

FOUR-YEAR UNDERGRADUATE PROGRAM

with
SINGLE MAJOR AND SINGLE MINOR COURSE
under
THE NEW CURRICULUM AND CREDIT FRAMEWORK, 2022

REVISED SYLLABUS



in

MATHEMATICS

(w.e.f. the academic session 2024-2025)

UNIVERSITY OF NORTH BENGAL



Raja Rammohunpur, P.O. - NBU Campus
District - Darjeeling, Pin - 734013, West Bengal, India

FYUGP REVISED SYLLABUS

Single Major and Single Minor

Paper Code	Paper Level	Paper	Paper Description	Paper Type	Full Marks			Credit	
					TH	TU	PR	L	T/P
SEMESTER 1									
MATHMAJ101	100	MAJ	Classical Algebra and Matrix Theory	TH	60	20	---	3	1
MATHMAJ102	100	MAJ	Calculus and Geometry	TH	60	20	---	3	1
SEMESTER 2									
MATHMAJ203	200	MAJ	Real Analysis	TH	60	20	---	3	1
MATHMAJ204	200	MAJ	Differential Equations	TH	60	20	---	3	1
SEMESTER 3									
MATHMAJ305	200	MAJ	Group Theory	TH	60	20	---	3	1
MATHMAJ306	200	MAJ	Theory of Real and Complex Functions	TH	60	20	---	3	1
SEMESTER 4									
MATHMAJ407	200	MAJ	Mechanics	TH	60	20	---	3	1
MATHMAJ408	200	MAJ	Ring Theory and Lattice Theory	TH	60	20	---	3	1
SEMESTER 5									
MATHMAJ509	300	MAJ	Linear Algebra	TH	60	20	---	3	1
MATHMAJ510	300	MAJ	Riemann Integration and Integral Transforms with applications	TH	60	20	---	3	1
MATHMAJ511	300	MAJ	Number Theory	TH	60	20	---	3	1
MATHMAJ512	300	MAJ	Probability and Statistic	TH	60	20	---	3	1
SEMESTER 6									
MATHMAJ613	300	MAJ	Vector and Tensor Calculus	TH	60	20	---	3	1
MATHMAJ614	300	MAJ	Numerical Analysis, C-programming and its applications	TH	60	20	---	3	1
MATHMAJ615	300	MAJ	Metric Spaces and Multivariate Calculus	TH	60	20	---	3	1
MATHMAJ616	300	MAJ	Linear Programming and Game Theory	TH	60	20	---	3	1

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU

DETAILED SYLLABUS

of

MAJOR COURSES

(semester wise)

Semester-1											
Paper Description	Classical Algebra and Matrix Theory			Paper Code				MATHMAJ101			
Paper (Type)	Major Course (Theory)			Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total	
100	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	----	80	

CLASSICAL ALGEBRA AND MATRIX THEORY

Classical Algebra:

Unit 1: **8 classes**
 Complex numbers: Polar representation, De Moivre's theorem for rational indices and its applications. Logarithm, trigonometric, exponential and hyperbolic functions of complex variable.

Unit 2: **15 classes**
 Theory of polynomial equations: Fundamental theorem of Classical Algebra (statement only). Location and nature of roots: Descartes' rule of signs and Sturms' theorem. Relation between roots and coefficients. Solution methods for cubic and biquadratic poly. equations: Cardan's and Ferrari's method. Symmetric functions of roots, transformation of equation, special roots, reciprocal equations.

Unit 3: **(5+12) classes**
 Inequality: $AM \geq GM \geq HM$, weighted means and m -th power theorem (statement only), Cauchy-Schwarz inequality (statements only) and their applications.

Integers: Well-ordering property of positive integers, division algorithm, Euclidean algorithm, congruence relation between integers, Fundamental Theorem of Arithmetic (statement only), solution of linear congruence, Chinese Remainder Theorem (statement only) and its applications to find a solution of system of linear congruences. Fermat's Little theorem & Wilson theorem (statement only) and their simple problems.

Matrix Theory:

Unit 4: **10 classes**
 Matrices: Elementary operations, elementary matrices, row/column equivalent matrix, echelon matrix, row/column reduced echelon matrix, rank of matrix, normal forms, congruence operations, congruence matrices. Signature and index. Solving system of linear equations by matrix method.

Unit 5: **10 classes**
 Eigen values and eigen vectors of a square matrix, characteristic equation of a matrix, Cayley-Hamilton theorem (statement only) and its simple applications.

Suggested Reading Books:

- S. Lang, Introduction to Linear Algebra, *Springer*.
- S.K. Mapa, Higher Algebra: Classical, *Levant*.
- S.K. Mapa, Higher Algebra: Abstract & Linear, *Levant*.
- W.S. Burnstine and A.W. Panton, Theory of equations, *Creative Media*.
- S.H. Friedberg, A.J. Insel and L.E. Spence, Linear Algebra, *Pearson Edu. Pub. (Indian)*.
- K. Hoffman and R. Kunze, Linear algebra, *Prentice Hall India*.
- V. Sahai and V. Bist, Linear Algebra, *Narosa Pub. House*.

Semester-1

Paper Description	Calculus and Geometry		Paper Code				MATHMAJ102			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
100	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	----	80

CALCULUS AND GEOMETRY

Calculus:

Unit 1: **15 classes**

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

Arc length of a curve including parametric curves, area enclosed by a curve, area between two curves.

Unit 2: **15 classes**

Successive derivatives, Leibnitz rule and its applications. Indeterminate forms, L'Hospital's rule and its applications.

Concept of simple and closed curves and their parameterizations, Pedal equation, envelopes, evolute, asymptotes, radius of curvature. Concavity, convexity, cusps and inflection points.

Geometry:

Unit 3: 2D **15 classes**

Circle, parabola, ellipse and hyperbola: Equations of pair of tangents from an external point, chord of contact, Poles and Polars. Conjugate point and conjugate line, diameter.

Pairs of straight lines: Condition that the general equation of second degree in two variables may represent two straight lines. Point of intersection of two intersection straight lines. Angle between two lines given by $ax^2 + 2hxy + by^2 = 0$. Angle bisectors. Equation of two lines joining the origin to the points in which a line meets a conic.

Transformations of rectangular Axes: Translation, Rotation and their combinations. Theory of Invariants.

General Equations of Second Degree in two variables: Classification of conics using the discriminant and reduction to canonical form.

Polar Equations: Polar equations of straight lines, circles and conic referred to a focus as pole, Equations of tangent, normal and chord of contact.

Unit 4: 3D **15 classes**

Rectangular Cartesian co-ordinate in space: Distance between two points, section formula.

Equation of plane: General form, intercept and Normal forms. The sides of a plane, signed distance of a point from a plane. Equation of a plane passing through the intersection of two planes. Angle between intersection planes, Bisectors of angles between two intersecting planes. Parallelism and perpendicularity of two planes.

Straight lines in space: Equation (symmetric and parametric form), Direction ratio and Direction cosines. Canonical equation of the line of intersection to two intersecting planes. Angle between two lines. Distance of a point from a line. Condition of coplanarity of two lines. Equations of skew lines. Shortest distance between two skew lines.

Sphere: General equation, circle, sphere through the intersection of two spheres. Radical Plane. Tangent, Normal, pole and polar with respect to sphere.

Other Surfaces: Cylindrical surfaces, cones, ellipsoids, paraboloids, hyperboloids, plane sections of conicoids, generating lines.

General equation of 2nd degree in 3 variables: Reduction to canonical forms. Classification of quadrics.

Suggested Reading Books:

- 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.
- H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, *Introduction to Calculus and Analysis (Volumes I & II)*, Springer Verlag, New
- T. Apostol, *Calculus*, Volumes I, and II.
- S. Goldberg, *Calculus and mathematical analysis*.
- S. K. Mapa, *Introduction to Real Analysis*, *Sarat Book House*.
- S. C. Malik and S. Arora, *Mathematical Analysis*, *New Age International*.
- U. Chatterjee and N. Chatterjee, *Advanced Analytical Geometry of Two and Three Dimensions*, *Academic Publishers*.
- R.M. Khan, *Analytical Geometry of Two and Three Dimensions & Vector Analysis*, *New Central Book Agency*

Semester-2										
Paper Description	Real Analysis		Paper Code				MATHMAJ203			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
100	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	----	80

REAL ANALYSIS

Unit 1:

12 classes

Finite and Infinite sets: Definitions and Examples, Uniqueness Theorem (statement only), infiniteness and well-ordered properties of \mathbb{N} (statement only). Countable, Denumerable and Uncountable sets: Definitions and Examples, Countability of union, intersection, product, subset, superset of countable sets. Countability of rational numbers. Uncountable subsets of \mathbb{R} etc.

Unit 2:

18 classes

Review of Algebraic and order properties of \mathbb{R} , ε -neighborhood of a point in \mathbb{R} . Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima with their properties and supporting examples. Order completeness property of \mathbb{R} and its equivalent properties. Archimedean property, density property, order property of \mathbb{R} , Intervals in \mathbb{R} , Limit point and isolated point of a set. Open set, closed set, derived set and their properties. Bolzano-Weierstrass theorem on limit point. Nested interval theorem. Compact sets in \mathbb{R} . Heine-Borel Theorem.

Unit 3:

15 classes

Sequences: Sequence, bounded sequence, convergent sequence. Limit and limit points of a sequence. Uniqueness of limit of convergent sequences. \liminf & \limsup . Limit theorems. Monotone sequences, monotone convergence theorem. Sandwich theorem. Subsequences. Divergence criteria. Monotone subsequence theorem (statement only). Bolzano Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion. Completeness property of \mathbb{R} and its equivalent properties.

Unit 4:

15 classes

Series: Infinite series, convergence and divergence of infinite series, Cauchy criterion. Tests for convergence: comparison test, limit comparison test, D'Alembert's ratio test, Cauchy's nth root test, integral test. Absolutely convergent series (Ratio test, Root test), conditionally convergent series (Leibniz's test) and alternating series. Re-arrangement of terms, power series and its radius of convergence.

Suggested Reading Books:

- R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
- 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.
- T. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, ,Voll II, Springer.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- T. Tao, Analysis II, Hindustan Book Agency, 2006.

Semester-2										
Paper Description	Differential Equations		Paper Code				MATHMAJ204			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
100	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	----	80

DIFFERENTIAL EQUATIONS

Unit 1:

14 classes

Differential equations: Lipschitz condition and Picard's Theorem (Statement only). General, particular, explicit, implicit and singular solutions of a differential equation. First order and first-degree equations: Existence theorem (statement only). Exact equation, integrating factors and different calculating rules (statement of relevant results). Linear equations and Bernoulli equation. First order but not of first-degree equations: Singular solution of Clairaut's equation only

Unit 2:

20 classes

General solution of homogeneous equation of second order, principle of super position for homogeneous equation. Wronskian: Its properties and applications. Higher order linear equations with constant coefficients: Complementary function and particular integral. Method of undetermined coefficients, method of variation of parameters. Euler's homogeneous equation. Second order linear equations with variable coefficients: Method of variation of parameters. Reduction to normal form. Change of dependent and independent variables.

Unit 3:

8 classes

Systems of linear differential equations, types of linear systems. Differential operators. An operator method for linear systems with constant coefficients. Basic theory of linear systems in normal form. Homogeneous linear systems with constant coefficients: Two equations in two unknown functions.

Unit 4:

18 classes

Partial differential equations: PDE of the first order, Lagrange's solution, nonlinear first order partial differential equations, Charpit's general method of solution, some special types of equations which can be solved easily by methods other than the general method.

Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.

Suggested Reading Books:

- B. Barnes and G. R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, Taylor and Francis, London and New York, 2009.
- C. H. Edwards and D. E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
- S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- M. L. Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- D. Murray, Introductory Course in Differential Equations, Longmans Green and Co.
- Boyce and Diprima, Elementary Differential equations and boundary Value problems, Wiley.
- G. F. Simmons, Differential Equations, Tata McGraw Hill.

Semester-3											
Paper Description	Group Theory			Paper Code				MATHMAJ305			
Paper (Type)	Major Course (Theory)			Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total	
200	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	20	---	80	

GROUP THEORY

Unit 1:

20 classes

Equivalence relations, partially ordered relation, functions, permutations, even and odd permutations, invertible functions.

Groupoid, semigroup, monoid, groups, finite and infinite groups, commutative groups. Basic properties of groups. Finite semigroup with cancellation properties, semigroup containing unique solution of $ax = b$ and $xa = b$. Well-known groups: \mathbb{Z}_n , U_n , $M_n(R)$, $GL(n, \mathbb{R})$, $SL(n, \mathbb{R})$, Klein's 4 group, multiplicative group of n -th roots of unity, symmetric group S_n (e.g. S_3, S_4, S_5, \dots), alternating group A_n , Dihedral group, Quaternion group. Direct product of groups.

Unit 2:

10 classes

Subgroups and its basic properties. Union, intersection and product of subgroups, necessary and sufficient condition for a subset of a group to be a subgroup. Centralizer, normalizer and center of a group.

Unit 3:

18 classes

Order of a group, order of an element. Cyclic group and its properties, cosets, normal subgroup & quotient group and their relevant results. Lagrange's theorem and consequences including Fermat's Little theorem, Cauchy's theorem for finite abelian groups.

Unit 4:

12 classes

Group homomorphism & isomorphism and their basic properties, Cayley's theorem, First, Second and Third isomorphism theorems and their problems.

Suggested Reading Books:

- J. B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- J. A. Gallian, Contemporary Abstract Algebra, Narosa Publishing House, New Delhi, 1999.
- J. J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 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.
- S.K. Mapa, Higher Algebra: Abstract & Linear, *Levant*.

Semester-3										
Paper Description	Theory of Real and Complex Functions			Paper Code			MATHMAJ306			
Paper (Type)	Major Course (Theory)			Credit			Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
200	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	20	---	80

THEORY OF REAL AND COMPLEX FUNCTIONS

Theory of Real Functions:

Unit 1:

15 classes

Limits of functions (ϵ - δ approach), sequential criterion for limits, divergence criteria. Limit theorems. One sided limit. Infinite limits and limits at infinity.

Continuous functions, sequential criterion for continuity. Algebra of continuous functions. Continuous functions on an interval. Intermediate value theorem. Location of roots theorem. Preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.

Unit 2:

15 classes

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

Rolle's theorem. Lagrange and Cauchy mean value theorem, applications of mean value theorem to inequalities and approximation of polynomials.

Unit 3:

10 classes

Sequence of functions and series of functions: Relevant theorems / tests (statements only) and problems. Taylor's theorem with Lagrange's form and Cauchy's form of remainder, application of Taylor's theorem to convex functions. Taylor's series and Maclaurin's series expansions of exponential, trigonometric functions, $\log(1+x)$, $1/(ax+b)$ and $(x+1)^n$ etc.

Theory of Complex Functions:

Unit 5:

20 classes

Geometric representation of complex numbers, stereographic projection. Complex functions, continuity and differentiability of complex functions, analytic functions, Cauchy-Riemann equation, harmonic functions, Milne's method (statement only). Conformal mapping, Bilinear transformation (simple problems).

Suggested Reading Books:

- R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
- 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.
- T. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, , Voll II, Springer.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- T. Tao, Analysis II, Hindustan Book Agency, 2006.
- J. W. Brown and R. V. Churchill, Complex Variables and Applications, McGraw-Hill Int. Edi. 2009.

Semester-4										
Paper Description	Mechanics		Paper Code				MATHMAJ407			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
200	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	20	---	80

MECHANICS

Introduction to Particle Dynamics

Unit 1:

20 classes

Motion along a straight line: Attractive force, repulsive force, motion under attractive and repulsive force, motion under repulsive force inversely proportional to the square of the distance, simple harmonic motion, damped harmonic oscillation, forced oscillation, damped forced oscillation.

Two dimensional motion: Velocity and acceleration in 2D cartesian coordinate system, equation of motion, angular velocity and angular acceleration, relation between angular velocity and linear velocity, normal acceleration, tangential and normal component of acceleration describing along a plane curve, radial and cross radial component of velocity and acceleration in 2D polar coordinate system.

Central force and central orbit: Differential equation of central orbit, pedal form, motion in a plane under central forces, motion under the inverse square law, apses, finding law of force moving along a plane curve, Kepler's laws, modelling ballistics and planetary motion.

Introduction to Rigid dynamics

Unit 2:

10 classes

System of Particles: Center of mass, motion of a center of mass, motion about center of mass. Principle of conservation of linear momentum and angular momentum.

Rigid body: Centre of gravity, moment and product of inertia, radius of gyration. Theorems of parallel and perpendicular axis. Calculation of moment of inertia, Routh's law. D'Alembert's principle, Equation of motion, Kinetic energy.

Statics

30 classes

Unit 3:

Co-planar forces: Astatic equilibrium, positions of equilibrium of a particle lying on a smooth plane curve under the action of given forces. Moment of a force about a line, axis of a couple, resultant of any number of couples acting on a rigid body.

Virtual work: Virtual displacement, virtual work, principle of virtual work, converse of the principle of virtual work.

Forces in three dimensions: Reduction of a system of forces acting on a rigid body, moment of a system of forces, Poinsot's central axis, uniqueness of Poinsot's central axis, equation of central axis, a given system of forces can have only one central axis. Wrench, Pitch, Intensity and Screw, condition that a given system of forces may have single resultant. Invariants of a given system of forces.

Stable and Unstable Equilibrium: Field of forces, conservative field, potential energy of a system, energy test of stability, a perfectly rough body rests in equilibrium on a fixed body-discuss the stability of such equilibrium.

Suggested Reading Books:

- S. L. Loney, An Elementary Treatise on the Dynamics of particle and of Rigid Bodies.
- S. L. Loney, Elements of Statics and Dynamics I and II
- N. Dutta and R.N. Jana, Dynamics of particle, Shreedhar Prakashani.
- S. Ganguly and S. Saha, Analytical dynamics of particle, New central book agency.
- M.C. Ghosh, Analytical Statics, Shreedhar Prakashani.
- S.A. Mollah, Analytical Statics, Books and Allied.
- B.C. Das and B.N. Mukherjee, Statics, U.N. Dhur and Sons.

Semester-4											
Paper Description	Ring Theory and Lattice Theory			Paper Code				MATHMAJ408			
Paper (Type)	Major Course (Theory)			Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total	
200	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	---	80	

RING THEORY AND LATTICE THEORY

Ring Theory:

Unit 1: **18 classes**

Ring and its properties. Well-known rings: Matrix ring, \mathbb{Z}_n , $\mathbb{Z}[i]$, $\mathbb{Q}[i]$, ring of quaternions, polynomial ring $R[x]$, ring of continuous functions. Divisors of zero, units, cancellation property, integral domains and its relevant results, division ring, field and their relevant results. Characteristics of a ring. Subring & subfield and their necessary and sufficient conditions.

Unit 2: **16 classes**

Ideals, ideal generated by a subset of a ring, principal ideal. Operations on ideals: $\text{sum}(A + B)$, intersection, union & product(AB). Prime and maximal ideals and their relevant results, Quotient rings and its properties.

Unit 3: **10 classes**

Irreducible and prime elements, greatest common divisor, least common multiple. Divisibility in integral domains, Euclidean domains, principal ideal domains, unique factorization domains and their relations.

Unit 4: **10 classes**

Ring homomorphism & isomorphism and their properties. Isomorphism theorem- I, II & III and their simple applications.

Lattice Theory:

Unit 5: **16 classes**

Lattice: Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms. Definition, examples and properties of modular and distributive lattices.

Suggested Reading Books:

- J. B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- J. A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, 1999.
- J. J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 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. B. A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge 1990.
- E. G. Goodaire and M. M. Parmenter, Discrete Mathematics with Graph Theory, (2nd Ed.), Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.

Semester-5										
Paper Description	Linear Algebra		Paper Code				MATHMAJ509			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	20	---	80

LINEAR ALGEBRA

Unit 1:

20 Classes

Vector spaces and its basic properties, subspaces, algebra of subspaces (sum, intersection & direct sum of subspaces), geometric significance of subspace, linear combination of vectors, linear span, linear dependence and linear independence of vectors, basis and dimension, existence, extension and replacement theorems for basis of a finite dimensional vector space, quotient space and its dimension, Vector space Isomorphism, Every n dimensional vector space $V(F)$ is isomorphic to F^n . Vector spaces of Matrices over field of real and complex numbers, Row space & Column space, Row Rank and Column Rank and relevant results.

Unit 2:

15 Classes

Linear transformations, algebra of linear transformations, Range and null space of a linear transformation, rank and nullity of a linear transformation and relevant theorems, matrix representation of a linear transformation relative to ordered bases, correspondence between LTs and matrices. Invertibility, isomorphisms, and their relevant theorems.

Unit 3:

15 Classes

Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Linear operator, the adjoint of a linear operator. Normal and self-adjoint operators. Orthogonal projections and Spectral theorem for normal operators and self adjoint operators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms.

Unit 4:

10 Classes

Inner product spaces, norm of a vector, Schwartz's inequality, orthogonal and orthonormal sets, Gram-Schmidt orthogonalisation process, orthogonal complements, Bessel's inequality.

Suggested Reading Books:

- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- G. Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- K. Hoffman, R. A. Kunze, Linear Algebra, Prentice-Hall of India Pvt. Ltd., 1971.
- S.H. Friedberg, A.L. Insel and L.E. Spence, Linear Algebra, Prentice Hall of India Pvt. Ltd., 2004.
- Sharma, Basishtha, Linear Algebra, Krishna Prakashan Mandir
- M.L.Khanna, Linear Algebra, Jai Prakash Nath & Co.

Semester-5										
Paper Description	Riemann Integration and Integral Transforms with applications		Paper Code				MATHMAJ510			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	20	---	80

RIEMANN INTEGRATION AND INTEGRAL TRANSFORMS WITH APPLICATIONS

Riemann Integration

25 classes

Unit 1

Partition and refinement of partition of a closed and bounded interval. Upper and lower Darboux sum with associated results. Upper integral and lower integral. Darboux's theorem. Darboux's definition of integration over a closed and bounded interval. Condition for integrability. Riemann's definition of integrability. Equivalence with Darboux definition of integrability (statement only). Concept of negligible set (or zero set) defined as a set covered by countable number of open intervals sum of whose lengths is arbitrary small. Basic examples of negligible sets, A bounded function on closed and bounded interval is Riemann integrable if and only if the set of points of discontinuity is negligible-Statement only and application of the result to show integrability of sum, scalar multiple, product, quotient, monotone functions, modulus of Riemann integrable functions. Properties of Riemann integrable functions arising from the above results. Antiderivative (primitive or indefinite integral) and associated results. Fundamental theorem of Integral Calculus. First Mean Value theorem of integral calculus

Improper Integrals

10 classes

Unit 2

Improper integrals of both kinds. Test of convergence: Comparison and μ -test. Absolute and non-absolute convergence and corresponding tests. Abel's and Dirichlet's tests for convergence of the integral of a product (statements only), Convergence of Beta and Gamma functions.

Fourier Series and Fourier Transform

13 classes

Unit 3

Fourier series: Trigonometric series. Statement of sufficient condition for a trigonometric series to be a Fourier series. Fourier coefficients for periodic functions defined on $[-\pi, \pi]$. Statement of Dirichlet's condition of convergence. Statement of theorem of sum of Fourier series. Parseval's Identity.

Fourier Transform: Definition and properties of Fourier transform, Transform of derivatives. Fourier cosine and sine transforms. Convolution theorem(statement), Inverse Fourier transform. Application to solving ordinary and partial differential equation up to second order.

Laplace Transform

12 classes

Unit 4

Concept of Laplace and Inverse Laplace Transform. Sufficient conditions for the existence of Laplace Transform. Elementary properties of Laplace Transform and its inverse. Laplace Transform of derivatives and integrals. Convolution theorem (statement only). Initial and final value theorems (Statement only). Application to solving ordinary differential equations with constant coefficient (up to third order)

Suggested Reading Books:

- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Wiley and Sons (Asia) Singapore, 2002.
- C. G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
- S. Goldberg, Calculus and mathematical analysis.

- S. Narayan, Integral calculus.
- T. Apostol, Calculus I, II.
- K. A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- S. K. Mapa, Real Analysis, Levant Book
- J. L. Schiff, The Laplace Transform, Springer, Indian reprint, 2005

Semester-5										
Paper Description	Number Theory		Paper Code				MATHMAJ511			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	---	80

NUMBER THEORY

Unit 1

20 classes

Euclidean Algorithm for GCD, linear representation of GCD. Prime numbers, Fundamental Theorem of Arithmetic and its consequences, the Sieve of Eratosthenes. Linear Diophantine Equation. Ring of Gaussian integers $\mathbb{Z}[i]$. Divisibility and primes in $\mathbb{Z}[i]$. Using properties of $\mathbb{Z}[i]$ to determine which integers can be written as sums of squares of two integers.

Unit 2

20 classes

Linear congruences, Chinese Remainder Theorem. Inverse modulo a prime, Fermat's Little Theorem, congruence theorem of Wilson and Lagrange. Check digits and the validity of products identification numbers, such as, Universal Product Codes (UPC), International Mobile Equipment Identification (IMEI), International Standard Book Number (ISBN), Credit Card Numbers. Round Robin Tournament.

Unit 3

20 classes

Arithmetical functions: Tau or divisor function, sigma function, Mobius μ -function, Euler φ -function. Euler's Generalization of Fermat's Theorem. The Greatest Integer function. Primitive roots, Quadratic residues, Legendre symbol, Quadratic reciprocity law, Pythagorean triples, Fermat's Two Square Theorem.

Suggested Reading Books:

- J. Stillwell, Elements of Number Theory, Springer, 2003.
- Niven and Zuckerman An introduction to theory of numbers, Wiley 1991.
- D. M. Burton, Elementary Number Theory, 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.
- N. Robinns, Beginning Number Theory, Narosa Publishing House Pvt. Ltd., Delhi, 2007.
- M. K. Sen and B. C. Chakraborty, Introduction to Discrete Mathematics, Books & Allied (P) Ltd. (2012)
- Kenneth H. Rosen, Elementary Number Theory, 6th Edition, 2010, Pearson.
- J. H. Silverman, A friendly introduction to number theory, Prentice Hall, 2001.
- Lo-keng Hua, Introduction to number theory, Springer-Verlag, 1982.

Semester-5											
Paper Description	Probability and Statistics			Paper Code				MATHMAJ512			
Paper (Type)	Major Course (Theory)			Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total	
300	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	---	80	

PROBABILITY AND STATISTICS

Probability:

Unit 1 :

20 classes

Random experiments, Simple and compound events, Event space, classical and frequency definitions of probability and their drawbacks, probability axioms, Statistical regularity, conditional probability, multiplication rule of probabilities, Bayes' theorem.

Independent events, independent random experiments, independent trials, Real random variables, cumulative distribution function (discrete and continuous), probability mass/density functions, Discrete distributions: Uniform, binomial, Poisson, geometric, negative binomial, Continuous distributions: Uniform, normal, exponential, transformation of random variables, mathematical expectation, mean, moments, variance, moment generating function, characteristic function.

Unit 2

15 classes

Joint cumulative distribution function (discrete and continuous) and its properties, joint probability density/mass functions, marginal and conditional distributions, uniform distribution, bivariate normal distribution. expectation of function of two random variables, covariance and correlation coefficient, joint moment generating function and characteristic function, conditional expectations, regression curve, least square regression lines.

Unit 3

10 classes

Chi-square, t-distributions and their properties (statement only), Tchebycheff's inequality, Convergence in probability, Tchebycheff's theorem, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central limit theorem for independent and identically distributed random variables with finite variance (statement only).

Statistics:

Unit 4

15 classes

Population and sample, Sampling Distributions: Sample mean, moments and variance.

Estimation of parameters: Unbiased and consistent estimates, method of maximum likelihood estimate and its application to Binomial, Poisson and Normal population, Interval Estimation: Confidence intervals for mean and variance of normal population.

Statistical hypothesis: Simple and composite hypotheses, null hypothesis, alternative hypothesis. Testing of hypothesis, critical region and accepted region, type-I and type-II errors, level of significance, best critical region of a test, Neyman-Pearson theorem (statement only) and its application to normal population. Likelihood ratio testing and its application to normal population.

Suggested Reading Books:

- R. V. Hogg, J. W. McKean and A. T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
- I. Miller and M. Miller, J. E. Freund, Mathematical Statistics with Applications, Pearson Education, Asia, 2006.

- S. Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
- A. M. Mood, F. A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, Tata McGraw- Hill, 2007.
- Lipschutz, Introduction to Probability and Statistics, Tata McGraw Hill.
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

Semester-6										
Paper Description	Vector and Tensor Calculus		Paper Code				MATHMAJ613			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	20	---	80

VECTOR AND TENSOR CALCULUS

Vector Calculus:

Unit 1

15 classes

Scalar triple product, Vector triple product. Lagrange's identity for four vectors, Vector product of four vectors. Reciprocal system of vectors. Applications in geometric, trigonometric and simple mechanical problems (work done by a force, moment of a force about a point).

Vector function. Limit, continuity of a vector function. Derivative of a vector, Conditions for a vector $\vec{r} = \vec{f}(t)$ having constant magnitude, constant direction. Velocity and acceleration vectors as derivatives. Partial derivatives of vectors

Application in elementary differential geometry: Curves and surfaces. Tangent and Normal vectors. Principal normal and Binormal vectors. Osculating plane, Tangent plane, Normal plane and Rectifying plane. Curvature, Torsion and Serret-Frenet formulae.

Unit 2

15 classes

Scalar and Vector fields. Directional derivative. Gradient, Divergence, Curl and the rules associated with them. Second order vector differential operators- Laplacian operator. Irrotational and Solenoidal vectors.

Vector Integration. Line integrals- Tangential line integral, Circulation. Conservative vector fields and conditions for conservativeness. Interpretation of a line integral as the work done by a force. Surface integrals- Normal surface integrals. Volume Integrals. Statements (only) and verifications of Gauss's Divergence theorem, Stoke's theorem, Green's theorem and their applications.

Tensor Calculus:

Unit 3

15 classes

A Tensor as a generalized concept of a vector in an Euclidean space E^3 . To generalize the idea in an n-dimensional space. Transformation of co-ordinates in $E^n (n = 2, 3)$. Summation convention. Contravariant, covariant and mixed tensors. The Kronecker delta. Invariants. Addition and subtraction of tensors. Contraction. Outer and Inner products of tensors. Symmetric and Skew-symmetric tensors. Quotient law. Reciprocal Tensor. Line element & Metric tensor. Reciprocal metric tensor. Associated tensor. Raising and lowering of indices.

Christoffel symbols and their laws of transformations. Covariant differentiation and it's laws. Ricci's Theorem. Gradient, Divergence, Curl and Laplacian operators in tensor form.

Unit 4

15 classes

Geodesic and its differential equation in Riemannian Space. Geodesics and Riemannian coordinates. Bianchi identity. Geodesics from the line element, Geodesic in Euclidean space. Parallelism or Levi-Civita's concept. Affine connection. Intrinsic derivatives of tensors.

Riemann-Christoffel tensor or Curvature tensor, Riemannian Curvature and its formula in terms of Covariant Curvature tensor, Gaussian Curvature. Flat space, Schur's theorem. Mean Curvature, Ricci tensor and its geometrical representation. Einstein Space and Einstein tensor.

Suggested Reading Books:

- I. Borisenko and I. E. Tarapov, Vector and Tensor Analysis with Applications, Dover Publications Inc., New York.
- E. C. Young, Vector and Tensor Analysis, Revised second edition, CRC Press, Taylor & Francis Group..
- Spiegel, M.R. Vector Analysis and Introduction to Tensor Analysis(McGraw Hill).
- J. Marsden and Tromba, Vector Calculus, McGraw Hill.
- K. C. Maity and R. K. Ghosh, Vector Analysis, New Central Book Agency(P) Ltd. Kolkata (India).
- Chakravorty, J. G. 7 Ghosh, P.R., Vector Analysis (U. N. Dhur and Sons).
- Khan R.M., Analytical Geometry in two and three Dimensions & Vector Analysis(New Central Book Agency)
- P. Grinfeld, Introduction to Tensor Analysis and the Calculus on Moving Surfaces, Springer.
- E. S. S. Filho, Tensor Calculus for Engineers and Physicists, Springer(2016)
- S. Sahraee and P. Wriggers, Tensor Calculus and Differential Geometry for Engineers, Springer
- J.A. Schouten, Tensor Analysis for Physicists, 2nd edition, Dover Books on Physics.
- Das, A.N., Introduction to Tensor Analysis, (U. N. Dhur and Sons).

Semester-6										
Paper Description	Numerical Analysis, C-programming and its applications		Paper Code				MATHMAJ614			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	---	80

NUMERICAL ANALYSIS, C-PROGRAMMING AND ITS APPLICATIONS

Numerical Analysis

Unit 1

10 classes

Errors: Absolute, relative, percentage, inherent, round off, truncation errors. Significant figures approximate number. Operators: Δ , ∇ , μ , E , δ (definitions and simple relations among them). Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.

Unit 2

10 classes

Transcendental and polynomial equations: Bisection method, secant method, Regula-Falsi method, fixed point iteration, Newton-Raphson method for simple as well as multiple roots and nth root of a number. Rate of convergence and conditions of convergence of these methods.

Unit 3

7 classes

System of linear algebraic equations: Gaussian elimination. Gauss Jacobi method, Gauss Seidel method and their convergence analysis.

Unit 4

10 classes

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule, Weddle's rule, Composite trapezoidal rule, composite Simpson's 1/3rd rule,

Unit 5

5 classes

Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders 2 (for order 4: statement only).

C Programming

Unit 6

4 classes

Programming language and importance of C programming. Characters, Constants and variables data types. Expression, statements, declaration. Operators: Arithmetic operators, increment and decrement operators, relational operators, logical operators, assignment operators, conditional operators.

Unit 7

4 classes

Conditional control statements: If, if-else, nested if-else statements. Switch, break and continue statements. Loop control statements: For, while and do-while statements.

Unit 8

10 classes

Arrays, One-dimension, two-dimension and multidimensional arrays, declaration and type of arrays. Reading and displaying elements of arrays. User-defined Functions: Function Prototype, Definition of functions, Type of functions, local and global variables in a function, type of return values, function declaration, nesting of functions, main () function, recurrence of function. Overview of Library functions, e.g. stdio.h, math.h, string.h, stdlib.h, conio.h, etc.

(PRACTICAL)

1. Solution of transcendental and algebraic equations by

- a) Bisection method
- b) Newton Raphson method (for simple root).
- c) Regula Falsi method.
- d) Fixed Point Iteration Method

2. Solution of system of linear equations

- a) Gaussian elimination method
- b) Gauss-Jacobi method
- c) Gauss-Seidel method

3. Interpolation

- a) Lagrange Interpolation
- b) Newton Forward and Backward Interpolation

4. Numerical Integration

- a) Trapezoidal Rule
- b) Simpson's one third rule
- c) Weddle's Rule

5. Solution of ordinary differential equations

- a) Euler method
- b) Modified Euler method
- c) Runge-Kutta method (4th order only)

Suggested Reading Books:

- 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, 6th Ed., New age International Publisher, India, 2007.
- C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
- U. M. Ascher and C. Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
- B. W. Kernighan and D. M. Ritchi : The C-Programming Language, 2nd Edi., Prentice Hall, 1977.
- E. Balagurnsamy : Programming in ANSI C, Tata McGraw Hill, 2004.
- Y. Kanetkar : Let Us C ; BPB Publication, 1999.
- C. Xavier : C-Language and Numerical Methods, New Age International.
- V. Rajaraman : Computer Oriented Numerical Methods, Prentice Hall of India, 1980.

Semester-6										
Paper Description	Metric Spaces and Multivariate Calculus		Paper Code				MATHMAJ615			
Paper (Type)	Major Course (Theory)		Credit				Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	20	---	80

METRIC SPACES AND MULTIVARIATE CALCULUS

Metric spaces:

Unit 1: 12 classes

Definition and examples of metric spaces with especial emphasize on \mathbb{R}^2 , \mathbb{R}^3 , more generally \mathbb{R}^n , subspace of metric space, bounded subset and diameter of a subset of metric spaces. Open and closed balls, neighbourhood, interior point and interior of a set, open set, limit point, boundary point, derive set, closed set and closure of a set, dense sets and separable spaces.

Unit 2: 12 classes

Sequences in metric space and sub sequences, Cauchy sequence and convergent sequence. Complete metric spaces with examples, Completion of metric spaces (\mathbb{Q} with usual metric to \mathbb{R} as an example), Cantor's intersection theorem. Continuous mapping (with examples in \mathbb{R}^2 , \mathbb{R}^3), sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of \mathbb{R} and \mathbb{R}^2 , Intermediate Value Theorem.

Unit 3: 12 classes

Compactness, sequential compactness, Heine-Borel property, continuous functions on compact sets, Total boundedness and its relation with boundedness, Characterization of Compact metric space in terms of completeness and total boundedness.

Multivariate Calculus:

Unit 4: 8 classes

Real Functions of two and three real variables: limit and continuity, Partial derivatives. Sufficient condition for continuity. Relevant results regarding repeated limits and double limits.

Unit 5: 8 classes

Differentiability of functions of two and three variables. Sufficient condition for differentiability. Differential of a function. Chain rule for one and two independent parameters. Homogeneous function, Euler's theorem and its converse. Young's and Schwartz's theorems on commutativity of order of mixed partial derivatives.

Unit 6: 8 classes

Only problems on: Mean value theorem and Taylor's theorem for function of two variables. Jacobian for functions of two and three variables and simple properties including functional dependence. Extrema of functions of two variables. Lagrange's method of undetermined multipliers.

Suggested Reading Books:

- M.N.Mukherjee, Elements of Metric Space, Academic Publisher
- SatishShirali and Harikishan L. Vasudeva, Metric Space, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- Joydeep Sengupta, Metric Spaces, 3rd Ed. U.N.Dhar & Sons Private Limited, 2011
- 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., D. K. (India) Pvt. Ltd., Delhi, 2007.
- E. Marsden, A. J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE).
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis (Vol I & II), Springer Verlag, New York, 1989.
- T. Apostol, Calculus, Volumes I and II.

Semester-6										
Paper Description	Linear Programming and Game Theory					Paper Code	MATHMAJ616			
Paper (Type)	Major Course (Theory)			Credit			Marks			
Paper Level	Class Hours	Sem. End Exam.	L	T	P	Total	TH	TU	PRC	Total
300	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	20	---	80

LINEAR PROGRAMMING AND GAME THEORY

Unit 1 **15 classes**

Introduction to linear programming problem (LPP), Problem formation, Type of solutions: Basic solution (BS), feasible solution (FS), basic feasible solution (BFS), degenerate and non-degenerate BFS. Matrix notation of LPP, graphical solution of LPP.

Unit 2 **20 classes**

Theory of simplex method, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables. Two-phase method, Big-M method and their comparison.

Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.

Unit 3 **10 classes**

Transportation and assignment problems: Mathematical formulation. North-west corner method, Least cost method and Vogel approximation method for determination of solution. Algorithm for solving transportation problem. Hungarian method for solving assignment problem.

Unit 4 **15 classes**

Game theory: Formulation of two-person zero sum games, solving two-person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.

Suggested Reading Books:

- M. S. Bazaraa, J. J. Jarvis and H. 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, Tata McGraw Hill, Singapore, 2009.
- H. A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006.
- G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU