)	SE-1 (3)	VA-1 (3)		27
II	DS-2(5)	MA-2(5) MB-2(5)	MD-2 (3)	AE-2 (3)	SE-2 (3)	VA-2 (3)	(4**)	27
Exit with certificate								(4**) + 54
III	DS-3(5)	MA-3(5) MB-3(5)	MD-3 (3)	AE-3 (3)	SE-3 (3)			24
IV	DS-4(5),DS-5(5) DS-6(5),DS-7(5)						(4**)	20
Exit with diploma								(4**) + 98
V	DS-8(5),DS-9(5) DS-10(5), DS-11(5)							20
VI	DS-12(5), DS-13(5) DS-14(5), DS-15(5)						(4**)	20
Exit with Major	75	30	9	9	9	6		(4**)+138
VII	DS-16(5) DS-17(5)	SMA(5) SMB (5)						20
VIII	DS-18(5) DS-19(5) DS-20(5) DS-21(5)							20
Credit	105	40	9	9	9	6	4	182

DS: Discipline specific core course,

MA: Minor discipline1, MB: Minor discipline2

SM: Special Minor courses from the two different disciplines either MA or MB, but of higher level.

Structure of the 4-year Undergraduate Programme (Honours with Research)

Table1A: Semester-wise and Course category-wise distribution of credits

SEM	Major (DSC)	Minor	MDC	AEC	SEC	VAC	Internship/ Research	Total Credits
I	DS-1(5)	MA-1(5) MB-1(5)	MD-1 (3)	AE-1 (3)	SE-1 (3)	VA-1 (3)		27
II	DS-2(5)	MA-2(5) MB-2 (5)	MD-2 (3)	AE-2 (3)	SE-2 (3)	VA-2 (3)	(4**)	27
Exit with certificate								(4**) + 54
III	DS-3(5)	MA-3(5) MB-3(5)	MD-3 (3)	AE-3 (3)	SE-3 (3)			24
IV	DS-4(5), DS-5(5) DS-6(5), DS-7(5)						(4**)	20
Exit with diploma								(4**) + 98
V	DS-8(5), DS-9(5) DS-10(5), DS-11(5)							20
VI	DS-12(5), DS-13(5), DS-14(5), DS-15(5)						(4**)	20
Exit with Major	75	30	9	9	9	6	(4**)	(4**) + 138
VII	DS16(5), DS-17(5)	SMA(5) SMB (5)						20
VIII	DS-18(5),						15	20
Credit	90	40	9	9	9	6	19	182

DS: Discipline specific core course,

MA: Minor discipline1, MB: Minor discipline2

SM: Special Minor courses from the two different disciplines either MA or MB, but of higher level.

Structure of the3-YearMultidisciplinaryUGProgramme

Table2:Semester-wise and course category-wise distribution of credits

SEM	Core course(A)	Core course(B)	Core course (C)	MDC	AEC	SEC	VAC	Inten-ship	Total credits
I	MA-1(5)	MB-1(5)	MC-1(5)		AE-1(3)		VA-1(3)		21
II	MA-2(5)	MB-2(5)	MC-2(5)		AE-2(3)		VA-2(3)	(4**)	21
Exit with Certificate									(4*)+ 42
III	MA-3(5)	MB-3(5)	MC-3(5)		AE-3(3)	SE-1 (3)			21
IV	MA-4(5)	MB-4(5)	MC-4(5)	MD-1(3)		SE-2(3)		(4**)	21
Exit with diploma									(4**)+ 84
V	MA-5(5)	MB-5(5)	MC-5(5)	MD-2(3)		SE-3(3)			21
VI	MA-6(5)	MB-6(5)	MC-6(5)	MD-3(3)		SE-4(3)		(4**)	21
Credits	30	30	30	9	9	12	6	4	(4**) + 126

MA: Core course from discipline 1,

MB: Core course from discipline 2

MC: Core course from discipline 3.

Semester wise Course Structures of Mathematics (NEP)

Semester	Major(CP:5), Marks:100, (L:T:P=4:1:0) - Theory (L:T:P=3:0:2) - Theory+Practical	Minor(CP:5) Marks:100, (L:T:P=4:1:0)	SEC(CP:3) Marks:50, (L:T:P=2:0:1)	MDC(CP:3) Marks:50 (L:T:P=2:1:0)
I	DS-1: Algebra (MTMDSC101T)	MA -1: Algebra (MTMMIN101T) (MTMCOR101T)	C-Programming Language (MTMHSE101M)	Basic Mathematics (MTMHMD101T)
II	DS-2:Calculus (MTMDSC202T)	MA-2: Calculus (MTMMIN202T) (MTMCOR202T)	Programming Language-Python (MTMHSE202M)	Basic Mathematics (MTMHMD201T)
III	DS-3: Analytical Geometry and Vector Analysis (MTMDSC303T)	MA-3: Differential Equations (MTMMIN303T) (MTMCOR303T)	C-Programming Language (MTMHSE303M) (MTMGSE301M)	Basic Mathematics (MTMHMD301T)
IV	DS-4: Ordinary Differential Equations-I and Mechanics-I (MTMDSC404T)	MA-4: Probability Theory & Mechanics (MTMCOR404T)	Programming Language-Python (MTMGSE402M)	Basic Mathematics (MTMGMD401T)
	DS-5: Real Analysis – I (MTMDSC405T)			
	DS-6: Group Theory-I and Number Theory (MTMDSC406T)			
	DS-7: Partial Differential Equations & Integral Transforms (MTMDSC407T)			
V	DS-8: Real Analysis–II (MTMDSC508T)	MA-5: Linear Programming Problem & Game Theory (MTMCOR505T)	C-Programming Language (MTMGSE501M)	Basic Mathematics (MTMGMD501T)
	DS-9: Ring Theory and Linear Algebra-I (MTMDSC509T)			
	DS-10: Numerical Analysis (Theory & Practical) (MTMDSC510M)			
	DS-11: Multivariate Calculus and Metric spaces (MTMDSC511T)			
VI	DS-12: Operations Research and Game Theory (MTMDSC612T)	MA-6: Numerical Methods and Integral Transforms (MTMCOR606T)	Programming Language-Python (MTMGSE602M)	Basic Mathematics (MTMGMD601T)
	DS-13: Group Theory- II and Ordinary Differential Equations –II (MTMDSC613T)			
	DS-14: Probability & Statistics (MTMDSC614T)			
	DS-15: Complex Analysis (MTMDSC615T)			

VII	DS-16: Topology (MTMDSC716T)	Discrete Mathematics (MTMSMC701T)		
	DS-17: Field Extension & Linear Algebra-II (MTMDSC717T)			
VIII	DS-18: Functional Analysis (MTMDSC818T)			
	DS-19: Mechanics-II (MTMDSC819T) DS-20: Discrete Mathematics & Differential Geometry (MTMDSC820T)	Hons with Research(CP:15, Marks: 300): Research Project/ Dissertation (MTMRES801T/M)		
	DS-21: Data Science (MTMDSC821M)			

Detailed Major Syllabus

SEM-I

Course: MTMDSC101T

Algebra (Marks:100, Credits: 5)

Unit -1 : Classical Algebra

De-Moivre's theorem for integer and rational indices and their applications, The n-th roots of unity. Definitions of exponential and trigonometrical functions of a complex variable, exponential values of sine and cosine. Periods of exponential and trigonometrical functions, Logarithm of a complex number and its properties, Definitions of a^z, Inverse circular functions, hyperbolic functions, along with exercises of all these concepts.

General properties of polynomials and polynomial equations, Fundamental theorem of algebra(statement only). Relation between roots and coefficients, Transformation of equation, Equation of squared differences of a cubic and the nature of the roots of a cubic, reciprocal equations, Binomial equations and their properties, special roots of $x^n = 1$, Descartes' rule of signs, Upper bounds for the real roots; Theorems on imaginary, integral and rational roots; Newton's method for integral roots, Cardan's solution of the cubic and the nature of the roots of the cubic, Descartes' and Ferrari's methods of solution of biquadratic equations, Sturm's theorem(statement only) and its applications.

The inequality involving AM $\geq$ GM $\geq$ HM, Extreme values of sum and product, theorem of weighted means, Weierstrass' & Cauchy's inequalities, m-th and generalized m-th power theorems.

Unit -2 : Number Theory

Equivalence relations and partitions, Functions, Invertible functions, One to one correspondence and cardinality of a set, Permutations, sign of a permutation, inversions, cycles and transpositions.

Well-ordering principle of non-negative integers, Principles of Mathematical Induction of positive integers, Division algorithm, Divisibility and Euclidean algorithm., g.c.d, Bezout's Theorem, Primes, Euclid's Lemma, Statement of Fundamental Theorem of Arithmetic, Euclid's proof of infinitely many primes, Congruence relation between integers, Euler ϕ function, Euler's theorem, Fermat's Theorem.

Unit – 3 : Matrix Theory

Matrix of real and complex numbers, Algebra of matrices (structure only); symmetric and skew symmetric matrices, Hermitian and skew- Hermitian matrices; Orthogonal and Unitary matrices. Determinants, Laplace expansions, cofactors, adjoint, inverse of a matrix, Cramer`s Rule.

Elementary row and Elementary column operations on matrices; elementary matrices; Echelon form; Triangular factorization of matrices: A = LU, A = L D V, PA = LU, EA = R; product of elementary matrices and inverse of a matrix.

Rank of a matrix; Determination of rank (relevant results are to be stated only); System of linear equations in matrix form AX = B; Consistency and inconsistency (by rank method); Types and determination of solution (by using notion of rank), Solving linear systems using Gaussian elimination, Gauss-Jordan row reduction, Reduced row echelon form, Equivalent systems.

Eigenvalues, Eigenvectors of matrices and their examples and properties, Characteristic polynomial of a matrix, Cayley-Hamilton theorem and its application for determining inverse of square matrix.

Books Recommended :

- TituAndreescu and DorinAndrica, Complex Numbers from A to Z, Birkhauser, 2006.
- Dickson, Leonard Eugene (2009), First Course in the Theory of Equations. John Wiley & Sons, Inc. The Project Gutenberg eBook:http://www.gutenberg.org/ebooks/29785 3
- W.S. Burnstine and A.W. Panton, Theory of equations, Vol. 1. Fourteenth Edition, S. Chand and Co Ltd, New Delhi.
- Burton, David M. (2011), Elementary Number Theory (7th ed.), McGraw-Hill Education Pvt. Ltd. Indian Reprint.
- S. Barnard and J.M. Child, Higher Algebra, Surjeet Pbl., New Delhi, 1990
- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K.B. Dutta, Matrix and Linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- Gilbert Strang, Introduction to Linear Algebra, 4th edition, Welleseley-Camberidge press, 2009.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least TWO from each unit. FIVE questions out of EIGHT are to be answered.

SEM-II

Course: MTMDSC202T

Calculus (Marks: 100, Credits: 5)

Unit – 1 : Limits, Continuity and Differentiability

Limit of a function, ε - δ definition of a limit, Infinite limits, Continuity and types of discontinuities; Differentiability of a function, Relation between differentiability and continuity, Successive differentiation, Leibnitz theorem and its applications to functions such as $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n \sin x, (ax+b)^n \cos x$; Partial differentiation, Euler's theorem on homogeneous functions and its converse.

Unit – 2 : Mean Value Theorems and its Applications

Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Geometrical interpretation of mean value theorems and applications to monotonic functions and inequalities; Taylor's theorem, Taylor's series, Maclaurin's series expansions of $e^x, \sin x, \cos x, \log(1+x), (1+x)^m$; Indeterminate forms.

Unit -3 : Integral Calculus

Integration of rational and irrational functions, Evaluation of definite integrals, Special integrals, Reduction formulae, derivations and illustrations of reduction formulae for the integration of $\sin^n x, \cos^n x, \tan^n x, \sec^n x, (\log x)^n, \sin^n x \cos^m x, e^{ax}\cos^n x, (x^2+a^2)^n$ and their applications; Improper integrals, Beta and Gamma functions.

Unit – 4 : Applications

Tangent and Normal; Curvature; Asymptotes of general algebraic curves, Parallel asymptotes, Asymptotes parallel to axes; Envelopes; Maxima and Minima; Concavity and convexity, Points of inflexion; Tracing of Cartesian and polar curves; Length of plane curve and area bounded by plane curves, Volume and surface area of solids of revolution.

Graphical Demonstration (Teaching Aid)

1. *Plotting of graphs of function e^{ax+b}, log(ax + b), 1/(ax + b), sin(ax + b), cos (ax + b), |ax + b| and to illustrate the effect of a and b on the graph.*
2. *Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.*

3. Sketching parametric curves.

4. Obtaining volume and surface of revolution of curves.

5. Tracing of conics in Cartesian coordinates/polar coordinates.

Books Recommended:

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
- Gorakh Prasad, Differential Calculus (19th edition), Pothishala Pvt. Ltd., 2016.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
- Gorakh Prasad, Integral Calculus, Pothishala Pvt. Ltd., Allahabad, 2015.
- Gabriel Klambauer, Aspects of Calculus, Springer-Verlag, 1986.
- Howard Anton, I. Bivens& Stephan Davis, Calculus (10th edition), Wiley India, 2016.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and Mathematical analysis.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking two from each unit. FIVE questions out of EIGHT are to be answered.

SEM-III

Course - MTMDSC303T
Analytical Geometry and Vector Analysis (Marks: 100, Credits: 5)

Group A : Analytical Geometry (70 marks)

Unit-1: Translation and Rotation of axes; Homogeneous and General Equation of Second degree in two variables, Angle between the pair of straight lines, Bisectors of the angles between the pair of straight lines, Condition that the general equation of second degree should represent a pair of straight lines, Metric classification of conics, Reduction into Canonical forms; Polar equations of conics; Equations of tangent, normal, Chord of contact; Poles and polars.

Unit-2: Equations of planes in different forms, Planes passing through three points, Angle between two intersecting Planes, Parallelism and Perpendicularity of two planes, Distance of a point from a plane, Equations of the planes bisecting the dihedral angle between two planes, Position of the origin, Two intersecting planes, Pair of planes.

Different forms of Straight lines in 3D, Intersection of a straight line and a plane, Plane through a straight line, Coplanar lines, Skew lines, Distance of a point from a straight line, Shortest distance between two Skew lines.

Unit-3: Spheres. Cylindrical surfaces. Central Conicoids, Paraboloids, Plane sections of Conicoids, Generating lines, General equation of Second degree in three variables: Reduction into Canonical forms, Classification of Quadrics, illustrations of Quadric surfaces like Cone, Paraboloid, Ellipsoid, Hyperboloids. Tangents and Normals of Conicoids. Enveloping cone, Reciprocal cones and Right Circular Cone, Enveloping Cylinder and Right Circular Cylinder.

Group B : Vector Analysis (30 marks)

Unit-1: Scalar Triple Product. Vector Triple Product. Properties and Applications.

Unit-2: Vector functions. Limits, Continuity. Operations with vector-valued Functions. Gradient, Divergence and Curl. Irrotational Vector fields.

Unit-3: Differentiation and Integration of Vectors. Green's Theorem, Stokes' Theorem and Gauss' Theorem and their applications. Line integral, Surface and Volume integrals.

Graphical Demonstration (Teaching Aid)

1. *Tracing of conics in Cartesian coordinates/polar coordinates.*
2. *Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, paraboloid, and hyperbolic paraboloid using Cartesian coordinates.*

Books Recommended:

- Robert J. T. Bell, Elementary Treatise on Coordinate Geometry of three dimensions, Macmillan India Ltd.
- S. L. Loney, The Elements of Coordinate Geometry, Macmillan.
- Shanti Narayan and P. K. Mittal, Analytical Solid Geometry, S. Chand & Company Pvt Ltd., India.
- R. M. Khan, Analytical Geometry Of Two And Three Dimensions And Vector Analysis.
- K. C. Maity, and R. K.Ghosh, Vector Analysis, New Central Book Agency (P) Ltd., Kolkata (India).
- Murray R Spiegel, Schaum's Outline of Theory and Problems of Vector Analysis and Introduction to Tensor Analysis, McGraw Hill, 2009.
- Shanti Narayan, A Textbook of Vector Analysis, S. Chand & Company Pvt Ltd., 2010.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FIVE from Group A and THREE from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FIVE from Group A and THREE from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least THREE from Group A and at least one from Group B) are to be answered.

SEM-IV

Course - MTMDSC404T

Ordinary Differential Equations-I and Mechanics-I (Marks: 100, Credits: 5)

Group A : Ordinary Differential Equations-I (50 marks)

Unit-1: Introduction to ODEs of nth –order. General solution and particular solution. Explicit and implicit solutions. Linear and nonlinear ODEs.

First–order equations: Geometrical interpretation. Separation of variables. Exact equations. Integrating factors. Linear equations. Bernuolli's equation. Clairaut's equation. Singular solutions.

First-order Initial-Value Problems. Lipschitz condition. Statement of Picard's Existence and Uniqueness Theorem, Successive Approximations.

Application of first –order ODEs ---tangent and normals, orthogonal trajectories.

Unit-2: Linear systems and linear equations of higher order. Linearly independent solutions. Wronskian. Properties of linear systems and equations (statements only).

Second and third-order equations with constant coefficients. Solution of homogeneous and non-homogeneous equations. Method of undetermined coefficients. Method of variation of parameters.

Unit-3: Plane autonomous nonlinear systems. Phase-planes and trajectories. Critical points of plane autonomous linear systems. Stability of critical points. Nonlinear autonomous systems. Critical points. Linearisation about critical points. Stability of critical points. Hyperbolic critical points. Hartman-GrobmanTheorem(statement only). Liapunov stability. Liapunov functions. Liapunov's Theorems(statement only).

Volterra-Lotka Predator-Prey system.

The motion of the pendulum in a vertical plane. Critical points and trajectories.

Group B : Mechanics-I (50 marks)

Unit-1: Elementary statics: Coplanar system of forces, astatic equilibrium. Friction. Centre of Gravity. Forces in three dimensions. General Conditions of equilibrium. Statement of the principle of Virtual Work and examples. Proof for a system of coplanar forces. Stability of equilibrium. Reduction of forces in three dimensions. Poinsot's central axis.

Unit-2: Particle Kinematics: Concepts of displacement, velocity, acceleration of a particle moving on a plane curve. Components in Cartesian, plane-polar forms, tangent-normal forms. Momentum, angular momentum, torque. Kinetic and Potential energies. Conservation of energy and momentum.

Unit-3: Motion in a straight line. SHMs. Forced and damped oscillations. Motion in a resisting medium.

Motion in a plane. Projectile in vacuum. Central orbits. Inverse square law. Planetary motion. Stability of nearly circular orbits. Constrained motion.

Graphical Demonstration (Teaching Aid):

1. *Plotting of family of curves which are solutions of second order differential equation.*
2. *Plotting of family of curves which are solutions of third order differential equation.*

Books Recommended:

- G. F. Simmons, Differential Equations, CRC Press, 2017.
- S. L. Ross, Ordinary Differential Equations, Wiley, 2007.
- Earl A. Coddington, An Introduction to Ordinary Differential Equations, Dover Pub., 1989.
- Michael D. Greenberg, Ordinary Differential Equations, Wiley, 2012.
- James C Robinson, An Introduction to Ordinary Differential equations, CUP, 2004.
- Chaitanya Kumar, Ordinary and Partial Differential Equations, Sultan Chand and Co.
- Kenneth B. Howell, Ordinary Differential Equations: An Introduction to the Fundamentals (Second Ed.), CRC Press, 2015.
- R. C. Hibbeler, Engineering Mechanics: Statics and Dynamics, Pearson (India), 2019.
- S. L. Loney,The Elements of Statics and Dynamics, Part I STATICS, Arihant Publications India Ltd.,2019.
- S. L. Loney, An Elementary Treatise on the Dynamics of a particle and rigid bodies.
- M. C. Ghosh, Analytical statics, Shreedhar Prakashani, 2010.
- S. Ganguly, S. Saha, Analytical Dynamics of a Particle, New Central Book Agency, 2012.
- J. G. Chakravorty, P. R. Ghosh, Advanced Analytical Dynamics, U. N. Dhur and sons, 1982.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

Course - MTMDSC405T
Real Analysis-I (Marks: 100, Credits: 5)

Unit-1: Review of Algebraic and Order Properties of $\mathbb{R}$, ε-neighbourhood of a point in $\mathbb{R}$. Idea of countable sets, uncountable sets and some properties including uncountability of $\mathbb{R}$. Bounded and Unbounded sets. Suprema and Infima. Completeness Property of $\mathbb{R}$ and its equivalent properties. The

Archimedean Property, Density of Rational (and Irrational) numbers in $\mathbb{R}$. Interior points, Open set, Limit points, Isolated points, Adherent point and closure of a set, closed set, properties of open and closed sets, derived set, Dense and Nowhere dense sets, Bolzano-Weierstrass theorem for sets, compact sets in $\mathbb{R}$, Heine-Borel Theorem and its converse.

Unit-2: Sequences, Bounded sequence, Convergent sequence, Algebra of sequences, Limit and limit points of a sequence, liminf, limsup. Limit Theorems. Monotone Sequences, Monotone Convergence Theorem. Subsequences, Divergence Criteria. Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence and its properties, Cauchy's Convergence Criterion.

Unit-3: Infinite series, convergence and divergence of infinite series, Necessary condition for convergence, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, D'Alembert's ratio test, Raabe's test, Integral test. Alternating series, Leibniz test. Absolute and Conditional convergence.

Unit-4: Limits of functions (ε - δ approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, uniform continuity theorem.

Unit-5: Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum, theorem. Intermediate value property of derivatives, Darboux's theorem.

Unit-6: Monotone function: Definition and nature of points of discontinuity.
Functions of bounded variation**:** Definition and basic properties, Jordan decomposition, Nature of points of discontinuity.

Graphical Demonstration (Teaching Aid)

1. Plotting of recursive sequences.
2. Study the convergence of sequences through plotting.
3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot**.**
4. Study the convergence/divergence of infinite series by plotting their sequences of partial sum**.**
5. Cauchy's root test by plotting nth roots.
6. Ratio test by plotting the ratio of nth and (n+1)th term.

Books Recommended:

- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Gerald G. Bilodeau , Paul R. Thie, G. E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.

- Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S. K. Berberian, A First Course in Real Analysis, Springer Verlag, New York, 1994.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, Vol I, Springer.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill.
- Terence Tao, Analysis I, Hindustan Book Agency, 2006.
- S. Goldberg, Calculus and mathematical analysis.
- K. A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
- A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
- S. R. Ghorpade and B.V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course: MTMDSC406T
Group Theory-I and Number Theory (Marks: 100, Credits: 5)

Group A : Group Theory-I (50 marks):

Unit-1: Definitions, examples of semi-groups and groups; conditions for a semi-group to be a group. Order of a group, order of an element in a group and its elementary properties for finite groups; subgroup and its examples, centralizer in a group, center of a group, properties of subgroups, product of two subgroups.

Unit-2: Permutation group, symmetric group S_n, $n \geq 2$, inverse, order, decomposition, cycles & transpositions, conjugate of a permutation in S_n, even and odd permutations, alternating group A_n .

Unit-3: Finitely generated groups (definition and forms only), examples of groups generated by two elements, e.g., K_4 , D_4 , Q_8 in GL (2; R); cyclic groups and their properties and exercises. Cosets and their properties, Lagrange's theorem and its applications, normal subgroup and its properties, normalizer of a subgroup, quotient groups, one to one correspondence between normal subgroups and congruence relations in a group, Cauchy's theorem for finite abelian groups, converse of Lagrange's theorem for finite Abelian group.

Unit- 4: Definition and properties of group homomorphisms, isomorphism, group of symmetries of an equilateral triangle and square and their respective isomorphism with S_3 and D_4 ; 1^{st}, 2^{nd} and 3rd isomorphism theorems, classification of finite and infinite cyclic groups, Cayley's theorem .

Recommended Books:

- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.

- Dummit and Foote, Abstract Algebra, 3rd ed. Wiley, New York, 2003.
- M. K. Sen, S. Ghosh, P. Mukhopadhaya, S. K. Maity, Topics in Abstract Algebra, Fourth edition, University Press.

Group B : Number Theory (50 marks):

Unit -1: Review of elementary number theory: Applications of division algorithm, Euclid's lemma, the fundamental theorem of arithmetic, solution of Linear Diophantine equation in two variables.

Unit -2: Elementary congruence: Definition, examples and properties; Linear congruence and the Chinese remainder theorem, solution of system of linear congruences in one variable; Fermat's little theorem and its applications, Wilson's theorem.

Unit -3: Number theoretic Functions : The sum and number of divisors, its elementary properties and exercises, multiplicative functions and its properties, Mobius μ- function, Mobius' inversion law, Euler's phi function φ, some properties of Euler's phi-function, Euler's generalization of Fermat's little theorem, solution of linear congruences in one variable.

Unit- 4: Primitive roots and Quadratic Congruence: The order of an integer modulo n and its elementary properties, primitive roots for primes, Lagrange's theorem (statement only), composite numbers having primitive roots.
Definition and examples of quadratic residues modulo a prime, Legendre symbol and its properties, statements of Euler's criterion and Gauss's Lemma, quadratic reciprocity law, applications of quadratic reciprocity law in solving quadratic congruences.

Recommended Book:

- David M. Burton, Elements of number theory, Seventh edition, McGraw Hill Education (India) Private Ltd, New Delhi, 2007.

Other References:

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- D. S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of Abstract Algebra, 1997.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, Cambridge University Press.
- K. Ireland and M. Rosen, A classical introduction to modern number theory.
- Niven, Zuckerman and Montogomery, An Introduction to the Theory of Numbers, John Wiley and sons.
- Jones and Jones, Elementary Number Theory.
- G. H. Hardy and E. M. Wright, An Introduction to the Theory of Numbers, Oxford University Press, 1992.
- Bhaskaracharya Pratishthana, An excursion in mathematics.
- Aurther Engel, Problem solving strategies.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

Course: MTMDSC407T

Partial Differential Equations & Integral Transforms (Marks: 100, Credits: 5)

Group A : Partial Differential Equations (60 marks):

Unit-1: Definition, Derivation of PDE by elimination of (i) constants (ii) arbitrary function, PDEs of first order. Linear and quasi-linear PDEs and their geometrical meaning, Complete, Particular, General and Singular integrals, Lagrange's method. Nonlinear PDEs, Charpit's method, Special types of first order PDEs. Cauchy method of characteristics, Integral surfaces.

Unit-2: Higher order PDEs with constant coefficients. Second order PDEs : reduction to canonical forms and classification, separation of variables method. Solution of non-linear equations of second order by Monge's method. Cauchy problem, Cauchy-Kowaleskaya theorem (Statement only). Well posed and ill posed problems.

Unit-3: Three Fundamental PDEs. Hyperbolic equations: Wave equation (Homogeneous), D'Alembert's solution, domain of dependence and range of influence, problem of vibrations of a finite string. Elliplic equations: Laplace equation, Dirichlet and Neumann boundary value problems in a circular domain, theory of Green's function for equations in two independent variables. Parabolic equations: Diffusion equation, one dimensional heat conduction problem for a rod of finite length. Elementary solutions by separation of variables method. Existence and uniqueness of solutions.

Group B : Integral Transforms (40 marks):

Unit-1: The Fourier Transform

Definition and properties of Fourier transform, Transform of derivatives. Fourier cosine and sine transforms. Convolution theorem, Inverse Fourier transform. Parseval's Identity. Finite Fourier Transform. Application to solving ordinary and partial differential equations upto second order.

Unit-2:

The Laplace transform

Definition and properties. Sufficient conditions for the existence of Laplace Transform. Transform of derivatives. Convolution theorem. Inversion of Laplace Transform. Initial and final value theorems. Heaviside expansion theorem. Application to solving ordinary differential equations (upto third order) and partial differential equations (upto second order), simultaneous ordinary differential equations.

The Hankel transform

Definition and elementary properties. Inversion theorem, transform of derivatives of functions, Perseval's relation, Relation between Fourier and Hankel transform. Application to Boundary value problems.

Books Recommended:

- I. N. Sneddon, Elements of Partial Differential Equations, McGraw Hill.
- F. H. Miller, Partial Differential Equations, John Wiley and Sons.
- R. Courant and D. Hilbert, Methods of Mathematical Physics (2 Vols.), Wiley, New York, 1966.
- A. Sommerfeld, Partial differential equations in physics, Academic Press, New York, 1967.
- Erich Zauderer, Partial Differential Equations of Applied Mathematics, A Wiley- Interscience Publication, John Wiley and Sons, 1983.
- H. F. Weinberger, A first course in partial differential equations, Blaisdell, 1965.
- C. R. Chester, Techniques in partial differential equations, McGraw Hill, New York, 1971.
- Lawrence C. Evans, Partial Differential Equations, Second Edition, American Mathematical Society, 2014.
- K. S. Rao, Introduction to partial differential equations, Prentice Hall, New Delhi, 1997.
- T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa Publishing House, 2006.
- V. Vladimirov, Equations of mathematical physics. Dekker, New York, 1971.
- Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.

- L. Debnath and D. Bhatta, Integral Transforms and their applications, C.R.C. Press, 2007.
- I. N. Sneddon, The Use of Integral Transforms, McGraw Hill, 1951.
- J. W. Miles, Integral Transforms in Applied Mathematics, Cambridge University Press, 2008.
- M. R. Spiegel, Laplace Transforms, McGraw Hill, 1965.
- R. N. Bracewell, The Fourier Transform and Its Applications, McGraw Hill, 1986.
- E. J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FIVE from Group A and THREE from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FIVE from Group A and THREE from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least THREE from Group A and at least ONE from Group B) are to be answered.

SEM-V

Course: MTMDSC508T
Real Analysis-II (Marks: 100, Credits: 5)

Unit-1: Review of integration and definite integral. Differentiation and integration under the sign of integration.

Riemann integration: inequalities of upper and lower sums, Darboux integration, Darboux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two Definitions.

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 theorem of Integral Calculus, integration by parts, change of variable in an integral.

Unit-2: 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.

Unit-3: Fourier series: Definition of Fourier coefficients and series, Reimann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition.
Examples of Fourier expansions and summation results for series.

Unit-4: Power series, radius of convergence, Cauchy Hadamard Theorem.
Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem.

Books Recommended:

- K. A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
- S. Goldberg, Calculus and Mathematical analysis.
- Santi Narayan, Integral calculus, S. Chand, 2005.
- T. Apostol, Calculus I, II, Wiley, 2007.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course: MTMDSC509T
Ring Theory and Linear Algebra-I (Marks: 100, Credits: 5)

Group A : Ring Theory (50 marks):

Unit-1: Definition and examples of rings, properties of rings; integral domain, field and their properties, characteristic of a rings; definition and examples of subrings, subfields, Ideals; operations on ideals, factor ring and its properties; ideal generated by a subset of a ring, principal ideal, principal ideal domain (PID).

Unit-2: Ring homomorphisms and their examples and properties; Isomorphism, Isomorphism theorems I, II and III; correspondence theorem, field of quotients and their examples, embedding of an integral domain into its field of quotients.

Unit-3: Definition and examples of maximal and prime ideas, their basic properties, factor ring , characterizations of maximal and prime ideals of commutative rings.

Unit-4: Divisibility in Integral domains, irreducible and prime elements in commutative rings and their properties; unique factorization domain (UFD), Euclidean domain and their properties. Polynomial rings in one indeterminate over commutative rings, division algorithm and consequences, factorization of polynomials, reducibility and irreducibility tests, Eisenstein's irreducibility criterion and unique factorization in Z[x].

Recommended Books:

- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- Dummit and Foote, Abstract Algebra, 3rd ed. Wiley, New York, 2003,
- M. K. Sen, S.Ghosh, P. Mukhopadhaya, S. K. Maity,Topics in Abstract Algebra, Fourth edition, University Press .

Group B : Linear Algebra-I (50 marks):

Unit-1: Vector spaces and subspaces with examples; sum, intersection & direct sum of subspaces; linear combination of vectors, linear span, linear independence, basis and dimension; row space, column space, null space and left null space of a matrix. Equality of row rank, column rank and rank of a matrix. Fundamental theorems of Linear algebra (Part -1 & Part-2) and the theorem that every matrix maps its row space into its column space; quotient space and its dimension.

Unit-2: Inner product spaces and norms with examples, Cauchy-Schwarz inequality with applications, orthogonality, orthogonal complements, orthonormal sets and bases, Gram-Schmidt orthogonalisation process.

Unit-3: Introduction to linear transformations, rank-nullity theorem, algebra of linear transformations, representation of linear transformations between finite dimensional vector spaces by matrices and vice versa, relation of matrix representations due to change of basis.

Unit-4: Linear functionals, dual spaces and dual basis, bi-dual spaces, notion of covariant and contravariant vector in light of a vector space and its dual, eigen spaces of a linear operator, invariant subspaces and Cayley-Hamilton theorem for linear operator.

Recommended Books:

- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003.
- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.

Further References:

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- D. S. Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, 1997.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, Cambidge University Press.
- S. Lang, Linear Algebra, Undergraduate Texts in Math, Springer-Verlag, NewYork, 1989.
- A. R. Rao, P. Bhimashankaram, Linear Algebra. (Tata Mc-Graw Hill).
- P. Lax, Linear Algebra, John Wiley & Sons, New York, Indian Ed., 1997.
- Evar D. Nering, Linear Algebra and Matrix Theory.
- B. C. Chatterjee, Linear Algebra.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- S. K. Berberian, Linear Algebra, Dover publications, New York.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking ONE question from each unit of Group A and Group B both) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

Course: MTMDSC510M

Numerical Analysis (Theory & Practical) (Marks: 100, Theory-50, Practical-50, Credits: 5)

Unit-1: Representation of real numbers, machine numbers - floating point and fixed point. Definition and sources of error. Significant digits and error propagation in machine arithmetic operations.

Finding of roots for transcendental and polynomial equations: Bisection method, Secant method, Regula-falsi method, Newton-Raphson method. Rate of convergence of these methods. Fixed point iteration method. Roots of polynomial equations: Bairstow's method.

Unit-2: System of linear algebraic equations: Gaussian elimination and Gauss Jordan methods. LU decomposition method. Gauss -Jacobi method, Gauss Seidel method and their convergence analysis. Ill-conditioned systems. Extreme eigenvalues of a square matrix (Power method). Eigenvalue location: Gerschgorin theorem.

Unit-3: Finite difference and shift operators. Table oriented interpolation formulae: Newton's (forward and backward) interpolation, Central difference interpolation: Stirling's and Bessel's formulae. Propagation of Errors. Lagrange's interpolation and Newton's divided differences interpolation. Error terms and bounds. Hermite interpolation. Piecewise polynomial interpolation: Cubic spline. The Weierstrass approximation theorem (Statement only).

Unit-4: Numerical Integration: Newton Cotes' formula, Trapezoidal rule, Simpson's 1/3rd rule, Weddle's rule, composite trapezoidal rule, composite Simpson's 1/3rd rule. Errors. Gaussian quadrature formula. Numerical differentiation: Methods based on interpolation, undetermined coefficients and finite differences.

Unit-5: Numerical solution of ordinary differential equations: The method of successive approximations (Picard's method), Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four. Multistep methods: Milne's predictor corrector method.

Numerical solution of partial differential equations by finite differences methods. One dimensional Heat equation: FTCS and Crank-Nicolson Methods. Laplace and Poisson equations: Solution by five point formula. Cauchy problem for the wave equation: Explicit finite difference method.

Practical (Programming problems using C):

1. Solution of transcendental and algebraic equations by
   i) Newton Raphson method.
   ii) Regula Falsi method.
2. Solution of system of linear equations
   i) Gaussian elimination method
   ii) Gauss-Seidel method
3. Interpolation
   i) Newton's forward difference interpolations
   ii) Newton's backward difference interpolations
   iii) Lagrange Interpolation
4. Numerical Integration
   i) Trapezoidal Rule
   ii) Simpson's one third rule
5. Method of finding the largest Eigenvalue (in magnitude) by Power method (up to 4×4 matrices).
6. Solution of ordinary differential equations
   i) Euler method
   ii) Runge Kutta method (order 4)
7. Solution of One dimensional Heat equation by FTCS Method / Crank-Nicolson Method.

Books Recommended:

- Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
- A. Gupta and S. C. Bose, Introduction to Numerical Analysis, Academic Publishers, Calcutta, 1989.
- M. Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa, 2007.
- 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.
- C. F. Gerald and P. O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
- Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
- James B. Scarborough, Numerical Mathematical Analysis, Oxford and IBH publishing co., 1966.
- K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
- A. Ralston and P. Rabinowitz, A First Course in Numerical Analysis, McGraw Hill, N.Y., 1978.
- E.V. Krishnamurthy and S. K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
- J. H. Mathews, Numeical Methods for Mathematics, Science, and Engineering, 2nd ed., Prentice-Hall, Inc., N.J., USA, 1992.
- E. A. Volkov, Numerical Methods, Mir Publishers, Moscow, 1986.
- Yashavant Kanetkar, Let Us C, BPB Publications, 2016.

Question pattern for End Semester Examination

Theory(50 marks):

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Practical(50 marks):

A. 25 marks (to be evaluated by the University):

(i) Lab notebook : 5 marks

(ii) One practical problem : 10 marks (To be evaluated by external expert)

(iii) Viva – 10 marks (To be evaluated by external expert)

B. 25 marks (to be evaluated by the respective Colleges):

(i) Attendance (considering both the theory and the practical classes) – 5

(ii) Continuous assessment / Internal assessment – 20 . Class tests (at least two) – 10 marks and viva – 10 marks.

Course: MTMDSC511T

Multivariate Calculus and Metric Spaces (Marks: 100, Credits: 5)

Group A: Multivariate Calculus (Marks: 50)

Unit-1: Functions of several variables, limit and continuity of functions of two or more variables. Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems.

Unit-2: Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical coordinates. Change of variables in double integrals and triple integrals.

Unit-3: Definition of vector field, divergence and curl. Line integrals, Applications of line integrals. Fundamental theorem for line integrals, conservative vector fields, independence of path.
Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem.

Group B: Metric Spaces (Marks: 50):

Unit-1: Metric spaces: Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, subspaces, dense sets, separable spaces. Sequences in Metric Spaces, Cauchy sequences. Complete Metric Spaces, Cantor's theorem.

Unit-2: Continuous mappings, sequential criterion and other characterizations of continuity, Uniform continuity, Connectedness and its properties, connected subsets of R.

Unit-3: Compactness: Sequential compactness, Heine-Borel property, Totally bounded spaces, finite intersection property, and continuous functions on compact sets.
Contraction mappings, Banach Fixed point Theorem and its application to first order ordinary differential equation.

Books Recommended:

- G. B. Thomas and R. L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
- E. Marsden, A. J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.
- James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House, 2nd Ed., 2002.
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer New York, 2012.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill, 3rd Ed., 2013.

- J. Marsden and Tromba, Vector Calculus, McGraw Hill, 6th revised international Ed, 2012.
- K. C. Maity and R. K. Ghosh, Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
- Terence Tao, Analysis II, Hindustan Book Agency, 3rd Ed., 2015.
- M. R. Speigel, Schaum's outline of Vector Analysis. Tata McGraw-Hill, 2009.
- Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- M. N. Mukherjee, Elements of Metric Spaces, Academic Publishers.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking at least ONE question from each unit of Group A and Group B) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

SEM-VI

Course: MTMDSC612T
Operations Research and Game Theory (Marks: 100, Credits: 5)

Unit-1: Origin and development of Operations Research (OR), Definition and characteristics of OR, objectives and limitations of OR, Mathematical formulation of real-life problems.

Introduction to linear programming problem (L.P.P.). Basic solutions and Basic Feasible Solution (B.F.S), matrix formulation of L.P.P., degenerate and non-degenerate B.F.S.

Hyperplane, convex set, extreme points, convex hull and convex polyhedron. Supporting and Separating hyperplane. Reduction of feasible solution to B.F.S., correspondence between B.F.S. and extreme points. Fundamental theorem of L.P.P.

Unit-2: Theory of simplex method, optimality and unboundedness. Simplex algorithm and its tableau format, artificial variables, Two-phase method, Charne's-M Method.

Unit-3: Degeneracy in L.P.P. and its resolution. Theory of Duality, Complimentary slackness theorem, Dual-simplex method, primal-dual relationships, economic interpretation of the dual.

Unit-4: Revised simplex method, Post Optimality Analysis (changes in (i) objective function, (ii) requirement vector, (iii) coefficient matrix; Addition and deletion of variables, Addition of constraints).

Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem, Traveling Salesman problem.

Unit-5: Game theory: Rectangular games. Pure strategy and Mixed strategy. Saddle point and its existence. Optimal strategy and value of the game. Formulation and solution of two-person zero-sum games. Algebraic method. Graphical method and Dominance method of solving Rectangular games. Linear programming method for solving a game.

Books Recommended:

- Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
- F. S. Hillier and G. J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.
- Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006.
- G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.
- S. I. Gass, Linear Programming: Methods and Applications, McGraw Hill, New York.
- Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, Sultan Chand & Sons.
- P. M. Karak, Linear Programming and Theory of Games, New Central Book Agency.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course: MTMDSC613T
Group Theory-II and Ordinary Differential Equations-II (Marks: 100, Credits: 5)

Group A :Group Theory-II (50 marks)

Unit-1: Direct products: Definition of external and internal direct product, isomorphism between external and internal direct products, U_n as external direct product, fundamental theorem of finite abelian group and its applications, theorem related to the number of non isomorphic abelian groups (statement only) and its applications.

Unit-2: Group actions, orbits, stabilizers, centralizer, normalizer of a subgroup, orbit–stabilizer theorem, applications of group actions, extended Cayley's theorem, Index theorem, action of a group on itself by conjugation, class equation and consequences, Burnside's theorem, Cauchy's theorem, Sylow p- subgroups, Sylow's Theorems 1st, 2nd, 3rd and their applications.

Unit-3: Composition series, Jordan-Holder theorem, solvable groups.

Recommended Books:

- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- Dummit and Foote, Abstract Algebra, 3rd ed. Wiley, New York, 2003.
- M. K. Sen, S. Ghosh, P. Mukhopadhaya, S. K. Maity, Topics in Abstract Algebra, Fourth edition, University Press.

Group B: Ordinary Differential Equations-II (50 marks):

Unit-1: Power series solution of linear Ordinary Differential Equations of second order. Ordinary points and regular singular points. The point at infinity as a regular singular point. Solutions about ordinary points, solutions about regular singularity. Frobenius' method.

Unit-2: Special Functions. Hypergeometric equation and hypergeometric series. Bessel's and Legendre's equation in real domain. Legendre polynomials. Rodrigue's formula. Orthogonality property. Generating function. Recurrence relations. Legendre series expansion. Solution of Bessel's equation and Bessel's function of first kind. Recurrence relations and other properties. Generating functions. Bessel series expansion.

Unit-3: Self-adjoint equations of second-order. Sturm's separation and comparison theorems. Sturm-Liouville Problems. Eigenvalues and eigenfunctions. Properties of eigenvalues. Properties of eigenfunctions. Orthogonality

of eigenfunctions. Generalised Fourier Series in terms of eigenfunctions. Parseval's inequality (statement). Green's function and solution of a Sturm-Liouville problem.

Books Recommended:

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- D. S. Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, 1997.
- Shapeley L. Ross, Differential Equations, John Wiley, 2007.
- E. A. Coddington, R Carlson, Linear Ordinary Differential Equations, PHI, 2007.
- G. Birkoff, Ordinary Differential Equations, Wiley India, 2016(4^{th} Ed.).
- K. S. Bhamra, Ordinary Differential Equations: A Graduate Text, Alpha Science, 2015.
- James C. Robinson, An Introduction to Ordinary Differential Equations, Cambridge India, 2013.
- A. K. Nandakumaran, P. S. Datti, R. K. George, Ordinary Differential Equations, Cambridge IISc, 2017.
- A. Chakrabarti, Elements of Ordinary Differential Equations and Special Functions, New Age International, 1996.
- D. Somasundaram, Ordinary Differential Equations: A First Course, Narosa, 2013.
- W. W. Bell, Special Functions for Scientists and Engineers, Dover Publications in Mathematics, 2004.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking at least ONE from each unit of Group A and Group B) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

Course: MTMDSC614T

Probability & Statistics (Marks: 100, Credits: 5)

Unit-1: Sample space, Axiomatic definition of probability, conditional probability, Bayes' Theorem. Independent events. Random variables (continuous and discrete). Distribution function. Probability density function, probability mass function. Mathematical expectation. Moments. Skewness and kurtosis. Moment generating function. Characteristic function. Discrete distributions: Uniform, binomial, Poisson, geometric, negative binomial. Continuous distributions: uniform, normal, exponential, gamma, beta.

Unit-2: Joint distribution function and its properties. Joint probability density functions, marginal and conditional distributions, expectation of a function of two random variables, conditional expectations, independent random variables, correlation coefficient, bivariate normal distribution, joint moment

generating function (jmgf) and calculation of covariance from jmgf. Linear and quadratic regression for two variables. Method of least squares.
Bivariate and multivariate normal distributions. Multinomial distribution. Special distributions : chi-square, t and F distributions.

Unit-3: Chebyshev's inequality, Convergence in probability, Statements of weak and strong laws of large numbers and their interpretations. Central limit theorem for independent and identically distributed random variables with finite variance. Markov chains. Chapman-Kolmogoroff equations. Classification of states.

Unit-4: Random Samples, Sampling Distributions, Exact sampling distributions, large samples, distribution of $\left(\overline{X},\ S^2\right)$ in sampling from a normal population. Point estimation. Unbiased estimator. Maximum Likelihood estimation. Consistent estimator. Confidence intervals.

Unit-5: Testing of Hypothesis about parameters. Null hypothesis, alternative hypothesis, simple and composite hypotheses. Test-statistic, P-Value. Level of significance, critical region, errors type I and II, Power of a test.

Hypothesis test for means, proportions and variances for single population. Confidence intervals for means, variances and proportions for single population.

Inferences for two populations. Confidence interval for difference of mean and difference of proportions, Hypothesis testing for ratios of variances. Interval for ratios of variances. Hypothesis testing for difference of means, and difference of proportions.

Chi-square test of goodness of fit.

Books Recommended:

- Sheldon Ross, A First Course in Probability, Pearson, 2022.
- Alexander M Mood, Franklin A Graybill, Duane C Boes, Introduction to the Theory of Statistics, Tata McGraw – Hill, 3rd Ed., Reprint 2007.
- Robert V Hogg, Elliot Tannis, Dale Zimmerman, Probability and Statistical Inference, Pearson Education 2021.
- Joseph K Blitzstein, Jessica Hwang, Introduction to Probability, CRC Press, 2019.
- BLS Prakasha Rao, A First Course in Probability and Statistics, World Scientific.
- Morris H DeGroot, Probability and Statistics, Pearson, 2016.
- Irwin Miller, Marylees Miller, John E Freund Introduction to Mathematical Statistics with Applications, Pearson Education, 2006.
- A Gupta, Ground work of Mathematical Probability and Statistics, Academic Publishers, 1983.
- Kai Lai Chung, A Course in Probability Theory, Academic Press(USA) 3rd Ed., 2001.
- T K Chandra, D Chatterjee, A First Course in Probability, Narosa, 3rd Ed., 2005.
- V K Rohatgi, A K Md E Saleh, An Introduction to Probability and Statistics, Wiley (India), 2nd Ed., Reprint 2009.
- S Lipschutz, J Schiller, Introduction to Probability and Statistics, Schaum's Outlines, Tata McGraw Hill, 2006.
- K R Parthasarathy, Introduction to Probability and Measure, McMillan, 1978.

- William Feller, An Introduction to Probability Theory and its Applications (Vol.I) John Wiley, 1968.
- William Feller, An Introduction to Probability Theory and its Applications (Vol.II) John Wiley, 1971.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course- MTMDSC615T

Complex Analysis (Marks: 100, Credits: 5)

Unit-1: The spherical representation of complex numbers, Riemann Sphere, Stereographic projection, distance between the stereographic projections, point at infinity and its deleted neighbourhood, the extended complex plane.

Unit-2: Functions of a complex variable, its limit, continuity and differentiability; analytic functions, exercises of analytic and non-analytic functions; exponential, logarithmic function and trigonometric functions; Cauchy-Riemann equations, sufficient conditions for differentiability, harmonic functions, The Milne-Thompson method; branch of a Logarithm.

Unit-3: Complex integration along a path, path addition, contours, contour integrals and its examples, upper bounds for moduli of contour integrals; Cauchy-Goursat theorem (statement only) and its consequences, Cauchy's integral formula, Cauchy's integral formula for derivative; Morera's theorem, Liouville's theorem, fundamental theorem of classical algebra, Schwarz's Reflection principle.

Unit-4: Elementary Theory of power series, Abel's Theorem on convergence of the power series (statement only), Cauchy-Hadamard theorem, analyticity of power Series, Weierstrass theorem on uniformly convergent series of analytic functions; Taylor's theorem and Laurent's theorem; Zeros of an analytic function, classification of singularities, Riemann's removal singularity theorem, limit points of zeros and poles.

Unit-5: Meromorphic functions, Calculus of residues, Cauchy's residue theorem, argument principle, Rouche's theorem, evaluation of real definite integrals using residue theorem.

Unit-6: Uniqueness theorem and maximum modulus theorem; brief studies of conformal mappings and Mobius transformations.

Recommended Books:

- J. B. Conway, Functions of One Complex Variable, Springer-verlag, 1978.
- S. Ponnusamy & H. Silverman, Complex Variables with Applications.

- R. V. Churchill and J. W. Brown, Complex Variables and Applications.

Further References:

- L. V. Ahlfors, Complex Analysis, third edition, McGraw-Hill.
- S. Ganguly and D. Mandal, Lecture Course on Complex Analysis, Academic Publishers, 2018.
- A. I. Markushevich, Theory of Functions of a Complex Variable (Vol. I, II and III).
- E. C. Titchmarsh, The Theory of Functions, Oxford University Press.
- E. T. Copson, An Introduction to the Theory of Functions of a Complex Variable.
- Narasimhan, Raghavan and Nievergelt, Yves, Complex Analysis in One Variable, second edition, Birkhauser Boston, Inc., MA, 2001.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each are to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

SEM-VII

Course- MTMDSC716T

Topology (Marks: 100, Credits: 5)

Unit-1: Topological spaces, examples of topological spaces, bases and sub-bases, open and closed sets. Closure and interior – their properties and relations; exterior, boundary, accumulation points, derived sets, adherent point, dense set, G_δ and F_σ sets. Kuratowski closure operator, neighbourhood systems. Statements of theorems concerning topology generated by Kuratowski closure operator and neighbourhood systems. Subspace or relative topology and metric topology.

Unit-2: Continuous, open, closed maps and their examples and characterizations, pasting lemma, homeomorphism and topological properties, hereditary property.

Unit-3: 1st and 2nd countability axioms, separability, Lindeloffness and their relationships; characterizations of accumulation points in a 1st countable space w.r.t. sequences and Heine's continuity criterion.

Unit-4: T_i spaces (i = 0, 1, 2, 3, 3½, 4, 5), their examples and hierarchy, characterizations and basic properties; Urysohn's lemma and Tieze's extension theorem (statement only).

Unit-5: Connected, disconnected spaces and their examples; connectedness on the real line, basic properties of connected spaces and components.

Unit-6: Compactness, its basic properties and characterizations, Alexander's subbase theorem (statement only), continuous functions and compact sets, compactness and separation axioms.

Unit-7: Product topology of finite number of topological spaces, projection maps; product theorems of finite number of (i) Hausdorff spaces, (ii) connected spaces and (iii) compact spaces.

Recommended Books:

- K. D. Joshi, Introduction to General topology, Wiley Eastern Ltd.
- J. Munkres, Topology, A first course, Prentice Hall, India.

Further References:

- C. Kosniwski, A first Course in Algebraic Topology, Cambridge University Press.
- S. Willard, General Topology, Addison-Wesley.
- J. Dugundji , Topology, Allyn and Bacon.
- J. L. Kelley, General Topology, Van Nostrand.
- G. F. Simmons, Introduction to topology and modern analysis, McGraw Hill.
- Martin D. Crossley, Essential topology, Springer- Verlag.
- Engelking, General Topology, Polish Scientific Publishers, Warszawa.
- L. Steen and J. Seebach, Counter examples in Topology.
- B. C. Chatterjee, S. Ganguly and M. Adhikari, A text book of Topology, Asian Books Pvt.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course- MTMDSC717T
Field Extension & Linear Algebra-II (Marks: 100, Credits: 5)

Group A: Field Extension (50 marks):

Unit-1: Definition and examples of extension fields, the degree of an extension field, finite extension field, algebraic element, algebra of algebraic elements, algebraic and transcendental numbers.

Unit-2: Splitting field for polynomial over a field, examples of splitting fields, existence and uniqueness of splitting field, algebraic and transcendental extensions and their characterizations, fundamental theorem of field theory, algebraic closure and algebraically closed field, fundamental theorem of algebra. Some impossibility theorem in the ruler and compass constructions proved as an application to algebraic extensions.

Unit-3: Prime Field and its representation; Finite fields or Galois fields, their orders, classification of finite fields, properties of finite fields, isomorphism between two finite fields having the same number of elements.

Unit-4: Group of automorphisms of a field and its fixed field; group of automorphisms G(K; F) of a field K relative to its subfield F; Galois group of a polynomial f(x) over a field F and its exercises; separable and normal extension of a field, fundamental theorem of Galois theory (statement only); theorem concerning the solvability by radicals of roots of a polynomial and solvability of its Galois group (statement only).

Recommended Books:

- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- Dummit and Foote, Abstract Algebra, 3rd ed. Wiley, New York, 2003.

Group B: Linear Algebra-II (50 marks):

Unit-1: Matrix polynomial, minimal polynomial, characteristic polynomials, eigen space of a matrix, algebraic and geometric multiplicities, semi simple (or diagonalization) of matrices and its characterizations, spectral decomposition of semi simple matrices.

Unit-2: Similarity of matrices, reduction to triangular forms, determinant divisors and invariant factors. Jordan canonical form, rational canonical form (statement only) and their examples.

Unit-3: The adjoint of a linear operator and it properties, least squares approximation; A = QR matrix factorization, minimal solutions to systems of linear equations; normal, self-adjoint and unitary operators

and their elementary properties, orthogonal projections, spectral theorem for the self adjoint and normal operators on finite dimensional vector spaces.

Unit-4: Bilinear forms, quadratic forms, Hermitian forms, positive definite Hermitian forms & its direct sum decomposition theorem, principal minor criterion, signature, Sylvester law of inertia.

Recommended Books:

- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003.
- S. K. Berberian, Linear Algebra, Dover publications, New York.

Further References:

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- D. S. Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, 1997.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, Cambidge University Press.
- S. Lang, Linear Algebra, Undergraduate Texts in Math, Springer-Verlag, NewYork, 1989.
- A. R. Rao, P. Bhimashankaram, Linear Algebra. (Tata Mc-Graw Hill).
- P. Lax, Linear Algebra, John Wiley & Sons, New York, Indian Ed. 1997.
- Evar D. Nering, Linear Algebra and Matrix Theory.
- B. C. Chatterjee, Linear Algebra.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- I. S. Luthar and I. B. S. Passi, Field Theory (Algebra, Vol. 4), Narosa Publishing House, Kolkata, 2010.
- Seymour Lipschutz, 3,000 Solved Problems in Linear Algebra.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (ONE question from each unit of Group A and Group B) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

SEM-VIII

Course- MTMDSC818T
Functional Analysis (Marks: 100, Credits: 5)

Unit-1: Review of Metric spaces: Metric Spaces, Hölder and Minkowski inequalities (statement only), continuity and uniform continuity, completeness, compactness, connectedness.
Baire's category theorem, Banach's fixed point theorem (statement only) and its application to solutions of certain systems of linear algebraic equations.

Unit-2: Real and Complex linear spaces. Normed linear space, Normed induced metric. Banach spaces, the spaces R^n, C^n, C [a, b], C_0, C, lp(n)($1\leq p\leq\infty$), lp($1\leq p\leq\infty$). Riesz's lemma. Finite dimensional normed linear spaces and subspaces, completeness, compactness criterion, Quotient space, equivalent norms and its properties.

Unit-3: Bounded linear operators, various expressions for its norm. Spaces of bounded linear operators and its completeness. Inverse of an operator. Linear and sublinear functionals, Hahn-Banach theorem in normed linear spaces (proof for real normed linear spaces only) and its applications.

Unit-4: Conjugate or Dual spaces, Examples, Separability of the Dual space. Reflexive spaces, weak and weak* convergence. Uniform boundedness principle and its applications. The Open mapping Theorem(statement only) and the Closed graph Theorem.

Unit-5: Inner product spaces and Hilbert spaces, examples of Hilbert spaces, continuity of inner product, C-S inequality, basic results on Inner product spaces and Hilbert spaces, parallelogram law, Pythagorean law, Polarization identity, orthogonality, orthonormality, orthogonal complement. The Riesz representation theorem, Bessel's inequality. Convergence of series corresponding to orthogonal sequence, Fourier coefficient, Perseval identity. Riesz- Fischer Theorem.

Books Recommended:

- W. Rudin, *Functional Analysis*, Tata McGraw Hill.
- B.V. Limaye, *Functional Analysis*, Second Edition, New Age – International limited, Madras.
- G. Bachman & L. Narici, *Functional Analysis*, Academic Press, 1966.
- N. Dunford & J. T. Scwarz, Linear operators, Vol – I & II, Interscience, New York, 1958.
- L. V. Kantorvich and G.P. Akilov, *Functional Analysis*, Pergamon Press, 1982.
- E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley Eastern, 1989.
- I. J. Madox, *Elements of Functional Analysis*, Universal Book Stall, 1992.
- A. H. Siddiqui, K. Ahmed and P. Manchanda, *Introduction to Functional Analysis with applications*, Anshan Publishers, 2007.
- A. E. Taylor, *Functional Analysis*, John Wiley and Sons, New York, 1958.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course- MTMDSC819T

Mechanics-II (Marks: 100, Credits: 5)

Unit-1: Kinematics of a system of particles. Centre of Mass. Linear Momentum. Angular Momentum. Conservation of linear and angular momenta. Break-up of kinetic energy and angular momentum with respect to centre of mass and about centre of mass. Velocity and acceleration components in three-dimensional Cartesian, cylindrical polar and spherical co-ordinates of a moving particle in space.

Unit-2: Dynamics of a rigid body. Degrees of freedom of a rigid body. Body and space reference systems. Euler angles. Infinitesimal rotations. Angular velocity. Angular momentum. Inertia tensor. Moments and products of inertia. Parallel and principal axis theorem. Kinetic energy of rotation. Moment of inertia about axis of rotation. Principal axis and principal moments of inertia. Euler's equation of motion. Torque-free motion of a symmetrical top.

Unit-3: Constraints. Forces of constraints. Holonomic, schleronomic, rheonomic, non-holonomic. Generalised co-ordinates. Degrees of freedom. Principle of Virtual work (statement only). D'Alembert's principle. Derivation of Lagrange's equations for a system under holonomic constraints in a conservative force-field. Lagrangian function. Ignorable co-ordinates. Routhian and Routh's equations. Lagrange's equations for a system with non-holonomic constraints.

Unit-4: Hamiltonian function and Hamilton's equations. Expression for Kinetic energy. Integral of energy. Conservation of energy. Hamiltonian for systems with time-independent constraints.

Small oscillations. Potential energy and equilibrium. Derivation of coupled equations of motion. Normal modes and normal coordinates. Examples of (i) double pendulum (ii) two coupled pendulums (iii) Linear triatomic molecules.

Unit-5: Hamilton's Principle. Hamilton's and Lagrange's equations from Hamilton's principle. Principle of Least Action. Canonical Transformations and generating functions. Poisson's brackets. Lagrange brackets. Phase-space and Liouville's theorem. Hamilton-Jacobi equations. Solution of (i) problem of harmonic oscillator (ii) Kepler's problem by solving Hamilton-Jacobi equation. Action and angle variables. Problem of the harmonic oscillator through action-angle variables.

Books Recommended:

- S. L. Loney, An Elementary Treatise on the Dynamics of a Particle and Rigid Bodies, New Ge International, 2016.
- A. S. Ramsey, Dynamics (Part 2), CBS Publishers, 2002.
- E. T. Whittaker, A Treatise on the Analytical Dynamics of Particles and Rigid Bodies, CUP, 1998.
- F. Grantmacher, Lectures in Analytical Mechanics, MIR Publications Moscow, 1975.

- H. Goldstein, Classical Mechanics, Narosa Publishing House, 1980.
- N. M. J. Woodhouse, Introduction to Analytical Dynamics, Springer (London), 2009.
- Grant R. Fowles, George L. Cassiday, Analytical Mechanics, Thomson Brookes/Cole USA, 2005.
- Louis N. Hand, Janet D. Finch, Analytical Mechanics, CUP, 1998.
- R. Douglas Gregory, Classical Mechanics, CUP, 2001.
- J. L. Synge, B. A. Griffith, Principles of Mechanics, McGraw Hill NY, 1970.
- N. C. Rana, P. S. Joag, Classical Mechanics, Tata McGraw Hill Publishing Company Ltd., 1998.
- K A I L W. Gamalath, Introduction to Analytical Mechanics, Narosa, 2011.
- L. N. Katkar, Problems in Classical Mechanics, Narosa, 2013.
- Madhumangal Pal, A Course on Classical Mechanics, Narosa, 2009.
- S. Deo, R. Rahman, Classical Mechanics: An Introduction, Narosa, 2023.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Course- MTMDSC820T

Discrete Mathematics & Differential Geometry (Marks: 100, Credits: 5)

Group A: Discrete Mathematics (50 marks)

Boolean Algebra

Unit-1: Huntington postulates for Boolean algebra, De Morgan's laws, Boolean expressions, Truth tables, Boolean functions, Normal forms. Quine Mc-Cluskey method. Karnaugh maps.
Logic diagrams, Switching circuits, Applications of switching circuits.

Graph Theory

Unit-2: Undirected graphs, Directed graphs, Geometrical representation of graphs, Handshaking lemma due to Euler and basic properties of graphs. Walks, Trails, Paths, Circuits and cycles with their properties. Connected and disconnected graphs, components of a graph, complete graphs, complement of a graph, complementary graphs, Ramsey problem. Bipartite graphs.

Eulerian circuits and paths, Eulerian graphs, Königsberg bridge problem, Hamiltonian paths and cycles, Hamiltonian graphs, examples of Eulerian and Hamiltonian graphs.

Unit-3: Trees and forests with their properties. Minimally connected graphs, spanning trees. Weighted graphs, Kruskal's algorithm for a minimal spanning tree. Rooted tree, binary tree.

Matrix representation of graphs, adjacency matrices of graphs and digraphs and their properties, incidence matrices of graphs and digraphs and their properties.

Books Recommended:

- N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall of India, 2000.
- F. Harary, Graph Theory, Addison-Wesley Publishing Company, 1972.

Group B: Differential Geometry (50 marks)

Unit-1: Curves in the plane, arc length, reparametrization, closed curves, level curves versus parametrized curves, curvature, plane curves; space curves, parametrized space curves - its curvature, normal, binormal and torsion, Frenet formulae; simple closed curves, the isoperimetric inequality, the four vertex theorem.

Unit-2: Surfaces in R^3, smooth surfaces, smooth maps, tangents and derivatives, normals and orientability, examples of surfaces: Level surfaces and Quadric surfaces, ruled surfaces and surfaces of revolution.

Unit-3: Lengths of curves on surfaces, first fundamental form, Isometries of surfaces, conformal mapping of surfaces. The second fundamental form, Gauss and Weingarten maps, Normal and geodesic curvatures, parallel transport and covariant derivative.

Unit-4: Gaussian and mean curvatures, principal curvatures of a surface, Euler's theorem, surfaces of constant Gaussian curvatures, surfaces of constant mean curvatures, geodesics.

Books Recommended:

- Andrew Pressley, Elementary Differential Geometry, Springer, Second edition, 2010.
- Christian Bar, Elementary Differential Geometry, Cambridge University Press, 2011.

Other References:

- J. A. Bondy and U.S.R. Murty, Graph Theory with Applications, Macmillan, 1976.
- D. S. Malik, M. K. Sen and S. Ghosh, Introduction to Graph Theory, Cengage Learning Asia, 2014.
- K. H. Rosen, Discrete Mathematics and its applications with combinatorics and Graph Theory, McGraw Hill, 2017.
- B. H. Arnold, Logic and Boolean Algebra, Prentice Hall, 1962.
- M. Do Carmo, Differential Geometry of curves and surfaces, Prentice-Hall, 1976.
- J. A. Thorpe, Elementary topics in Differential Geometry, Springer-Verlag (UTM), 1979.
- B. O'Neill, Elementary Differential Geometry, Academic, 1996.
- A. Gray, Modern Differential Geometry of Curves and Surfaces, CRC Press, 1993.
- Serge Lang, Differential Manifolds.
- I. M. Singer, J. A Thorpe, Lecture notes on Elementary topology and Geometry, Springer – Verlag, 1967.
- S. Sternberg, Lectures on Differential Geometry, Prentice-Hall, 1964.
- K. Tapp, Differential Geometry of Curves and Surfaces; Undergraduate Texts in Mathematics, Springer, 2016.
- M. Spivak, A Comprehensive Introduction to Differential Geometry-Vol. I; Publish or Perish, Boston, 1970.

- Thomas F. Banchoff and Stephen T. Lovett, Differential Geometry of Curves and Surfaces, A. K Peters/CRC press, 2010.
- W. Klingenberg, A course in Differential Geometry, Springer-Verlag, New York, 1978.
- D. S. Malik and M. K. Sen, Discrete Mathematics: Theory and Applications, Cengage Learning India Private Limited, Delhi, 2010.
- A. H. Basson and D. J. O'Connor, Introduction to Symbolic Logic, Surjeet Publications, Delhi, 2017.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

Course- MTMDSC821M
Data Science (Marks: 100, Credits: 5)

Theory [50 marks]:

Unit-1: Review of programming with Python.

Unit-2: Statistics Essentials for Data Science (Descriptive statistical methods-graphical representation &summary measures;Correlation; Regression-simple and multiple regression models; Probability, Distributions, Inference-Hypothesis testing and estimation).

Unit-3: Odds ratio and interpretation; Binary Logistic Regression with single predictor: Interpreting the parameters, Inference for the parameters (Description of testing procedures).

Unit-4: Clustering and Classification: Hierarchical clustering for continuous and categorical data-different choices of proximity measures, Agglomerative and Divisive algorithms, K-means clustering, optimum choice of the number of clusters. Discrimination between two multivariate normal populations, Probabilities of misclassification and their estimation.

Unit-5: Qualitative idea of big data; Missing Value mechanism:Informative or non-informative missingness; MCAR, MAR and MNAR. Mean imputation, Hot and cold deck imputation

Practical [50 marks]

1. Lab (Hands-on: using Python): Data Analytics Process with Python: Exploratory Data Analysis (EDA) -Quantitative and Graphical Technique; Data Types and Plotting

2. Lab (Hands-on: using Python): Descriptive statistical measures with Python and interpretation; Data Distribution with Histogram
3. Lab (Hands-on: using Python): Bivariate data handling: Scatterplot, Correlation and Regression (Linear and Multiple)
4. Lab (Hands-on: using Python): Handling the Categorical Data; Fitting Binary Logistic Regression, Application and inference
5. Lab (Hands-on: using Python): Clustering and Classification with practical applications

Books Recommended:

- Hadrien Jean, Essential Math for Data Science: Calculus, Statistics, Probability Theory, and Linear Algebra.
- Andrew Park, Data Science for Beginners.
- Peter Bruce, Andrew Bruce, and Peter Gedeck, Practical Statistics for Data Scientists: 50+ Essential Concepts Using R and Python (2nd Edition).
- Luca Massaron & John Paul Mueller, Python for Data Science for Dummies, 2ed.
- R. J. A. Little & D. B. Rubin, Statistical Analysis with Missing Data.

Question pattern for End Semester Examination

Theory (50 marks):

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

Practical (50 marks):

C. 25 marks, Evaluated by the University:

(i) Lab notebook : 5 marks

(ii) One practical problem : 10 marks (To be evaluated by external expert)

(iii) Viva – 10 marks (To be evaluated by external expert)

D. 25 marks, Evaluated by the respective Colleges:

(i) Attendance (considering both the theory and the practical classes) – 5

(ii) Continuous assessment / Internal assessment – 20. Class tests (at least two) – 10 marks and viva – 10 marks.

Honours with Research (CP: 15, Marks: 300):
Research Project/ Dissertation
(MTMRES801T/M)

Research Project/ Dissertation : As per UG Regulation

Detailed Minor Syllabus

SEM-I

Course: MTMMIN101T / MTMCOR101T
Algebra (Marks: 100, Credits: 5)

Unit -1 : Classical Algebra

De-Moivre's theorem for integer and rational indices and their applications, The n-th roots of unity. Definitions of exponential and trigonometrical functions of a complex variable, Logarithm of a complex number and its properties, Definitions of a^z, Inverse circular functions, hyperbolic functions.

Relation between roots and coefficients, Transformation of equation, Equation of squared differences of a cubic, reciprocal equations, Binomial equations and their properties, Descartes' rule of signs, Upper bounds for the real roots; Cardan's solution of the cubic and the nature of the roots of the cubic, Ferrari's methods of solution of biquadratic equations.

The inequality involving AM $\geq$ GM $\geq$ HM, Extreme values of sum and product, theorem of weighted means, Cauchy's inequalities, m-th power theorem.

Unit – 2 : Abstract Algebra

Equivalence relations and partitions, Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Permutations, inversions, cycles and transpositions.

Definition and examples of groups, examples of abelian and nonabelian groups, the group Zn of integers under addition modulo n and the group U(n) of units under multiplication modulo n, groups of symmetries of an equilateral triangle, the permutation group S3, the general linear group GL(n, R), $n \leq 3$.

Subgroups, cyclic subgroups, the concept of a subgroup generated by a subset, Cosets, Index of subgroup, Lagrange's theorem and its converse, order of an element, Normal subgroups: their definition, examples, and characterizations.

Definition and examples of rings, examples of commutative and non-commutative rings, Zn, the ring of integers modulo n, polynomial rings, Definitions of Subrings, Integral domains, skew-fields, fields and subfields, their examples and elementary properties.

Unit – 3 : Linear Algebra

Matrix of real and complex numbers, Algebra of matrices(structure only); symmetric and skew symmetric matrices, Hermitian and skew Hermitian matrices; Orthogonal and Unitary matrices. Determinants, Laplace expansions, cofactors, adjoint, inverse of a matrix, Cramer`s Rule.

Vector space, Linearly dependent and independent set, Basis, Dimension, Linear Transformation and their elementary properties and examples, Matrix representation of Linear Transformation. Rank of a matrix;

Determination of rank (relevant results are to be stated only); System of linear equations in matrix form AX = B; Consistency and inconsistency (by rank method); Types and determination of solution (by using notion of rank), Solving linear systems using Gaussian elimination.

Eigenvalues, Eigenvectors, Eigenspace, Diagonalization of matrices, Characteristic polynomial of a matrix, Cayley-Hamilton theorem and its application for determining inverse of square matrix . Bilinear forms, real quadratic forms Sylvester`s law of inertia, positive definiteness.

Books Recommended :

- Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- Dickson, Leonard Eugene (2009), First Course in the Theory of Equations, John Wiley & Sons, Inc. The Project Gutenberg eBook: http://www.gutenberg.org/ebooks/29785 3
- W.S. Burnstine and A.W. Panton, Theory of equations, Vol. 1. Fourteenth Edition, S. Chand and Co Ltd, New Delhi.
- S. Barnard and J.M. Child, Higher Algebra, Surjeet Pbl., New Delhi, 1990.
- Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K.B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least TWO from each unit. FIVE questions out of EIGHT are to be answered.

SEM-II

Course: MTMMIN202T/MTMCOR202T

Calculus (Marks: 100, Credits: 5)

Unit – 1 : Limits, Continuity and Differentiability

Limit of a function, ε - δ definition of a limit, Infinite limits, Continuity and types of discontinuities; Differentiability of a function, Relation between differentiability and continuity, Successive differentiation, Leibnitz theorem and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n \sin x, (ax+b)^n \cos x$; Partial differentiation, Euler's theorem on homogeneous functions and its converse.

Unit – 2 : Mean Value Theorems and its Applications

Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Geometrical interpretation of mean value theorems and applications to monotonic functions and inequalities; Taylor's theorem, Taylor's series, Maclaurin's series expansions of $e^x, \sin x, \cos x, \log(1+x), (1+x)^m$; Indeterminate forms.

Unit -3 : Integral Calculus

Integration of rational and irrational functions, Evaluation of definite integrals, Special integrals, Reduction formulae, derivations and illustrations of reduction formulae for the integration of $\sin^n x, \cos^n x, \tan^n x, \sec^n x, (\log x)^n, \sin^n x \cos^m x$ and their applications; Improper integrals, Beta and Gamma functions.

Unit – 4 : Applications

Tangent and Normal; Curvature; Asymptotes of general algebraic curves, Parallel asymptotes, Asymptotes parallel to axes; Envelopes; Maxima and Minima; Concavity and convexity, Points of inflexion; Tracing of Cartesian and polar curves; Length of plane curve and area bounded by plane curves, Volume and Surface area of solids of revolution.

Graphical Demonstration (Teaching Aid)

1. Plotting of graphs of function e^{ax+b}, log(ax + b), 1/(ax + b), sin(ax + b), cos (ax + b), |ax + b| and to illustrate the effect of a and b on the graph.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Sketching parametric curves.
4. Obtaining surface of revolution of curves.
5. Tracing of conics in Cartesian coordinates/polar coordinates.

Books Recommended :

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
- Gorakh Prasad, Differential Calculus (19th edition), Pothishala Pvt. Ltd., 2016.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
- Gorakh Prasad, Integral Calculus, Pothishala Pvt. Ltd., Allahabad, 2015.
- Gabriel Klambauer, Aspects of Calculusm, Springer-Verlag, 1986.
- Howard Anton, I. Bivens & Stephan Davis, Calculus (10th edition), Wiley India, 2016.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and Mathematical analysis.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(ii) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking TWO from each unit. FIVE questions out of EIGHT are to be answered.

SEM-III

Course: MTMMIN303T / MTMCOR303T

Differential Equations (Marks: 100, Credits: 5)

Group A: Ordinary Differential Equations (60 marks)

Unit-1: First-order exact equations, integrating factors, rules of finding integrating factors. First-order equations of higher degree solvable for x, y and p. Singular solutions. Application of first-order ODEs: Decay problems, Newton's law of cooling, and Orthogonal trajectories. Linear ODEs of order higher than 1. Systems of Linear first-order ODEs. Basic theory of linear ODEs and systems. Linearly independent solutions. Wronskian and its properties. Solving a linear ODE by reducing its order.

Unit-2: Linear homogeneous and non-homogeneous ODEs with constant coefficients. Complementary function and Particular integrals. Method of variation of parameters. The Cauchy-Euler Equation. Simultaneous Differential Equations. Total differential equation.
Application of second-order linear ODEs to problems of Dynamics: motion in a straight line.

Group B: Partial Differential Equations (40 marks)

Unit-1: Order and Degree. First-order PDE, classification into linear, semi-linear, quasi-linear and non-linear equations. Derivation/ Formation of PDEs by (i) elimination of arbitrary constants, (ii) elimination of arbitrary functions. Solution of First-order quasi-linear PDEs by Lagrange's method and first-order non-linear PDEs by Charpit's method.

Unit-2: Second-order linear partial differential equations and their classification into elliptic, parabolic and hyperbolic types. Reduction to canonical forms through illustrative examples only.

Books Recommended:

- Shepley L. Ross, Differential Equations, John Wiley and Sons, 3rd Ed., 1984.
- I. Sneddon, Elements of partial differential Equations, Mc. Graw-Hill, 1967.
- Daniel A. Murray, Introductory Course in Differential Equations, Khosla Publishing House, 2021.
- H. T. H. Piaggio, An Elementary Treatise on Differential Equations.
- Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, NY.
- P. R. Ghosh and J. G. Chakravorty, Differential Equations, U N Dhur, 1993.
- T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa, 2003.
- Donald Greenspan, Introduction to Partial Differential Equations, Dover Books in Mathematics, 2003.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FIVE from Group A and THREE from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FIVE from Group A and THREE from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least THREE from Group A and at least ONE from Group B) are to be answered.

SEM-IV

Course: MTMCOR404T

Probability Theory & Mechanics (Marks: 100, Credits: 5)

Group A: Probability Theory (60 marks)

Unit-1: Sample space, Classical and axiomatic definition of probability, conditional probability, Bayes' Theorem. Independent events. Random variables (continuous and discrete). Distribution function. Probability density function, probability mass function. Mathematical expectation. Moments. Moment generating function. Characteristic function. Discrete distributions: Uniform, binomial, Poisson. Continuous distributions: uniform, normal, exponential.

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

Group B: Mechanics (40 marks)

Unit-1: Conditions of equilibrium of a particle and of coplanar forces acting on a rigid body. Laws of friction. Problems of equilibrium under forces including friction. Centre of gravity.

Unit-2: Motion in a straight line. Concept of Work, power, kinetic and potential energies. Simple Harmonic Motion. Motion on a plane. Velocity and acceleration components in Cartesian, plane-polar and tangent-normal systems. Central orbits and motion under inverse –square law.

Motion of a projectile.

Books Recommended:

- Sheldon Ross, A First Course in Probability, Pearson, 2022.
- T. K. Chandra, D. Chatterjee, A First Course in Probability, Narosa, 3rd Ed., 2005.
- V. K. Rohatgi, A. K. Md E. Saleh,An Introduction to Probability and Statistics, Wiley (india), 2nd Ed. Reprint, 2009.
- S. Lipschutz, J. Schiller, Introduction to Probability and Statistics, Schaum's Outlines, Tata McGraw Hill, 2006.
- A. M. Gun, M. K. Gupta, B. Dasgupta, Fundamentals of Statistics, Vol. I, World Press.
- N. G. Das, Statistical Methods, Vol I, Tata McGraw Hill.
- S. L. Loney, Dynamics of Particles and of Rigid Bodies, AITBS Publishers, India Reprint, 2018.
- A. S. Ramsey, Statics, CBS Publishers and Distributors, 2004.
- S. L. Loney, The Elements of Statics and Dynamics, (Part I, Statics), Arihant Publishers, 2016.
- S. L. Loney, The Elements of Statics and Dynamics, (Part II, Dynamics), Arihant Publishers, 2016.
- A. P. Roberts, Statics and Dynamics with background Mathematics, CUP, 2003.
- S. Ganguly, S. Saha, Analytical Dynamics of a Particle (including elements of Statics), New Central Book Agency, 2012.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FIVE from Group A and THREE from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FIVE from Group A and THREE from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least THREE from Group A and at least ONE from Group B) are to be answered.

SEM-V

Course: MTMCOR505T

Linear Programming Problem & Game Theory (Marks: 100, Credits: 5)

Unit-1: Introduction to linear programming problem (L.P.P.). Formation of L.P.P. from daily life involving inequations. Graphical solution, Basic solutions and Basic Feasible Solution (B.F.S), matrix formulation of L.P.P., degenerate and non-degenerate B.F.S.

Hyperplane, convex set, extreme points, convex hull and convex polyhedron. Supporting and Separating hyperplane. Reduction of feasible solution to B.F.S., correspondence between B.F.S. and extreme points. Fundamental theorem of L.P.P.

Unit-2: Theory of simplex method, optimality and unboundedness. Simplex algorithm and its tableau format, artificial variables, Two-phase method, Charne's-M Method.

Unit-3: Degeneracy in L.P.P. and its resolution. Theory of Duality, primal-dual relationships, economic interpretation of the dual.

Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem, Traveling Salesman problem.

Unit-4: Game theory: Rectangular games. Pure strategy and Mixed strategy. Saddle point and its existence. Optimal strategy and value of the game. Formulation and solution of two person zero sum games. Algebraic method. Graphical method of solving Rectangular games.

Books Recommended:

- Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
- Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006.
- G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.
- S. I. Gass, Linear Programming: Methods and Applications, McGraw Hill, New York.
- Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, Sultan Chand & Sons.
- P. M. Karak, Linear Programming and Theory of Games, New Central Book Agency.
- J. G. Chakraborty and P. R. Ghosh, Linear Programming and Game Theory, Moulik Library, 2021.

Question pattern for End Semester Examination:

(iii) Short answer type questions (10 marks): FIVE questions out of EIGHT questions of 2 marks each to be answered.

(iv) Broad questions (40 marks): EIGHT questions of 8 marks each (which may be subdivided into multiple parts) will be set taking at least ONE from each unit. FIVE questions out of EIGHT are to be answered.

SEM-VI

Course: MTMCOR606T

Numerical Methods and Integral Transforms (Marks: 100, Credits: 5)

Group A: Numerical Methods (60 marks)

Unit-1: Representation of real numbers, machine numbers - floating point and fixed point. Errors: relative, absolute, round off, truncation. Significant digits and error propagation in machine arithmetic operations.

Bisection method, Secant method, False position method, Fixed point iteration method, Newton-Raphson method. System of linear equations, LU decomposition, Gauss-Jacobi, Gauss-Siedel methods.

Unit-2: Finite difference operators, Newton's forward and backward interpolation. Lagrange's interpolation. Numerical differentiation: forward, backward and central differences.

Integration: Trapezoidal rule, Simpson's $1/3^{rd}$ rule and their composite rules. Euler's method for solving ordinary differential equations.

Group B: Integral Transforms (40 marks)

Unit-1: The Fourier Transform

Definition and properties of Fourier transform, Transform of derivatives. Fourier cosine and sine transforms. Convolution theorem, Inverse Fourier transform. Parseval's identity. Application to solving ordinary and partial differential equations (upto second order).

Unit-2: The Laplace Transform

Definition and properties. Sufficient conditions for the existence of Laplace Transform. Transform of derivatives. Convolution theorem. Inversion of Laplace Transform. Initial and final value theorems. Application to solving ordinary and partial differential equations (upto second order).

Books Recommended:

- B. Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
- M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, 5th Ed., New age International Publisher, India, 2007.
- K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
- James B. Scarborough, Numerical Mathematical Analysis, Oxford and IBH publishing co, 1966.
- S. A. Mollah, Numerical analysis, Books & Allied Ltd; 5th Revised edition (2000)
- Amritava Gupta & Subhas Chandra Bose, Introduction to Numerical Analysis, Academic Publisher.
- S. S. Sastry, Introductory Methods of Numerical Analysis, PHI, 2022
- L. Debnath and D Bhatta, Integral Transforms and their applications, C.R.C. Press, 2007.
- I. N. Sneddon, The Use of Integral Transforms, McGraw Hill, 1951.
- J. W. Miles, Integral Transforms in Applied Mathematics, Cambridge University Press, 2008.
- M. R. Spiegel, Laplace Transforms, McGraw Hill, 1965.
- R. N. Bracewell,The Fourier Transform and its Applications, McGraw Hill, 1986.

- E. J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.

Question pattern for End Semester Examination:

(i) Short answer type questions (10 marks): EIGHT questions (FIVE from Group A and THREE from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(ii) Broad questions (40 marks): EIGHT questions (FIVE from Group A and THREE from Group B, taking at least ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least THREE from Group A and at least ONE from Group B) are to be answered.

SEM-VII

Course: MTMSMC701T

Discrete Mathematics (Marks: 100, Credits: 5)

Group A (50 marks)

Unit-1: Propositional 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. De Morgan's Laws for Logic, Tautologies and contradictions, Predicates and quantifiers: Introduction, Quantifiers, Binding variables and Negations.

Unit- 2: Boolean Algebra

Huntington postulates for Boolean algebra, De Morgan's laws, Boolean expressions, Truth tables, Boolean functions, Normal forms. Quine Mc-Cluskey method. Karnaugh maps.
Logic diagrams, Switching circuits, Applications of switching circuits.

Group B: Graph Theory (50 marks)

Unit-1: Undirected graphs, Directed graphs, Geometrical representation of graphs, Handshaking lemma due to Euler and basic properties of graphs. Walks, Trails, Paths, Circuits and cycles with their properties. Connected and disconnected graphs, components of a graph, complete graphs, complement of a graph, complementary graphs, Ramsey problem. Bipartite graphs.

Eulerian circuits and paths, Eulerian graphs, Königsberg bridge problem, Hamiltonian paths and cycles, Hamiltonian graphs, examples of Eulerian and Hamiltonian graphs.

Unit-2: Trees and forests with their properties. Minimally connected graphs, spanning trees. Weighted graphs, Kruskal's algorithm for a minimal spanning tree.

Matrix representation of graphs, adjacency matrices of graphs and digraphs and their properties, incidence matrices of graphs and digraphs and their properties.

Books Recommended:

- B. H. Arnold, Logic and Boolean Algebra, Prentice Hall, 1962.
- I. M. Copi, Symbolic Logic, PHI.
- K. H. Rosen, Discrete Mathematics and its Applications, Tata-McGraw Hill.
- D. D. Givone, Introduction to Switching Circuit Theory, McGraw Hill.
- Richard Johnsonbaugh, Discrete Mathematics, Pearson Education.
- J. Eldon Whitesitt, Boolean Algebra and Its Applications, Dover Books in Computer Science.
- R. I. Goodstein, Boolean Algebra , Dover Books on Mathematics.
- Elliot Mendelson, Boolean Algebra and Switching Circuits, Schaum's Outline series, McGraw Hill.
- N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall of India, 2000.
- F. Harary, Graph Theory, Addison-Wesley Publishing Company, 1972.
- J. A. Bondy and U. S. R. Murty, Graph Theory with Applications, Macmillan, 1976.
- D. S. Malik, M. K. Sen and S. Ghosh, Introduction to Graph Theory, Cengage Learning Asia, 2014.
- K. H. Rosen, Discrete Mathematics and its applications with combinatorics and Graph Theory, McGraw Hill, 2017.
- D. S. Malik and M. K. Sen, Discrete Mathematics: Theory and Applications, Cengage Learning India

Private Limited, Delhi, 2010.
- A. H. Basson and D. J. O'Connor, Introduction to Symbolic Logic, Surjeet Publications, Delhi, 2017.

Question pattern for End Semester Examination:

(iii) Short answer type questions (10 marks): EIGHT questions (FOUR from Group A and FOUR from Group B) each of 2 marks will be set. FIVE questions are to be answered.

(iv) Broad questions (40 marks): EIGHT questions (FOUR from Group A and FOUR from Group B, taking ONE from each unit of each group) of 8 marks each (which may be subdivided into multiple parts) will be set. FIVE questions (at least TWO from each Group) are to be answered.

Syllabus for Multidisciplinary Course (MDC)

SEM-I / II / III / IV / V / VI

Course: MTMHMD101T / MTMHMD201T / MTMHMD301T/ MTMGMD401T / MTMGMD501T / MTMGMD601T

Basic Mathematics (Marks: 50, Credits: 3)

Sets, Relations & Functions: Sets, subsets, set operations, Venn diagram, relations, equivalence relations, mappings, functions, domain & co-domain, one-to-one and onto functions, inverse function; logarithamic, exponential functions and their elementary properties, periodic functions, trigonometric functions.

Probability and Statistics: Events, probability of an event, conditional probability, Bayes' theorem and their applications, discrete random variable and its probability distribution, expectation (mean) and variance of a single random variable.

Computation or calculation of mean, median, mode, variance and standard deviation for ungrouped and grouped data.

Matrix and Determinants: Matrix, order of Matrix, Types of Matrix, equality of matrices, Algebra or operations of Matrices, symmetric & skew symmetric matrices, elementary operations of a matrix, inverse of matrix, Inverse of a matrix by elementary operations (up to order 3x3).

Determinant, properties of determinants, cofactor, adjoint and inverse of a square matrix (up to order 3); determination of rank of matrix, solution of system of linear equations using (i) inverse of a matrix, and (ii) Cramer's Rule; conditions of consistency & inconsistency (all up to order 3).

Co-ordinate Geometry (2D): Distance between two points, slope of a line, angle between two lines, conditions for parallelism and perpendicularity of lines, equations of a straight line in various forms; distance of a point from a line and distance between two parallel lines. Standard equations of circle and parabola, ellipse and hyperbola. Latus rectum of parabola, ellipse and hyperbola, co-ordinates of their foci, eccentricity of ellipse and hyperbola (problems using formulae only).

Linear Programming Problem (LPP): Graphical solution of a system of Linear inequations in two variables. Linear Programming Problem (LPP) and its mathematical formulations, objective function, linear constraints, graphical method of solving LPP, feasible region, feasible solution, corner (extreme) point, optimal solution.

Books Recommended:

- R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998.
- P.R. Halmos, Naive Set Theory, Springer, 1974.
- E. Kamke, Theory of Sets, Dover Publishers, 1950.
- A.M.Gun, M.K. Gupta, B. Dasgupta, An Outline of Statistical Theory, Vol1 & Vol2, TheWorld Press PVT, 2003.
- Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
- N.G. Das, Statistical Methods, combined edition (volumes I & II), Mc Graw Hill Education PVT Ltd, New Delhi, 2015.
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers, 1983.
- Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006.
- F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.
- Gilbert Strang, Introduction to Linear Algebra, 4th edition, Welleseley-Camberidge press, 2009.
- K. Hoffman, R. Kunze, Linear algebra.

Evaluation procedure and Question pattern to be adopted by the affiliated colleges will be as follows:

(i) Attendance – 10.

(ii) Continuous assessment / Internal assessment – 20. At least two home assignments consisting of at least five problems for each assignment. Documents to be preserved by the Department.

Written Examination – 20. Two examinations of 20 marks each. Average of two written examinations each of 20 marks will be considered. **Question pattern:** FOUR questions out of SEVEN questions of 5 marks each to be answered in each of the written examination.

Syllabus for Skill Enhancement Course (SEC)

SEM-I / III / V

Course: MTMHSE101M / MTMHSE303M / MTMGSE301M / MTMGSE501M

C-Programming Language (Marks: 50, Credits: 3)

Unit 1 : Basics of Computer Programming

Definition, Requirement of programming language, Machine language, high-level programming languages, machine code of a program: compilation process, Problem solving approaches: algorithm and flowchart.

Unit 2 : Fundamentals of Programming

Built in Data Types: int, float, double, char; Constants and Variables; first program: printf( ), scanf( ), compilation etc., keywords, Arithmetic operators: precedence and associativity, Assignment Statements: post & pre increment/decrement, logical operators: and, or, not.

Unit 3 : Statements

Relational operators, if-else statement, Iterative Statements: for loop, while loop and do-while loop; controlling loop execution: break and continue, nested loop.

Unit 4 : Arrays

Definition & requirement, declaration & initialization, indexing, one dimensional array: finding maximum, minimum, simple sorting and searching.

Unit 5 : Multi-dimensional arrays

Matrix Manipulations (Addition, Multiplication, Transpose)

Arrays and Pointers, Memory allocation and deallocation: *malloc( )* and *free( )* functions.

Unit 6 : Functions

How to declare, define and invoke a function, Variables' scope, local & global variables and function parameters, Pointers, arrays as function parameters, *return* statement, Header files and their role. Illustrate different examples like swapping values, compute n!, ${}^{n}C_{r}$, find max/min from a list of elements, sort a set of numbers, matrix addition/multiplication etc.

Books Recommended :

- B. W. Kernighan and D. M. Ritchi, The C-Programming Language, 2nd Edi.(ANSI Refresher), Prentice Hall, 1977.
- Y. Kanetkar, Let Us C ; BPB Publication, 1999.

- C. Xavier, C-Language and Numerical Methods, New Age International.

Evaluation procedure and Question pattern to be adopted by the affiliated colleges will be as follows:

(i) Attendance – 5.

(ii) Continuous assessment / Internal assessment – 5. At least two home assignments. Documents to be preserved by the Department.

(iii) Written Examination – 20. Two examinations of 20 marks each. Average of two written examinations each of 20 marks will be considered. **Question pattern:** FOUR questions out of SEVEN questions of 5 marks each to be answered in each of the written examination.

(iv) Practical – 20 (Programming – 16, Lab Notebook - 4). TWO problems of programming each of 8 marks to be solved.

SEM-II / IV / VI

Course: MTMHSE202M / MTMGSE402M / MTMGSE602M

Programming Language-Python (Marks: 50, Credits: 3)

Unit-1 : Introduction

History and Importance of Python, Installing and Running Python, Executing Python programs, Python Interpreter and Interactive Mode.
Debugging: Syntax Errors, Runtime Errors, Semantic Errors.

Unit-2 : Variables and Expressions

Values and Types, variables, expressions, statements, comments, Operator Precedence, Arithmetic Expression, Boolean Expressions, Mixed-Mode Arithmetic and type conversion, type( ), Input( ), print( ), id( ), int( ), str( ), float( ), Elementary Programming.

Unit-3 : Conditionals, Loops, Functions and Strings

Conditionals: Conditional (if), Alternative (if-else), Chained conditional (if-elif-else).
Loops: Loop Structures/Iterative Statements – while loop, range( ) function, for loop; break statement, continue statement.
Functions: Built-in Functions, User Defined Functions, Function Call and Returning Values, Parameter Passing, Recursive Functions.
Strings: String slices, Immutability, String functions, String methods-find, join, split, lower, upper, len( ).

Unit-4 : Lists, Tuples and Dictionaries

Lists : List Operations, List Concatenation, List slices, List methods - append, extend, insert, pop, sort, Max( ), Min( ), List loop, Mutability, Aliasing.
Tuples : Creation, Accessing, Updating, Deleting Elements in a Tuple, Tuple Assignment, Tuple as Return Value, Nested Tuples, Basic Tuple Operations.
Dictionaries: Dictionary Operations, Built-in Dictionary Functions & Methods.

Unit-5 : Files and Modules

Files: Opening and Closing Files, Reading and Writing Files, Errors and Exceptions, Handling Exceptions.

Modules: Introduction, Module Loading and Execution, Math Module - sin( ), cos( ), exp( ), sqrt( ), Random Module, Time Module; Packages.

Python Programming Examples:
Calculating the factors of an integer, Checking Prime numbers, Generating multiplication tables, Finding the roots of a quadratic equation, Symbolic math using SymPy library, Converting strings to mathematical expressions, Solving a system of linear equations, Plotting Functions.

Books Recommended :

- W.J. Chun, Core Python Programming, Prentice Hall, 2013.
- Kenneth A. Lambert, Fundamentals of Python, Cengage, 2015.
- E. Balagurusamy, Introduction to Computing and Problem Solving Using Python, McGraw Hill India, 2016.
- Timothy A. Budd, Exploring Python, McGraw Hill India.

Evaluation procedure and Question pattern to be adopted by the affiliated colleges will be as follows:

(i) Attendance – 5.

(ii) Continuous assessment / Internal assessment – 5. At least two home assignments. Documents to be preserved by the Department.

(iii) Written Examination – 20. Two examinations of 20 marks each. Average of two written examinations each of 20 marks will be considered. **Question pattern:** FOUR questions out of SEVEN questions of 5 marks each to be answered in each of the written examination.

(iv) Practical – 20 (Programming – 16, Lab Notebook - 4). TWO problems of programming each of 8 marks to be solved.

****For the Tutorial part (50 marks) of Major and Minor/Core courses the following evaluation process to be adopted by the respective colleges:**

(i) Attendance – 10.

(ii) Presentation / Home assignment – 20. At least two home assignments consisting of at least five problems for each assignment. Documents to be preserved by the Department.

(iii) Continuous / Internal assessment (Written Examination) – 20. Two examinations of 20 marks each. Average of two written examinations each of 20 marks will be considered. Question pattern: FOUR questions out of SEVEN questions of 5 marks each to be answered in each of the written examination.