Tripura University

(A Central University)
Suryamaninagar
West Tripura

Syllabus for

Four Years UndergraduateProgramme

Subject: Mathematics

(As per NEP-2020)

Year - 2023

Tripura University
(A Central University)

Course Structure of MATHEMATICS (UG Programme)
As per NEP-2020 under Tripura University

MATHEMATICS MAJOR

Year	Semester	Paper	Course Content	Credit	Mark
1st	I	MT101C Theory	FoundationsandClassical Algebra	4	100 (IA=40 + ESE=60)
	I	MT102C Theory	Matrix Theoryand 2-Dimensional Geometry	4	100 (IA=40 + ESE=60)
	II	MT201C Theory	DifferentialCalculus	4	100 (IA=40 + ESE=60)
	II	MT202C Theory	Basic Abstract Algebraand3-Dimensional Geometry	4	100 (IA=40 + ESE=60)
2nd	III	MT301C Theory	Ordinary andPartial Differential Equations	4	100 (IA=40 + ESE=60)
	III	MT302C Theory	Analysis1	4	100 (IA=40 + ESE=60)
	IV	MT401C Theory	Linear Algebra andComplexAnalysis	4	100 (IA=40 + ESE=60)
	IV	MT402C Theory	Integral and Vector Calculus	4	100 (IA=40 + ESE=60)
3rd	V	MT501C Theory	Linear Programming and Game Theory	4	100 (IA=40 + ESE=60)
	V	MT502C Theory	Advanced Abstract Algebraand Number Theory	4	100 (IA=40 + ESE=60)
	V	MT503C Theory	ProbabilityandStatistics	4	100 (IA=40 + ESE=60)
	V	MT504C Theory	Dynamics andTensors	4	100 (IA=40 + ESE=60)
	VI	MT601C Theory	Analysis2	4	100 (IA=40 + ESE=60)
	VI	MT602C Theory	NumericalAnalysisandIntegral Transforms	4	100 (IA=40 + ESE=60)
	VI	MT603C Theory + Practical	Python Programming with Practical	Th -2 P-2	Th-60 (IA=24+ESE=36); P-40 (IA=16+ESE=24)
	VI	MT604C	Project	4	100 (IA=40 + ESE=60)

B.Sc. Mathematics (Honours)					
4th	VII	MT701C	Advanced Linear Algebra	4	100 (IA=40 + ESE=60)
	VII	MT702C	Analysis-3	4	100 (IA=40 + ESE=60)
	VII	MT703C	Complex Analysis	4	100 (IA=40 + ESE=60)
	VII	MT704C	Advanced Ordinary Differential Equations	4	100 (IA=40 + ESE=60)
	VIII	MT801C	Advanced Abstract Algebra-II	4	100 (IA=40 + ESE=60)
	VIII	MT802C	Topology	4	100 (IA=40 + ESE=60)
	VIII	MT803C	Integral Equations and Calculus of Variations	4	100 (IA=40 + ESE=60)
	VIII	MT804C	Advanced Partial Differential Equations	4	100 (IA=40 + ESE=60)
B.Sc. Mathematics (Honours with Research)					
4th	VII	MT701C	Advanced Linear Algebra	4	100 (IA=40 + ESE=60)
	VII	MT702C	Analysis 3	4	100 (IA=40 + ESE=60)
	VII	MT703C	Complex Analysis	4	100 (IA=40 + ESE=60)
	VII	MT704C	Advanced Ordinary Differential Equations	4	100 (IA=40 + ESE=60)
	VIII (Any one of these 4 papers)	MT801C	Advanced Abstract Algebra-II	4	100 (IA=40 + ESE=60)
		MT802C	Topology	4	100 (IA=40 + ESE=60)
		MT803C	Integral Equations and Calculus of Variations	4	100 (IA=40 + ESE=60)
		MT804C	Partial Differential Equations	4	100 (IA=40 + ESE=60)
	VIII	MT802C	Research Project/Dissertation	12	

DETAILED COURSE CONTENT OF MATHEMATICS MAJOR

1ST YEAR

SEMESTER I

Paper- 1 (Theory)

MT101C: Foundations and Classical algebra

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Statements, quantifiers, negation, compound statements (conjunction, disjunction, conditional and bi-conditional), contra-positive statement, proofs in Mathematics.
Brief review of sets, finite, countable and arbitrary union and intersection of sets; power set, cartesian product.
Equivalence relations, equivalence classes, partition, fundamental theorem of equivalence relation.
Functions, injection, surjection and bijection; image and pre-image of set under function, composition of functions, invertible functions.

Unit-2

Partial order relation, poset, chain, upper & lower bounds in poset, greatest & least elements, maximal & minimal elements, Axiom of choice. Zorn's lemma, equivalence of the two Peano's axioms, principle of mathematical induction (in all forms), well ordering principle, finite and infinite sets, countable and uncountable sets, Schroder-Bernstein theorem.

Unit-3

Inequalities involving arithmetic, geometric, and harmonic means, theorem on weighted means, Cauchy-Schwarz inequality, m-th power theorem, Weierstrass inequality and their applications.

Polynomials, The remainder and factor theorems, Synthetic division, Factored form of a polynomial, G.C.D. of polynomials, Fundamental theorem of algebra (statement only), Relations between the roots and the coefficients of polynomial equations, Imaginary roots, Integral and rational roots, irrational roots.

Unit-4

Transformation of equations, reciprocal equations, Descarte's rule of sign. Elementary theorems on the roots of an equations including Cardan'smethod of solution of cubics, Ferrari's method and Descarte's method of solution of quartics.

Suggested books:

1. Kumar A, Kumaresan S and Sarma B. K.: A foundation course in Mathematics; Narosa publications
2. Mapa S.K.: Classical Algebra; Levant publications
3. Khan R.M.: Algebra; NCBA

Paper- 2 (Theory)

MT102C: Matrix theory and 2-dimensional geometry

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Matrices and System of linear equations(homogeneous and non-homogeneous), Matrix operations, Symmetric, skew-symmetric, orthogonal, Hermitian, skew- Hermitian and unitary matrices, Determinant of a square matrix, The inverse of a square matrix (upto order 3). Solution of system of linear equations by matrix method (upto order 3). Transpose of matrices. Elementary operations and elementary matrices, Reduced Row-Echelon form and its relevance to system of linear systems.

Unit-2

The rank of a matrix and its properties, applications of rank of a matrix in checking the consistency of a system of linear equations and solving the system if it is consistent.

Vectors in R^n with more emphasis on $R^2$and R^3, addition and scalar multiplication of vectors and their properties, linear combination of vectors of R^n. Linear span , Linear independence and linear dependence of vectors of R^n .

Eigenvectors and eigen values of a real square matrix, The characteristic equation and the Cayley-Hamilton theorem, Characteristics polynomial & minimal polynomials, Simple properties of eigenvalues and eigenvectors.

Unit-3

Transformation of rectangular axes, translation, rotation and their combinations, theory of invariants. General equation of second degree in two variables and the conditions for representing a pair of straight lines, a parabola, an ellipse and a circle, reduction into canonical form, lengths and position of the axes.

The equation of tangent, condition of tangency of a line, equation of normal, pair of tangents and director circle, chord of contact, pole and polar, chord in terms of middle points, diameter and conjugate diameters.

Unit-4

Pair of straight lines: Condition that the general equation of second degree in two variables may represent a pair of straight lines. Point of intersection of two intersecting straight lines, angle between two lines given by $ax^2+2hxy+by^2=0$, equation of bisectors of the angle between the pair of straight lines, equation of two lines joining the origin to the point in which two curves meet.

Polar coordinates, polar equation of straight lines, circles, parabolas, hyperbolas and ellipses referred to a focus as pole, equation of chord, tangent and normal.

Suggested books:

1. Mapa S.K.: Higher Algebra (Abstract and Linear); Levant publications
2. Khan R.M.: Algebra; NCBA
3. Sengupta S.B.: Coordinate geometry and vector analysis
4. Khan R.M.: Analytical geometry of two and three dimensions and vector analysis; NCBA
5. Loney S.L.: The elements of coordinate geometry; Arihant publications.
6. Fenn R: Geometry; Springer publications.

SEMESTER II

Paper- 3 (Theory)

MT201C: Differential Calculus

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Limits of functions (epsilon − δ approach), uniqueness of limit, algebra of limits, continuity, examples of continuous functions, types of discontinuities, intermediate value theorem, Differentiability and its geometrical interpretation, higher order derivatives, Leibniz rule and its applications. Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem and their geometrical interpretations, Darboux's theorem. Indeterminate forms, L'Hospital's rule.

Unit-2

Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's seriesexpansions of some basic functions.

Functions of several variables, limit and continuity of functions of two variables, repeated limits.

Unit-3

Partial differentiation, chain rule, change of variables, total derivative, equality of mixed partial derivatives, Euler's theorem for homogeneous functions of two and three variables, converse of Euler's theorem, Jacobian, functional dependence.

Tangent planes and normal lines. Envelopes and evolutes.

Criteria for Maxima/ Minima/ Saddle points, method of Lagrange multipliers, constrained optimization problems.

Unit-4

Curvature – Radius of curvature, centre of curvature, chord of curvature; Asymptotes of general algebraic curves(Cartesian and polar); Symmetry, Concavity and convexity, Points of inflection, Tangents at origin, Multiple points, Position and nature of double points; Tracing of Cartesian, polar and parametric curves.

Suggested books:

1. Maity and Ghosh: Analysis (Differential Calculus); Central publications.
2. Shanti Narayan and Mittal P.K.: Differential Calculus, S. Chand publications.
3. Pundir S.K.: Mathematical Analysis; CBS publishers.
4. Klymchuk S: Counterexamples in Calculus; Mathematical Association of America.
5. Marsden, Tromba and Weinstein: Basic Multivariable Calculus; Springer.

Paper- 4 (Theory)

MT202C: Basic abstract algebra and 3-dimensional geometry

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Binary operations, groupoid, semigroup, monoid, Groups, Abelian groups, Examples of groups: viz matrix groups, general linear and special linear groups, groups of integers modulo n, group of units modulo n, and other examples of groups. Elementary properties of groups, subgroups, necessary and sufficient condition for subgroups, intersection, union and product of subgroups, centre of agroup, centralizer of an element, subgroup generated by an element.

Unit-2

Cyclic groups, examples and various properties, generators of a cyclic group, Fundamental theorem of finite cyclic groups and it's applications; order of a group and order of an element and their properties,related theorems.

Rings, commutative rings, rings with unity, divisors of zero, integral domains, division rings, fields. Definition,examples, simple properties following from the definition. Subring, subfield, necessary and sufficient conditions for these, examples; characteristic of a ring.

Unit-3

Planes: Equation of a plane in general form, intercept and normal form, Distance of a point from a plane, Angle between two planes, pair of planes, Bisectors of angles between two planes;

Straight lines: Equations of straight lines, Distance of a point from a straight line, Distance between two straight lines, Distance between a straight line and a plane;

Spheres: Different forms, Intersection of two spheres, Orthogonal intersection, section of a sphere by a plane, great circle, sphere through a given circle, Tangents and normal, Radical plane, Radical line, Coaxial system of spheres, Pole, Polar and Conjugacy.

Unit-4

Space curves, Algebraic curves, Ruled surfaces, Some standard surfaces, Classification of quadric surfaces, Cone, Cylinder, Central conicoids – Ellipsoid, Hyperboloid of one and two sheets, Tangent plane, Normal, Polar planes, and Polar lines. Enveloping cone, enveloping cylinder.

Suggested books:

1. Mapa S.K.: Higher Algebra (Abstract and Linear), Levant publications.
2. Gallian J.: Contemporary Abstract Algebra, Narosa publications.
3. Khanna V. and Bhambri S.K.: Abstract Algebra, Vikas publications.
4. Herstein I.N.: Topics in Algebra; Wiley publications.
5. Dummit and Foote: Abstract Algebra; Wiley publications.
6. Khan R.M.: Analytical geometry of two and three dimensions and vector analysis; NCBA.
7. Sengupta S.B.: Coordinate geometry and vector analysis.
8. Fenn R: Geometry; Springer publications.

2ND YEAR

SEMESTER III

Paper- 5 (Theory)

MT301C: Ordinary and Partial Differential Equations

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Significance of ordinary differential equation. Geometrical and physical consideration. Formation of differential equation by elimination of arbitrary constant. Order and degree of an ordinary differential equation, Meaning of the solution of ordinary differential equation. General, particular, explicit, implicit and singular solutions of a differential equation, Concept of linear and non-linear differential equations. Wronskian and its properties.

Exact differential equations and integrating factors, separable equations and equations reducible to this form, homogeneous equations, linear equations and Bernoulli equations, special integrating factors and transformations.

Equations of first order but not of first degree, Clairaut's equation. Singular solution.

Applications: Geometric applications, Orthogonal trajectories.

Unit-2

Solutions of linear equations of higher order with constant coefficients(upto 4^{th} order), Complementary function, Particular Integral, Symbolic operator D, Method of undetermined coefficients, method of variation of parameters.

General solution of homogeneous equation of second order, linear homogeneous and non-homogeneous equations, principle of superposition for linear homogeneous equation, method of variation of parameters, Solutions of second order linear equations with variable coefficients.

Unit-3

Reduction to normal form. Change of independent variable.
Simultaneous differential equations and total differential equations. Simple Eigen value problems. Introduction to compartmental model, exponential decay model, lake pollution model (case study of lake burley griffin), drug assimilation into the blood (case of a single cold pill, case of a course of cold pills), exponential growth of population, limited growth of population, limited growth with harvesting.

Unit-4

Partial differential equations – basic concepts and definitions, mathematical problems, first order equations, classification, construction and geometrical interpretation, some exact solutions of first order non-linear PDE (method of inspection)

Canonical forms of first-order linear equations, method of separation of variables for solving first order partial differential equations, Langrange's equation and it's solutions

Suggested books:

1. Ross S.L.: Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
2. Ahsan Z: Differential Equations & their applications, Prentice Hall of India.
3. Raisinghania M.D.: Ordinary Differential Equations; S.Chand and Sons.
4. Kapur J.N.; Mathematical Modelling; New Age International Publishers.
5. Raisinghania M.D.: Advanced Differential Equations; S. Chand and Sons.
6. Amaranath T.: Partial Differential Equations, Narosa Publications.
7. Boyce D Prima: Differential Equations, Wiley publications.

Paper- 6 (Theory)

MT302C: Analysis 1

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Review of algebraic and order properties of R, neighborhood of a point in R, idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, bounded below sets, bounded sets, unbounded sets, supremum (l.u.b) and infimum (g.l.b), the completeness property of R, the Archimedean property, density of rational (and irrational) numbers in R, intervals in R. Limit points of a set, isolated points, derived sets, open and closed sets, closure of a set, Bolzano-Weierstrass theorem for sets.

Unit-2

Sequences, bounded sequence, convergent sequence, limit of a sequence, limit theorems, monotone sequences, monotone convergence theorem.

Subsequences, divergence criteria, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequence, Cauchy's convergence criterion.

Sequential criterion for limits, divergence criteria. Sequential criterion for continuity and discontinuity.

Unit-3

Infinite series, convergence and divergence of infinite series, Cauchy criterion, tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, Raabe's test, Gauss test, Logarithmic test, integral test, alternating series, Leibniz test, absolute and conditional convergence, rearrangement of series.

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions, relative extrema, interior extremum theorem.

Unit-4

Uniform continuity, non-uniform continuity criteria via sequences, algebra of uniformly continuous functions, uniform continuity theorems, sufficient condition for uniform continuity using derivative, Lipchitz's continuity.

Suggested books:

1. Bartle R.G.and Sherbert D.R., Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Kumar A and Kumaresan S: A basic course in Real Analysis, CRC Press.
3. Goldberg R.R.: Real Analysis.
4. Ross K.A.: Elementary Analysis; Springer publications.
5. Gelbaum and Olmsted: Counterexamples in Analysis; Dover publications.

SEMESTER IV

Paper- 7 (Theory)

MT401C: Linear Algebra and Complex analysis

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear dependence and independence, basis and dimension. Sums, direct sums of subspaces.

Unit-2

Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation. Algebra of linear transformations, isomorphisms, isomorphism theorems, invertibility and isomorphisms, change of basis.

Unit-3

Eigen spaces of a linear operator, Characteristic polynomial, minimal polynomial for a linear operator. Cayley-Hamilton theorem

Inner product spaces and norms, Cauchy-Schwartz inequality, Gram-Schmidt orthogonalisation process, orthogonal complements, orthonormal vectors.

Unit-4

Polar representation of complex numbers, De Moivre's theorem for rational indices, related problems, expansions of sin $n\theta$, $\cos n\theta$, $\sin\theta$, $\cos\theta$, trigonometric, exponential and logarithmic functions of complex arguments, Gregory's series.

Algebra of complex numbers, polar representation of complex numbers, geometrical interpretation of argument and modulus of complex numbers , complex equations of straight lines, circles. Limits, continuity of functions of complex variable, regions in the complex plane.

Derivatives, differentiation formulae, Cauchy-Riemann equations, sufficient conditions for differentiability, analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function.

Suggested books:

1. Mapa S. K.: Higher Algebra (Abstract and Linear); Levant publications.
2. Lipschutz S.,and Lipson M: Linear Algebra; Schaum Series.
3. Pundir S. K.: A Competitive Approach to Linear Algebra, CBS Publishers and Distributors Pvt. Ltd.
4. Ponnusamy S.: Foundations of Complex Analysis, Narosa Publishers.
5. Spiegel M.R.: Complex Analysis; McGraw Hill Publications.
6. Kumaresan S: A pathway to complex analysis; Techno world.

Paper- 8 (Theory)

MT402C: Integral and vector calculus

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Reduction formulae, derivations and illustrations of reduction formulae of the type $\sin^n x$, $\cos^n x$, $\tan^n x$, $\sec^n x$, $\log x$, $\sin^m x \cos^n x$ etc.

Geometric interpretation of definite integral, Fundamental theorem of integral calculus, area enclosed by plane curves, Cartesian and Parametric equations of plane curves, rectification of plane curves; volume and surface areas of solids of revolution.

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 co-ordinates. Change of variables in double integrals and triple integrals, Change of order of integration in double integral, Dirichlet integrals.

Unit-3

Vector point functions, limits, continuity and differentiation of vector functions. Definition of vector field, gradient, divergence, curl and Laplacian. Line integrals, Applications of line integrals. Mass and work.

Unit-4

Fundamental theorem for line integrals, conservative vector fields, independence of path, Green's theorem, surface integrals, integrals over parametricallydefined surfaces, Volume integrals. Green's theorem, Stoke's theorem, the Gauss divergence theorem. Their Applications.

Suggested books:

1. Das B.C. and Mukherjee B.N.; Integral Calculus, U.N. Dhur and Sons.
2. Spiegel M.R.; Vector Analysis, McGraw Hill.
3. Thomas G.B. and Finney R.L.; Calculus, 9th Ed., Pearson Education, Delhi, 2005.
4. Shantinarayan and Mittal P.K.: Integral Calculus; S. Chand and Sons.
5. Klymchuk S: Counterexamples in Calculus; Mathematical Association of America.
6. Marsden, Tromba and Weinstein: Basic Multivariable Calculus; Springer.
7. Jain, R. K. and Iyengar, S. R. K. *Advanced Engineering Mathematics,* Third Edition, (Narosa publishing house, India).
8. Ramana, B. V. *Higher Engineering Mathematics*, (McGraw Hill, India).

.

3RD YEAR

SEMESTER V

Paper-9 (Theory)

MT501C: Linear programming and Game theory

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1:

Formulation**,** Canonical and standard forms, Graphical method; Convex and polyhedral sets, Hyperplanes, Extreme points; Basic solutions, Basic Feasible Solutions, Reduction of feasible solution to basic feasible solution, Correspondence between basic feasible solutions and extreme points; Slack and surplus variables, Standard form of an LPP.

Unit-2:

Optimality criterion, Improving a basic feasible solution, Unboundedness, Unique and alternate optimal solutions; Simplex algorithm and its tableau format; Artificial variables, Big-*M* method, Two-phase method.

Unit-3:

Formulation of the dual problem, primal-dual relationships, Duality theorems, Complimentary slackness theorem, Economic interpretation of the dual, Dual-simplex method.

*Transportation Problem***:** Definition and formulation, Methods of finding initial basic feasible solutions: Northwest-corner rule, Row minima, Column minima, matrix minima, Least- cost method, Vogel approximation method; Unbalanced transportation problems, Optimality tests for transportation problems and MODI method for obtaining optimal solution, degeneracy in transportation problems;.

*Assignment Problem***:** Mathematical formulation and Hungarian method.

Unit-4:

*Game Theory***:** Formulation and solution of two-person zero-sum games, Games with mixedstrategies, Linear programming method for solving a game.

Suggested books:

1. Paul R. Thie & Gerard E. Keough (2014). *An Introduction to Linear Programming and Game Theory* (3rd edition). Wiley India Pvt. Ltd.

2. Frederick S. Hillier & Gerald J. Lieberman (2015). *Introduction to Operations Research* (10th edition). McGraw-Hill Education.

3. J.G. Chakraborty and P.R.Ghosh; Linear Programming and Game theory; MoulikLibrary.

4. P.M.Karak; Linear Programming and theory of games; New Central Book Agency

Paper-10 (Theory)

MT502C: Advanced Abstract Algebra and Number Theory

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Properties of cosets, Lagrange's theorem and it's corollaries, Fermat's Little theorem, Normal subgroups, examples and related theorems, Simple groups, Factor groups, Cauchy's theorem for finite abelian groups; Normalizer.

Permutations, permutations on I_n, Cycle notation for permutations, Properties of permutations, Even and odd permutations, alternating groups, Cayley's theorem and its applications.

Unit-2

Group homomorphisms, Properties of homomorphisms, Group isomorphisms, Properties of isomorphisms; First, second and third isomorphism theorems for groups; ring homomorphisms, theorems on ring homomorphisms (isomorphism theorems); Ideals - prime and maximal ideals, examples and properties, quotient rings, Generation of polynomial ring from a commutative ring with unity.

Unit-3

Divisibility, Euclid's division algorithm, greatest common divisor (g.c.d.), least common multiple. Relatively prime integers. The equation ax+ by = c has integral solution iff (a,b) divides c. (a , b, c are integers). Prime numbers. Euclid's first theorem: If some prime p divides ab, then p divides either a or b. Euclid's second theorem: There are infinitely many prime integers. Factorization in prime numbers, fundamental theorem of arithmetic.

Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, perfect numbers, Mersenne numbers, Fermat numbers, linear congruences, complete set of residues, Chinese Remainder theorem,Fermat's Little theorem, Wilson's theorem.

Unit-4

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula.
The greatest integer function, Euler's φ-function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.
Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots.

Suggested books:

1. Mapa S.K.: Higher Algebra (Abstract and Linear), Levant publications.
2. Gallian J.A.: Contemporary Abstract Algebra, Narosa publications.
3. Khanna V. and Bhambri S.K.: Abstract Algebra, Vikas publications.
4. Herstein I.N.: Topics in Algebra; Wiley publications.
5. Dummit and Foote: Abstract Algebra; Wiley publications.
6. Musili C.: Rings and Modules; Narosa publications.
7. Elementary Number Theory, David. M. Burton, MacGrawHill.
8. Malik S.B.: Basic Number Theory.

Paper-11 (Theory)

MT503C: Probability and Statistics

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Brief review of Measures of Central Tendency. Measures of Dispersion: Definition, properties (without proof) and calculation of Range, Quartile Deviation, Mean Deviation, Standard Deviation and coefficient of variation. Definition and calculation of moments, skewness and kurtosis.

Unit-2

Correlation and Regression: Concept of bivariate frequency distribution, marginal frequency distribution and conditional frequency distribution. Pearson's correlation coefficient: Definition, properties and calculation. Regression: Definition and different properties, fitting of regression lines by method of least squares. Curve fitting: Second degree polynomial and exponential.

Unit-3

Probability and Random Variables: Axiomatic and empirical definitions of probability, Independent and dependent events, Conditional probability and Baye's theorem; Discrete and continuous random variables and their probability distributions, Cumulative distribution function, *n*th Moments, Moment generating function, Characteristic function.

Univariate Distributions:

Discrete distributions**:** Bernoulli trials and Bernoulli distribution, Binomial and Poisson distributions; Continuous distributions**:** Uniform, Geometric, Gamma, Exponential, Chi-square, Beta and normal distributions; Normal approximation to the binomial distribution, Central limit theorem.

Unit-4

Bivariate Distribution:

Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions and expectations, Independence of bivariate random variables.

The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Linear regression for two variables, The method of least squares, Bivariate normal distribution.

Suggested books:

1. S.C. Gupta and V.K. Kapoor: *Fundamentals of Mathematical Statistics*, Sultan Chand andSons.

2. Sheldon Ross: *Introduction to Probability Models*, 9th Ed., Academic Press, IndianReprint, 2007.

3. Medhi, J.: *Statistical Methods: An introductory Text*, (New Age International (P) Ltd, 2000).

Paper-12 (Theory)

MT504C: Dynamics and Tensors

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Expression for velocity and acceleration of particle moving in a straight line and in a planecurve.

Rectilinear motion of a particle under attractive force.

Simple Harmonic Motion, damped vibrations, forced vibration, damped forced oscillationsTangent and normal acceleration. Velocity and acceleration along radial and transverse directions.

Unit-2

Central orbits, central forces, motion of a particle under central force. Differential equation inpolar and pedal coordinates, velocity under central force. Apse, apsidal distance and apsidal angle. Areal velocity, Characteristics of central orbits, Kepler's laws of planetary motion, artificial satellite and stationary orbit. Motion in resisting medium.

Unit-3

Summation convension, Kronecker symbol, n-dimensional space, transformation of coordinate axes in S_n, Invariants, covariant and contravariant vectors, Covariant, contravariant and mixed tensors,. Algebra of Tensors. Symmetric and skew-symmetric tensors, Contraction, outer and inner product of tensors, Quotient law, reciprocal tensors. Riemann space, the line element and metric tensor, raising and lowering of indices, associate tensor, magnitude of a vector, inclination of two vectors, orthogonal vectors, parallel vectors, Christoffel symbols and their properties, transformation lawof Christoffel symbols.

Unit-4

Covariant differentiation of tensors, covariant differentiation of sum, difference and product of tensors. Gradient, divergence, curl and Laplacian. Curvilinear coordinate system in E^3 : line element, lengthy of vector, angle between two vectors in E^3 in a curvilinear coordinate system. Basis in a curvilinear coordinate system, reciprocal base, covariant and contravariant components of a vector in E^3, partial derivative of a vector. Sperical and cylindrical coordinate system.

Curves in E^3 . Parallel vector fields along a curve in E^3 , parallel vector field in E^3 , parallel vector space in a Riemannian space, parallel vector field in a surface of a Riemannian space. Serret-Frenet formulas.

Suggested books:

1. De U.C. , Shaikh A.A. , Sengupta J.: Tensor Calculus; Narosa Publications.
2. Chaki M.C.: Tensor Calculus; Calcutta publishers.
3. Datta N. and Jana R.N.: Dynamics of a Particle.
4. Chakraborty and Ghosh: Dynamics of Particle and Rigid bodies; U N Dhur and Sons.
5. Loney, S. L., Elements of Statics & Dynamics, Part I (Maxford Books, 2003).
6. Rao, S. Engineering Mechanics - Statics and Dynamics (Pearson Education, 2008).

SEMESTER VI

Paper-13 (Theory)

MT601C: Analysis 2

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Riemann integration; inequalities of upper and lower sums; Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions; Riemann integrability of monotone and continuous functions

Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals; Fundamental theorems of Calculus, Mean value theorems, Riemann integrability of composition of Riemann integrable functions.

Unit-2

Definition and examples of metric spaces, Open spheres and closed spheres,

Neighbourhoods, Open sets, Interior, exterior and boundary points, Closed sets, Limit points and isolated points, Interior and closure of a set, Boundary of a set, Bounded sets, Distance between two sets, Diameter of a set, Subspace of a metric space.

Unit-3

Pointwise and uniform convergence of sequence and series of functions, definitions, examples, simple problems, Cauchy criterion for uniform convergence and Weierstrass M-Test. Limit superior and Limit inferior, power series, radius of convergence, Cauchy Hadamard theorem.

Unit-4

Improper integrals and their convergence, Dirichlet test and Abel's test for improper integrals.Beta and Gamma functions.
Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, Bessel's inequality, The complex form of Fourier series.

Suggested books:

1. Mapa S.K.: Real Analysis; Levant Publications
2. Maity and Ghosh: Analysis (Integral Calculus); NCBA
3. Bartle R.G. and Sherbert D.R.: Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
4. Karunakaran V.: Real Analysis; Pearson.
5. Bartle R.G.: A Modern Theory of Integration; AMS.
6. Gelbaum and Olmsted: Counterexamples in Analysis; Dover publications.

Paper-14 (Theory)

MT602C: Numerical Analysis and Integral Transforms

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Approximate numbers, significant figures, errors: relative, absolute and percentage. rounding off, truncation. Definition and properties of finite difference operators, shift operator.

Interpolation: Newton's forward, backward formulae, Lagrange's formula. related problems. Differentiation formula based on Newton forward and backward formula. Inverse interpolation.

Numerical integration : General quadrature formula - Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, Weddle's rule.

Unit-2

Numerical solution of ordinary differential equations : Taylor series method, Picard's method, Euler's method, modified Euler's method, Runge-Kutta method.

Transcendental and polynomial equations : bisection method, regula-falsi method, secant method, Newton-Raphson method, iteration method, rates of convergence of these methods, related problems.

System of linear algebraic equations: Gaussian Elimination and Gauss -Jordan methods including matrix inversion, Gauss- Seidel method and their convergence, related problems.

Unit-3

Laplace transform, Linearity, Existence theorem, Laplace transforms of derivatives and integrals, Shifting theorems, Change of scale property, Laplace transforms of periodic functions, Dirac's delta function.

Convolution theorem, Inverse Laplace transform, Linearity property of inverse Laplace transform, Translations theorems of inverse Laplace transform, Applications of Laplace transform in obtaining solutions of ordinary differential equations.

Unit-4

Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Relation between Fourier and Laplace transforms. Convolution theorem for Fourier transform, Parseval's identity for Fourier transform. Finite Fourier sine and cosine transform.

Suggested books:

1. Mukherjee Kalyan: Numerical Analysis; NCBA.
2. Mollah S.A.; Numerical Analysis and Computational procedures; Books and Allied Pvt. Ltd.
3. Scarborough J.B.; Numerical mathematical analysis; Oxford University Press.
4. Rao G.S. ; Numerical Analysis; New Age International.
5. Chakraborty and Ghosh; Numerical Analysis; U.N. Dhur and sons.
6. Jain M.K., Iyengar S.R.K. and Jain R.K., Numerical Methods for Scientific and Engineering Computation, 6th Ed., New age International Publisher, India, 2007.
7. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). Wiley.
8. Ross, S.L., Differential equationsm 3rd edition, (Wiley, 2016).

Paper-15 (Theory and Practical))

MT603C: Python programming with practical

Group A (Theory)

Total Mark = 60 (IA = 24 + ESE = 36); Credit = 02

Unit-1

Introduction to Python Programming: Features, basic syntax, Writing and executing simple program, Basic Data Types such as numbers, strings, etc Declaring variables, Performing assignments, arithmetic operations, Simple input-output.

Sequence Control – Precedence of operators, Type conversionConditional Statements: if, if-else, nested if –else

Looping: for, while, nested loops

Unit-2

Control statements: Terminating loops, skipping specific conditionsString Manipulation: declaring strings, string functions Manipulating Collections Lists, Tuples

Dictionaries – Concept of dictionary, techniques to create, update & delete dictionary items. Functions: Defining a function, calling a function, Advantages of functions, types of functions, function parameters, Formal parameters, Actual parameters, anonymous functions, global and local variables.

Group B (Practical)

Total Mark = 40 (IA = 16 + ESE = 24); Credit = 02

Unit-1

1. Ascending / Descending order. Finding Largest / smallest.

2. Sum of finite series.

3. Sum of Convergent series.

4. Checking whether a number is prime or not. Generation of prime numbers.

5. Solution of Quadratic equation

6. Mean, variance, correlation coefficient, equation of regression lines.

7. Operations on integers, matrices,

8. Drawing graphs of functions,

9. Generating diagrams of surface areas and volumes under surfaces of revolution.

Unit-2

1. Newton's forward interpolation formula.

2. Newton's Backward interpolation formula.

3. Lagrange interpolation formula.

4. Bisection method.

5. Newton-Raphson method.

6. Regula Falsi method.

7. Trapezoidal Rule.

8. Simpson's 1/3 rule.

Suggested books:

1. Yashavant Kanetkar, Aditya Kanetkar: Let Us Python, 5th Edition, BPB Publications.
2. M. Lutz: Learning Python, 5th Edition, O'Reilly Media(2013).

Paper-16

MT604C: Project work

Total Mark = 100 (IA = 40 + ESE = 60); Credit = 04

Details: Students will do a project work under the supervision of a faculty member from the Department of Mathematics of their respective college. The project work will be broadly based on topics studied during the UG (Mathematics major) programme, but need not be limited to those only. The topic of the project will be decided by the concerned project supervisor. The project work can be carried out individually or in small groups. The students have to give two presentations (using PPT, pdf, etc), one in the mid-semester to show their progress (as internal assessment) and one at the end semester to present their whole work. Also, they have to submit a project report on the completion of the project work.

4TH YEAR

SEMESTER VII

Paper-17 (Theory)

MT701C: Advanced Linear Algebra

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit - 1

Linear transformations and matrices, Similarity of matrices and linear operators, nilpotent matrix and nilpotent operators; Linear functional, dual space, double dual, transpose of a linear transformation, annihilators.

Unit - 2

Annihilating polynomials, characteristic polynomials, minimal polynomials, diagonalization of linear transformations and matrices, Invariant subspaces, primary decomposition theorem, Schur's unitary triangularization, Jordon canonical form, rational canonical form.

Unit - 3

Inner product spaces, orthogonal projection, best approximation. Adjoint of an operator, normal, unitary and self adjoint operators, spectral decompositions and spectral theorem for normal operators.

Unit - 4

Bilinear forms, Matrices of bilinear forms, Symmetric, Skew-symmetric and Alternating bilinear forms, Diagonalization of symmetric matrices, quadratic forms and matrices, rank and signature, various types of quadratic forms, Sylvester's law of inertia.

SUGGESTED READINGS:

1. Gilbert Strang, *Linear Algebra and its Applications*, Cenage Learning

2. Gareth Williams, *Linear Algebra and its Applications*, Jones and Bartlett Publishers.

3. Friedberg, Insel, Spence, *Linear Algebra*, Prentice-Hall India.

4. S Kumaresan, *Linear Algebra: A Geometric Approach*, PHI.

5. Hoffman and Kunze, *Linear Algebra*, Pearson.

6. Sudhir Kumar Pundir , *A Competitive Approach to Linear Algebra*, CBS Publishers and Distributors.

Paper-18 (Theory)

MT702C: Analysis 3

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

***Metric Spaces**:* Revision of basics, convergent sequences, Cauchy sequences, Cantor intersection theorem, complete metric space, continuity, equivalent definition of continuity, uniform continuity.

Unit-2

Compact and connected Metric spaces: Compact space and continuous function, Arzela-Ascoli theorem, Connected space, path connected space, completion of a metric space, Baire Category, Banach's contraction principle.

Unit-3

Functions of bounded variation: Total variation, additive property of total variation,monotonic functions are of bounded variation, functions of bounded variation are bounded,conditions for differentiable functions to be of bounded variation, continuous functions not ofbounded variation, function of bounded variation expressed as the difference of two increasingfunctions.

Unit-4

Riemann – Stieltje's integral:Definitions and examples, linearity properties, integration by parts, reduction to Riemann integral, step functions as integrators, reduction of Riemann Stieltjes integral to finite sums, Euler Summation formula, the upper and lower Darboux-Stieltje's integrals, Riemann's condition, comparison theorems, integrators of bounded variation, necessary and sufficient conditions for existence of Riemann-Stieltje's integral.

SUGGESTED READINGS:

1. W. Rudin, Principle of Mathematical Analysis, Mc Grow Hill.

2. T. M. Apostal, Mathematical Analysis ,Narosa pub. House.

3. M. H. Potter and C. B. Morrey, A first course in Real analysis, Springer.

4. D. Somasundaram& B. Choudhury, A first course in Mathematical analysis, Narosa pub. House.

5. S. Kumaresan, Topology of Metric Spaces, Publisher: Alpha Science.

Paper-19 (Theory)

MT703C: Complex Analysis

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Analytic function. Complex integration, Cauchy theorem, Cauchy-Goursat theorem. Cauchy integral formula, Cauchy integral formula for higher derivatives, Moreras theorem, Cauchy inequality, Liouville's theorem, Fundamental theorem of Algebra.

Sequence and series of functions, power series, Taylor theorem, zeros of an analytic function, Schwarz lemma.

Unit-2

Isolated singularity. Laurent's theorem, classification of isolated singularities: pole, essential singularity, removable singularity, residues, Casorati-Weierstrass theorem. Meromorphic function, Rouche's theorem, Inverse function theorem, open mapping theorem, Cauchy residue theorem. Contour integration.

Unit-3

Maximum module theorem, convex function, Hadamard three circle theorem. Many-valued function, Branches of many-valued function, branch points. Conformal transformation, Bilinear transformation, cross ratio.

Unit-4

Method of analytic continuation, Schwarz reflection theorem, analytic continuation along a path, power series method of analytic continuation, Monodromy theorem.

Harmonic function: Harmonic function on a disk, Harnack' inequality, Harnack' theorem, Poisson integration formula.

SUGGESTED READINGS:

1. J.B.Conway ,Functions of a one complex variable, Narosa publishing house.

2. W.Rudin, Real and Complex Analysis, McGrawHill.

3. H.S.Kasana, Complex Variable, Prentice Hall of India.

4. S.Ponnusamy, Foundations of Complex Analysis, Narosa publishing house.

5. L.V.Ahlfors, Complex Analysis, McGrawHill.

6. Churchill,Complex Variables and Applications, McGrawHill.

Paper-20 (Theory)

MT704C: Advanced Ordinary Differential Equations

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

First Order Differential Equations: First order equations, existence, uniqueness of solutions, Gronwall's inequality and applications, Ascoli-Arzoli theorem (statement only), theorem on convergence of solution of initial value problem, Picard-Lindeloff theorem, Peano existence theorem.

Unit- 2

n-th Order Linear Differential Equations: Independence of the solution of linear differential equation. Recartti dequations, Wronskian and it's properties, Solution by method of variation of parameters

Unit-3

Power series solutions: ordinary points, regular singular points, irregular singular points and Frobenius methods; special functions: Legendre and Bessel functions, properties.

Unit-4

Two-point boundary value problems: Adjoint and self adjoint boundary value problems, Sturm-Liouville equations, Green's functions, construction of Green's functions, non-homogeneous boundary conditions, eigenvalues and eigenfunctions of Sturm-Liouville equations, eigenfunction expansions.

SUGGESTED READINGS:

1. W. E. Boyce, and R. C. DiPrima, *Elementary Differential Equation and Boundary*

Value Problems, 7th Edition, John Wiley & Sons(Asia).

2. S. L. Ross, *Introduction to OrdinaryDifferential Equations*, John Wiley & Sons.

3. Morris W. Hirsch, Stephen Smale, and Robert L. Devaney, *Differential Equations, Dynamical Systems, and an Introduction to Chaos*, 3rd ed., Academic Press, 2012.

4. E. A. Coddington, *An Introduction to Ordinary Differential Equations* (Prentice-Hall).

5. S. J. Farlow, *An Introduction to Differential Equations and Their Applications*,

(McGraw-Hill International Editions).

SEMESTER VIII

Paper-21 (Theory)

MT801C: Advanced Abstract Algebra-II

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit - 1

Definition and examples of external direct products, properties of external direct products, definition and examples of internal direct products, fundamental theorem of finite Abelian groups and applications.

Definition and examples of group action, properties of group action, Orbits and Stabilizers, Orbit-Stabilizer theorem, Burnside lemma, Extended Cayley's theorem.

Unit - 2

Conjugate elements, Conjugacy classes, class equation, p-groups and related theorems, Sylow p-subgroups, Conjugate subgroups, Sylow's theorems and applications, Cauchy theorem, groups of certain special order (viz. p^2, 2p, pq, etc.); Simple groups, determination of all simple groups of order ≤ 60.

Unit - 3

Ideals, Prime and maximal ideals in a quotient ring. Chinese Remainder Theorem. Field of fractions of an integral domain.

Polynomial rings, Division algorithm and consequences, Factorization of polynomials, Einstein's irreducibility criterion and Gauss's lemma.

Unit - 4

Principal ideal domain, Associates, Prime elements, irreducible elements, Unique factorization domain, Euclidean domain, Gaussian domain.

Fields, Field extensions, algebraic and transcendental elements, splitting field, finite fields, structure of finite fields, normal, separable and inseparable extension of fields.

SUGGESTED READINGS:

1. J. A. Gallian, *Contemporary Abstract Algebra*, Narosa Publishing house.

2. D. S. Dummit & R. M. Foote, *Abstract Algebra*, John Wiley & Sons,Indian reprint.

3. I. N. Herstein, *Topics in Algebra*, John Wiley & Sons.

4. C. Musili, *Introduction to Rings and Modules,* Narosa publishing house.

5. V. K. Khanna & S. K. Bhambri, *A Course in Abstract Algebra*, Vikas Publishing.

6. M.K. Sen, S. Ghosh, P.S. Mukhopadhyay, *Topics in Abstract Algebra*, Universities Press.

Paper-22 (Theory)

MT802C: Topology

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Topological spaces: Topological structures, accumulation points, closed sets, closure of a set, interior, exterior, boundary, subspaces.
Bases and sub-bases: Base for a topology, sub base, local bases. Product space.

Unit-2

Continuity and topological equivalence: Continuous function, continuity at a point, open and closed functions, homeomorphic spaces.

Unit-3

Separation axioms: Separation by open sets, separation axioms and T_i-spaces (i = 0, 1, 2, 3, 4), Urysohn's lemma(statement only), completely regular spaces.

Countability: First countable spaces, second countable spaces.

Unit-4

Compact Spaces: Covers, compact sets, sub set of a compact space, finite intersection property.

Connectedness: Separated sets, connected sets, connected spaces.

SUGGESTED READINGS:

1. J. L. Kelly, General Topology, Von Nostradon 1066.

2. J. R. Munkres, Topology- A first Course, Pearson.

3. K. D. Jhoshi, Introduction to General Topology, Wiley Eastern.

4. S. W. Davis, Topology, Tata McGraw Hill.

5. S. William, General Topology, Addiotson Wesley.

Paper-23 (Theory)

MT803C: Integral Equations and Calculus of Variations

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1: Introduction to Integral Equations

Definitions: Classification of integral equations (Fredholm and Volterra equations of the first and second kind).
Relationship: Conversion of initial value problems (IVP) and boundary value problems (BVP) into integral equations.
Kernels: Types of kernels (separable/degenerate kernels, symmetric kernels, L2 kernels).

Unit-2: Fredholm Integral Equations

Methods of Solution: Solution of Fredholm equations with separable kernels.
Iterative Methods: Method of successive approximations (Neumann series) and resolvent kernel.
Eigenvalues: Fredholm alternative theorem and eigenfunction expansions.
Hilbert-Schmidt Theory: Theory for symmetric kernels.

Unit-3: Volterra Integral Equations

Solution Methods: Successive approximation method, Neumann series for Volterra equations.
Convolution Equations: Solution using Laplace transforms.
Integral Equation of First Kind: Numerical methods for solutions.

Unit-4: Calculus of Variations

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

SUGGESTED READINGS:

1. I.N. Sneddon, The Use of Integral Transforms, McGraw Hill.

2. R.R. Goldberg, Fourier Transforms, Cambridge University Press.

3. M.G. Smith, Laplace Transform Theory, Van Nostrand Inc.

4. L. Elsegolc, Calculus of Variation, Dover Publications.

5. R.P. Kenwal, Linear Integral Equation; Theory and Techniques, Academic Press.

6. F.B. Hildebrand, Methods of Applied Mathematics, Dover Publications.

7. S. Pal and S.C. Bhunia, Engineering Mathematics, Oxford University Press.

Paper-24 (Theory)

MT804C: Advanced Partial Differential Equations

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

First Order Partial Differential Equations: Formation of partial differential equations, linear partial differential equations, semi-linear partial differential equations, quasi-linear partial differential equations, compatible systems, complete integral, singular integral, Charpit's method, Cauchy problem for first order partial differential equations.

Unit-2

Second Order Partial Differential Equations with Constant Coefficients: Classification of second order partial differential equations, elliptic, parabolic and hyperbolic equations, linear partial differential equations with constant coefficients, complementary function, particular integral, operator methods, reducible and irreducible equations, general solution.

Unit-3

Second Order Partial Differential Equations with Variable Coefficients: Second order partial differential equations with variable coefficients, characteristic curves of second order partial differential equations, reduction to canonical forms, transformation of variables, classification by discriminant, canonical equations.

Unit-4

Classical Boundary Value Problems: D'Alembert's solution of the wave equation, separation of variables, Laplace equation, heat equation, wave equation, initial and boundary value problems.

SUGGESTED READINGS:

1. Prasad, P., and Ravindran, R., Partial Differential Equations, 1st ed., New Age International.
2. Amarnath, T., An Elementary Course in Partial Differential Equations, 1st ed., Narosa Publishing House.
3. Sneddon, I. N., Elements of Partial Differential Equations, Dover Publications.
4. Copson, E. T., Partial Differential Equations, Oxford University Press.
5. Evans, L. C., Partial Differential Equations, 2nd ed., AMS.

Tripura University
(A Central University)

Course Structure of MATHEMATICS (UG Programme)
As per NEP-2020 under Tripura University

MATHEMATICS MINOR

Year	Semester	Paper	Course Content	Credit	Marks
1st	I	MT101M Theory	Foundations and Algebra	4	100 (IA=40 + ESE=60)
	II	MT201M Theory	Linear Algebra and Geometry	4	100 (IA=40 + ESE=60)
2nd	III	MT301M Theory	Calculus	4	100 (IA=40 + ESE=60)
	IV	MT401M Theory	Differential equations and Linear programming problems	4	100 (IA=40 + ESE=60)
3rd	V	MT501M Theory	Real Analysis and Numerical Analysis	4	100 (IA=40 + ESE=60)
	VI	MT601M Theory	Probability, Statistics and Theory of Integration	4	100 (IA=40 + ESE=60)
4th	VII	MT701M Theory	Mechanics, Number theory and Complex Analysis	4	100 (IA=40 + ESE=60)
	VIII	MT801M Theory+ Practical	Python programming with practical	Th -2 P-2	Th-60 (IA=24+ESE=36); P-40 (IA=16+ESE=24)

DETAILED COURSE CONTENT OF MATHEMATICS MINOR

First Year

SEMESTER I

PAPER 1

MT101M: Foundations and Algebra

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Statements, quantifiers, negation, compound statements (conjunction, disjunction, conditional and bi-conditional), contra-positive statement, proofs in Mathematics.

Brief review of sets, finite, countable and arbitrary union and intersection of sets; power set, cartesian product.

Equivalence relations, equivalence classes, partition, fundamental theorem of equivalence relation.

Functions, injection, surjection and bijection; image and pre-image of set under function, composition of functions, invertible functions.

Unit-2

Inequalities involving arithmetic, geometric, and harmonic means, theorem on weighted means, Cauchy-Schwarz inequality, m-th power theorem, Weierstrass inequality and their applications.

Polynomials, The remainder and factor theorems, Synthetic division, Factored form of a polynomial, G.C.D. of polynomials, Fundamental theorem of algebra (statement only), Relations between the roots and the coefficients of polynomial equations, Imaginary roots, Integral and rational roots, irrational roots.

Transformation of equations, reciprocal equations, Descarte's rule of sign. Elementary theorems on the roots of an equations including Cardan'smethod of solution of cubics, Ferrari's method and Descarte's method of solution of quartics.

Unit-3

Binary operations, groupoid, semigroup, monoid, Groups, Abelian groups, Examples of groups: viz matrix groups, general linear and special linear groups, groups of integers modulo n, group of units modulo n, and other examples of groups. Elementary properties of groups, subgroups, necessary and sufficient condition for subgroups, intersection, union and product of subgroups,

centre of agroup, centralizer of an element, subgroup generated by an element.

Unit-4

Cyclic groups, examples and various properties, generators of a cyclic group, Fundamental theorem of finite cyclic groups and it's applications; order of a group and order of an element and their properties,related theorems.

Rings, commutative rings, rings with unity, divisors of zero, integral domains, division rings, fields. Definition,examples, simple properties following from the definition. Subring, subfield, necessary and sufficient conditions for these, examples; characteristic of a ring.

Suggested books:

1. Kumar A, Kumaresan S and Sarma B. K.: A foundation course in Mathematics; Narosa publications
2. Mapa S.K.: Classical Algebra; Levant publications
3. Khan R.M.: Algebra; NCBA
4. Gallian J.A.: Contemporary Abstract Algebra, Narosa Publications.

SEMESTER II

PAPER 2

MT201M: Linear Algebra and Geometry

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Matrices and System of linear equations(homogeneous and non-homogeneous), Matrix operations, Symmetric, skew-symmetric, orthogonal, Hermitian, skew- Hermitian and unitary matrices, Determinant of a square matrix, The inverse of a square matrix (upto order 3). Solution of system of linear equations by matrix method (upto order 3). Transpose of matrices. Elementary

operations and elementary matrices, Reduced Row-Echelon form and its relevance to system of linear systems. The rank of a matrix and its properties, applications of rank of a matrix in checking the consistency of a system of linear equations and solving the system if it is consistent.

Unit-2

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear dependence and independence, basis and dimension. Sums, direct sums of subspaces.

Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation. Algebra of linear transformations, isomorphisms, isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.

Eigen spaces of a linear operator, Characteristic polynomial, minimal polynomial for a linear operator. Cayley-Hamilton theorem.

Unit-3

Transformation of rectangular axes, translation, rotation and their combinations, theory of invariants. General equation of second degree in two variables, reduction into canonical form, lengths and position of the axes.

Pair of straight lines: Condition that the general equation of second degree in two variables may represent a pair of straight lines. Point of intersection of two intersecting straight lines, angle between two lines given by $ax^2+2hxy+by^2=0$, equation of bisectors of the anglebetween the pair of straight lines, equation of two lines joining the origin to the point in which two curves meet.

Polar coordinates, polar equation of straight lines, circles and conic referred to a focus as pole, equation of chord, tangent and normal.

Unit-4

Planes: Distance of a point from a plane, Angle between two planes, pair of planes, Bisectors of angles between two planes; Straight lines: Equations of straight lines, Distance of a point from a straight line, Distance between two straight lines, Distance between a straight line and a plane; Spheres: Different forms, Intersection of two spheres, Orthogonal intersection, section of a sphere by a plane, great circle, sphere through a given circle, Tangents and normal, Radical plane, Radical line, Coaxial system of spheres, Pole, Polar and Conjugacy.

Classification of quadric surfaces, Cone, Cylinder, Central conicoids, Tangent plane, Normal, Polar planes, and Polar lines.

Suggested books:

1. Mapa S.K.: Higher Algebra (Abstract and Linear); Levant publications
2. Khan R.M.: Algebra; NCBA
3. Sengupta S.B.: Coordinate geometry and vector analysis
4. Khan R.M.: Analytical geometry of two and three dimensions and vector analysis; NCBA
5. Loney S.L.: The elements of coordinate geometry; Arihant publications.
6. Fenn R: Geometry; Springer publications.

SECOND YEAR

SEMESTER III

PAPER 3

MT301M: Calculus

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Limits of functions (epsilon − δ approach), continuity, examples of continuous functions, intermediate value theorem, Differentiability and its geometrical interpretation, higher order derivatives, Leibniz rule and its applications. Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem and their geometrical interpretations, Darboux's theorem. Indeterminate forms, L'Hospital's rule.

Unit-2

Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's seriesexpansions of exponential and trigonometric functions.

Convexity and point of inflexion; Tangent and Normal; Curvature of plane curves; Asymptotes; Envelopes; Singular points.

Unit-3

Functions of several variables, limit and continuity of functions of two variables, repeated limits, partial differentiation, chain rule, change of variables, total derivative, equality of mixed partial derivatives, Euler's theorem for homogeneous functions of two and three variables, converse of Euler's theorem, Jacobian, functional dependence.

Criteria for Maxima/ Minima/ Saddle points, method of Lagrange multipliers, constrained optimization problems.

Unit-4

Double integration over rectangular and nonrectangular regions, Double integrals in polar coordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, Line integrals, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, The Gauss divergence theorem.

Suggested books:

1. Maity and Ghosh: Analysis (Differential Calculus); Central publications.
2. Shanti Narayan and Mittal P.K.: Differential Calculus, S. Chand publications.
3. Pundir S.K.: Mathematical Analysis; CBS publishers.
4. Klymchuk S: Counterexamples in Calculus; Mathematical Association of America.
5. Marsden, Tromba and Weinstein: Basic Multivariable Calculus; Springer.

SEMESTER IV

PAPER 4

MT401M: Differential equations and Linear programming problems

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Significance of ordinary differential equation. Geometrical and physical consideration. Formation of differential equation by elimination of arbitrary constant. Meaning of the solution of ordinary differential equation. Concept of linear and non-linear differential equations. Order and degree of an ordinary differential equation, Equations of first order and first degree : Statement of existence theorem. Separable, Homogeneous and Exact equation. Condition of exactness, Integrating factor. Rules of finding integrating factor, (statement of relevant results only),Equations reducible to first order linear equations.

Equations of first order but not of first degree, Clairaut's equation. Singular solution, Applications : Geometric applications, Orthogonal trajectories. Higher order linear equations with constant coefficients : Complementary function, Particular Integral, Symbolic operator D.

Method of undetermined co-efficients, Method of variation of parameters. Euler's homogeneous equation and Reduction to an equation of constant coefficients.

Unit-2

Exact differential equations of higher order, method of solution, Non-linear exact equations, linear equations of some special forms, Second order linear equations with variable coefficients, Reduction of order when one solution the homogeneous part is known. Complete solution. Method of variation of parameters.

Reduction to Normal form. Change of independent variable. Operational Factors. Simple eigenvalue problems. Simultaneous linear differential equations.

Unit-3

Formulation**,** Canonical and standard forms, Graphical method; Convex and polyhedral sets, Hyperplanes, Extreme points; Basic solutions, Basic Feasible Solutions, Reduction of feasible solution to basic feasible solution, Correspondence between basic feasible solutions and extreme points; Slack and surplus variables, Standard form of an LPP.

Optimality criterion, Improving a basic feasible solution, Unboundedness, Unique and alternate optimal solutions; Simplex algorithm and its tableau format; Artificial variables, Two-phase method, Big-*M* method.

Unit-4

Formulation of the dual problem, primal-dual relationships, Duality theorems, Complimentary slackness theorem, Economic interpretation of the dual, Dual-simplex method.

Applications:

*Transportation Problem***:** Definition and formulation, Methods of finding initial basic feasible solutions: Northwest-corner rule, Row minima, Column minima, matrix minima, Least- cost method, Vogel approximation method; Unbalanced transportation problems, Optimality tests for transportation problems and MODI method for obtaining optimal solution, degeneracy in transportation problems;

*Assignment Problem***:** Mathematical formulation and Hungarian method.

Suggested books:

1. Ross S.L.: Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
2. Ahsan Z: Differential Equations & their applications, Prentice Hall of India.
3. Raisinghania M.D.: Ordinary Differential Equations; S.Chand and Sons.
4. Raisinghania M.D.: Advanced Differential Equations; S. Chand and Sons.
5. Paul R. Thie & Gerard E. Keough (2014). *An Introduction to Linear Programming and Game Theory* (3rd edition). Wiley India Pvt. Ltd.
6. Frederick S. Hillier & Gerald J. Lieberman (2015). *Introduction to Operations Research* (10th edition). McGraw-Hill Education.
7. J.G. Chakraborty and P.R.Ghosh; Linear Programming and Game theory; MoulikLibrary.
8. P.M.Karak; Linear Programming and theory of games; New Central Book Agency

THIRD YEAR

SEMESTER V

PAPER 5

MT501M: Real Analysis and Numerical Analysis

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Review of algebraic and order properties of R, neighborhood of a point in R, idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, bounded below sets, bounded sets, unbounded sets, supremum (l.u.b) and infimum (g.l.b), the completeness property of R, the Archimedean property, density of rational (and irrational) numbers in R, intervals in R. Limit points of a set, isolated points, derived sets, open and closed sets, closure of a set, Bolzano-Weierstrass theorem for sets.

Unit-2

Sequences, bounded sequence, convergent sequence, limit of a sequence, limit theorems,monotone sequences, monotone convergence theorem.

Subsequences, divergence criteria, monotone subsequence theorem (statement only), Bolzano Weierstrass theorem for sequences, Cauchy sequence, Cauchy's convergence criterion

Infinite series, convergence and divergence of infinite series, Cauchy criterion, tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, integral test, alternating series, Leibniz test, absolute and conditional convergence.

Unit-3

Approximate numbers, significant figures, errors: relative, absolute and percentage. rounding off, truncation. Definition and properties of finite difference operators, shift operator

Interpolation: Newton's forward, backward formulae, Lagrange's formula. related problems. Differentiation formula based on Newton forward and backward formula

Numerical integration : General quadrature formula - Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule.

Unit-4

Numerical solution of ordinary differential equations : Taylor series method, Picard's method, Euler's method, modified Euler's method.

Transcendental and polynomial equations : bisection method, regula-falsi method, secant method, Newton-Raphson method, iteration method, rates of convergence of these methods, related problems.

System of linear algebraic equations: Gaussian Elimination and Gauss -Jordan methods including matrix inversion, Gauss- Seidel method and their convergence, related problems.

Suggested books:

1. Bartle R.G.and Sherbert D.R., Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Kumar A and Kumaresan S: A basic course in Real Analysis, CRC Press.
3. Goldberg R.R.: Real Analysis.
4. Mukherjee Kalyan: Numerical Analysis; NCBA.

5. Mollah S.A.; Numerical Analysis and Computational procedures; Books and Allied Pvt. Ltd.

6. Scarborough J.B.; Numerical mathematical analysis; Oxford University Press.

7. Rao G.S. ; Numerical Analysis; New Age International.

8. Chakraborty and Ghosh; Numerical Analysis; U.N. Dhur and sons.

SEMESTER VI

PAPER 6

MT601M: Probability, Statistics and Theory of Integration

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Brief review of Measures of Central Tendency. Measures of Dispersion: Definition, properties (without proof) and calculation of Range, Quartile Deviation, Mean Deviation, Standard Deviation and coefficient of variation. Definition and calculation of moments, skewness and kurtosis.

Correlation and Regression: Concept of bivariate frequency distribution, marginal frequency distribution and conditional frequency distribution. Pearson's correlation coefficient: Definition, properties and calculation. Regression: Definition and different properties, fitting of regression lines by method of least squares. Curve fitting: Second degree polynomial and exponential.

Unit-2

Probability :Different terminology regarding probability, Classical definition, Statistical definition and Axiomatic definition of probability. Addition theorem and multiplication theorem of probability.

Probability Distribution: One dimensional random variable and two dimensional random variable (Definition only), univariate and bivariate probability distribution, cumulative distribution function: definition and properties. Mathematical expectation, addition andmultiplication theorem of expectation, moment generating function and characteristic function. Marginal and conditional probability distribution. Regression curve.

Uniform, Bernoulli, Binomial, Poisson and Normal distribution.

Unit-3

Riemann integration; inequalities of upper and lower sums; Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions; Riemann integrability of monotone and continuous functions

Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals; Fundamental theorems of Calculus, Mean value theorems, Riemann integrability of composition of Riemann integrablefunctions.

Unit-4

Reduction formulae, derivations and illustrations of reduction formulae of the type sinnx, cosnx, tannx, secnx, log x , sinmxcosnx etc. Working knowledge of Beta and Gamma integrals (assuming their convergence and other properties),

Improper integrals and their convergence, Beta and Gamma functions, related problems.

Suggested books:

1. S.C. Gupta and V.K. Kapoor: *Fundamentals of Mathematical Statistics*, Sultan Chand andSons.
2. Sheldon Ross: *Introduction to Probability Models*, 9th Ed., Academic Press, IndianReprint, 2007.
3. Medhi, J.: *Statistical Methods: An introductory Text*, (New Age International (P) Ltd, 2000).
4. Mapa S.K.: Real Analysis; Levant Publications
5. Maity and Ghosh: Analysis (Integral Calculus); NCBA
6. Bartle R.G. and Sherbert D.R.: Introduction to Real Analysis, 3rd Ed., John Wiley andSons (Asia) Pvt. Ltd., Singapore, 2002.

FOURTH YEAR

SEMESTER VII

PAPER - 7

MT701M: Mechanics, Number theory and Complex Analysis

Total Mark = 100 (IA = 40 + ESE = 60) Credit = 04

Unit-1

Expression for velocity and acceleration of particle moving in a straight line and in a planecurve.

Rectilinear motion of a particle under attractive force.

Simple Harmonic Motion, damped vibrations, forced vibration, damped forced oscillations Tangent and normal acceleration. Velocity and acceleration along radial and transverse directions.

Unit-2

Central orbits, central forces, motion of a particle under central force. Differential equation inpolar and pedal coordinates, velocity under central force. Apse, apsidal distance and apsidal angle. Motion in resisting medium. Areal velocity, Characteristics of central orbits, Kepler's laws of planetary motion.

Unit-3

The division algorithm, The greatest common divisor (g.c.d.) of two integers a and b. Relatively prime integers. The equation ax+ by = c has integral solution iff (a,b) divides c. (a , b, c are integers). Prime numbers. Euclid's first theorem: If some prime p divides ab, then p divides either a or b. Euclid's second theorem: There are infinitely many prime integers. Unique factorization theorem. Statement Chinese Remainder Theorem and simple problems. Euler ϕ function.

Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Fermat's Little theorem, Wilson's theorem.

Unit-4

Polar representation of complex numbers, De Moivre's theorem for rational indices, related problems, expansions of sin $n\theta$, $\cos n\theta$, $\sin\theta$, $\cos\theta$, trigonometric, exponential and logarithmic functions of complex arguments, Gregory's series.

Algebra of complex numbers, polar representation of complex numbers, geometrical interpretation of argument and modulus of complex numbers , complex equations of straight lines, circles. Limits, continuity of functions of complex variable, regions in the complex plane.

Derivatives, differentiation formulae, Cauchy-Riemann equations, sufficient conditions for differentiability, analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function.

Suggested books:

1. Datta N. and Jana R.N.: Dynamics of a Particle.
2. Chakraborty and Ghosh: Dynamics of Particle and Rigid bodies; U N Dhur and Sons.
3. Loney, S. L., Elements of Statics & Dynamics, Part I (Maxford Books, 2003).
4. Rao, S. Engineering Mechanics - Statics and Dynamics (Pearson Education, 2008).
5. Elementary Number Theory, David. M. Burton, MacGrawHill.
6. Malik S.B.: Basic Number Theory.
7. Ponnusamy S.: Foundations of Complex Analysis, Narosa Publishers.
8. Spiegel M.R.: Complex Analysis; McGraw Hill Publications.

SEMESTER VIII

PAPER 8

MT801M: Python programming with practical

Group A (Theory)

Total Mark = 60 (IA = 24 + ESE = 36); Credit = 02

Unit-1

Introduction to Python Programming: Features, basic syntax, Writing and executing simple program, Basic Data Types such as numbers, strings, etc Declaring variables, Performing assignments, arithmetic operations, Simple input-output

Sequence Control – Precedence of operators, Type conversion Conditional Statements: if, if-else, nested if –else

Looping: for, while, nested loops.

Unit-2

Control statements: Terminating loops, skipping specific conditionsString Manipulation: declaring strings, string functions Manipulating Collections Lists, Tuples

Dictionaries – Concept of dictionary, techniques to create, update & delete dictionary items. Functions: Defining a function, calling a function, Advantages of functions, types of functions, function parameters, Formal parameters, Actual parameters, anonymous functions, global and local variables

Group B (Practical)

Total Mark = 40 (IA = 16 + ESE = 24); Credit = 02

Unit-1

1. Ascending / Descending order. Finding Largest / smallest.

2. Sum of finite series.

3. Sum of Convergent series.

4. Checking whether a number is prime or not. Generation of prime numbers.

5. Solution of Quadratic equation

6. Mean, variance, correlation coefficient, equation of regression lines.

7. Operations on integers, matrices,

8. Drawing graphs of functions,

9. Generating diagrams of surface areas and volumes under surfaces of revolution.

Unit-2

1. Newton's forward interpolation formula.

2. Newton's Backward interpolation formula.

3. Lagrange interpolation formula.

4. Bisection method.

5. Newton-Raphson method.

6. Regula Falsi method.

7. Trapezoidal Rule.

8. Simpson's 1/3 rule.

Suggested books:

1. Yashavant Kanetkar, Aditya Kanetkar: Let Us Python, 5th Edition, BPB Publications.
2. M. Lutz: Learning Python, 5th Edition, O'Reilly Media(2013).

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