UNIVERSITY OF NORTH BENGAL

Revised Syllabus for B.Sc. Three-year Honours/Programme Course under CBCS

in

MATHEMATICS

(w.e.f. 02.01.2023 and Onward Session)

Raja Rammohunpur, P.O. - NBU Campus

District - Darjeeling, Pin - 734013, West Bengal, India

SYLLABUS FOR B.SC. MATHEMATICS HONOURSE & PROGRAMME COURSE UNDER CBCS

OLD SYLLABUS		**2018 B.SC. SYLLABUS IN MATHEMATICS HONS/PROG COURSE**
NEW SYLLABUS		**2023 REVISED B.SC. SYLLABUS IN MATHEMATICS HONS/PROG COURSE**

SESSION	1ST SEM	2ND SEM	3RD SEM	4TH SEM	5TH SEM	6TH SEM
2018-2021						
2019-2022						
2020-2023						
2021-2024						
2022-2025						
ONWARDS						

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REVISED SYLLABUS FOR B.SC. MATHEMATICS HONOURS COURSE UNDER CBCS SYSTEM 2023

CREDIT DISTRIBUTION

Sl. No.	Course Type	Total Papers	Credits		Marks
			Theory + Tutorial	Theory + Practical	
1	Core Courses (**CC**)	14	$(13 \times 5) + (13 \times 1) = 78$	----	75 ($60 + 10 + 5$)
			----	$(1 \times 4) + (1 \times 2) = 6$	75 ($40 + 20 + 10 + 5$)
2	Discipline Specific Electives (**DSE**)	4	$(4 \times 5) + (4 \times 1) = 24$	----	75 ($60 + 10 + 5$)
3	Generic Electives (**GE**)	4	$(4 \times 5) + (4 \times 1) = 24$	----	75 ($60 + 10 + 5$)
4	Skill Enhancement Courses (**SEC**)	2	$2 \times 2 = 4$	----	75 ($60 + 10 + 5$)
5	Ability Enhancement Language Courses (**AE**)	2	$2 \times 2 = 4$	----	100 (AE-I) ($80 + 15 + 5$) 50 (AE-II) ($35 + 10 + 5$)
	Total	**26**	**140**		**1950**

B.SC. HONOURS COURSE IN MATHEMATICS

SEMESTER-1				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATH 15 AE-I	AE-I	Eng. Com./EVS	2	----
MATH 11 HCC-I	HCC-I	Calculus and Geometry	5 + 1	1
MATH 11 HCC-II	HCC-II	Algebra	5 + 1	2
MATH 13 GE-I	GE-I	Other Department	5 + 1	----
SEMESTER-2				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATH 25 AE-II	AE-II	Eng. Com/EVS	2	----
MATH 21 HCC-III	HCC-III	Real Analysis	5 + 1	3
MATH 21 HCC-IV	HCC-IV	Differential Equation & Vector Calculus	5 + 1	4
MATH 23 GE-II	GE-II	Other Department	5 + 1	----
SEMESTER-3				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATH 31 HCC-V	HCC-V	Theory of Real Functions & Introduction of the Metric Space	5 + 1	5
MATH 31 HCC-VI	HCC-VI	Group Theory-I	5 + 1	6
MATH 31 HCC-VII	HCC-VII	Riemann Integration & Series of Functions	5 + 1	7
MATH 33 GE-III	GE-III	Other Department	5 + 1	----
MATH 34 SE-I	SEC-I	Logic & Sets/Graph Theory	2	8 - 9
SEMESTER-4				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATH 41 HCC-VIII	HCC-VIII	Multivariate Calculus	5 + 1	10
MATH 41 HCC-IX	HCC-IX	Ring Theory & Linear Algebra-I	5 + 1	11
MATH 41 HCC-X	HCC-X	Metric Spaces & Complex Theory	5 + 1	12
MATH 43 GE-IV	GE-IV	Other Department	5 + 1	----
MATH 44 SE-II	SEC-II	C Programming Language/ Operating System: Linux	2	13 – 14
SEMESTER-5				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATH 51 HCC-XI	HCC-XI	Group Theory-II	5 + 1	15
MATH 51 HCC-XII	HCC-XII	Numerical Methods + LAB	4 + 2	16-17
MATH 52 DSE-I	DSE-I	Probability & Statistics / Differential Geometry	5 + 1	18 – 19
MATH 52 DSE-II	DSE-II	Mechanics / Number Theory	5 + 1	20 – 21
SEMESTER-6				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATH 61 HCC-XIII	HCC-XIII	Ring Theory & Linear Algebra-II	5 + 1	22
MATH 61 HCC-XIV	HCC-XIV	Partial Differential Equations & Applications	5 + 1	23
MATH 62 DSE-III	DSE-III	Linear Programming / Point Set Topology	5 + 1	24 – 25
MATH 62 DSE-IV	DSE-IV	Mathematical Modelling/ Boolean Algebra & Automata Theory	5 + 1	26 – 27

DETAILED HONOURS SYLLABUS

Semester 1					
Course Name	Calculus and Geometry			**Total Credit**	5+1=6
Subject Course No.	MATH 11 HCC-I	**Core Course**	HCC-I	**Total Marks**	60+10+5=75

CALCULUS AND GEOMETRY

Unit 1 : Calculus

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to the problems of the type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$. L'Hospital's rule and it's applications. Concept of plane, simple and closed curves, parameterizing a curve. Pedal equation, envelopes, evolute, asymptotes, radius of curvature, curve tracing in Cartesian and polar coordinates of standard curves. Concavity, convexity, cusps and inflection points.

Unit 2

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n x\,dx, \int \cos^n x\,dx, \int \sec^n x\,dx, \int \tan^n x\,dx,\ \int (logx)^n\,dx, \sin\int \sin nx\,x\,cos\,mx\,dx$ etc. Arc length of a curve, arc length of parametric curves, area enclosed by a curve, area between two curves, area and volume of revolution.

Unit 3 : Geometry

2D: Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, tangent and normal, polar equations of conics.

Unit 4

3D: Spheres, cylindrical surfaces, central conicoids, paraboloids, hyperboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.

Reference 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, 7th Ed., 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 York, Inc., 1989.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.
- The Elements of Co-ordinate Geometry: S. L. Loney (New Age International Publishers)
- Advanced Analytical Geometry: J. G. Chakravorty and P. R. Ghosh (U. N. Dhur and Sons)

Semester 1					
Course Name	Algebra			**Total Credit**	5+1=6
Subject Course No.	MATH 11 HCC-II	**Core Course**	HCC-II	**Total Marks**	60+10+5=75

ALGEBRA

Unit 1

Complex numbers: Polar representation, De Moivre's theorem for rational indices and its applications. Trigonometric, logarithm, exponential and hyperbolic functions of complex variable.

Theory of equations: Fundamental theorem of Classical Algebra (statement only), relation between roots and coefficients, symmetric functions of roots, transformation of equation, Descartes' rule of signs, Sturms' theorem, cubic equation (Cardan's method), biquadratic equation (Ferrari's method), graphical representation of a polynomial.

Inequality: $AM \geq GM \geq HM$, theorem of weighted means and m-th power theorem (statement only), Cauchy-Schwartz inequality (statements only) and its application.

Unit 2

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

Well-ordering property of positive integers, principles of mathematical induction, division algorithm, divisibility and Euclidean algorithm, congruence relation between integers, Fundamental Theorem of Arithmetic (statement only), solution of linear congruence equations.

Unit 3

Matrices: Inverse of a matrix, characterizations of invertible matrices, elementary operations and matrices, echelon matrix, row/column reduced echelon matrix, rank of matrix, normal forms, equivalency and congruency of matrices. Eigen values and eigen vectors of a square matrix, characteristic equation of a matrix, Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Unit 4

Systems of linear equations: Consistency, the matrix equation $AX = B$ of a system of linear equations, solution sets of linear systems, solution of linear systems using row reduced form.

Reference Books

- T. Andreescu and D. Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- E. G. Goodaire and M. M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
- D. C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K. B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- W. S. Burnstine and A. W. Panton, Theory of equations.

Semester 2					
Course Name	Real Analysis			**Total Credit**	5+1=6
Subject Course No.	MATH 21 HCC-III	**Core Course**	HCC-III	**Total Marks**	60+10+5=75

REAL ANALYSIS

Unit 1

Review of Algebraic and order properties of ℝ, ε-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. Suprema and infima. Completeness property of ℝ and its equivalent properties. Archimedean property, density of rational (and irrational) numbers in ℝ, intervals. Limit points of a set, isolated points, open set, closed set, derived set, illustrations of Bolzano-Weierstrass theorem for sets, compact sets in ℝ, Heine-Boreal Theorem.

Unit 2

Sequences: Sequence, bounded sequence, convergent sequence, limit of a sequence, lim inf, lim sup. 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.

Unit 3

Series: 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.

Reference Books

- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- G. G. Bilodeau, P. R. Thie, G. E. Keough, An Introduction to Analysis, 2nd ed., Jones & Bartlett, 2010.
- B. S. Thomson, A. M. Bruckner and J. B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S. K. Berberian, a First Course in Real Analysis, Springer Verlag, New York, 1994.
- T. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, Vol I, Springer.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill.
- T. Tao, Analysis I, Hindustan Book Agency, 2006.
- S. Goldberg, Calculus and mathematical analysis.

Semester 2					
Course Name	Differential Equations and Vector Calculus			**Total Credit**	5+1=6
Subject Course No.	MATH 21 HCC-IV	**Core Course**	HCC-IV	**Total Marks**	60+10+5=75

DIFFERENTIAL EQUATIONS AND VECTOR CALCULUS

Unit 1 : Differential Equations

Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Unit 2

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 3

Lipschitz condition and Picard's Theorem (Statement only). Autonomous system, Equilibrium points, Interpretation of the phase plane.

Unit 4 : Vector Calculus

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.

Reference 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.
- J. Marsden, and Tromba, Vector Calculus, McGraw Hill.
- K. C. Maity, and R. K. Ghosh, Vector Analysis, New Central Book Agency (P) Ltd. Kolkata.

Semester 3					
Course Name	Theory of Real Functions and Introduction to Metric Space			**Total Credit**	5+1=6
Subject Course No.	MATH 31 HCC-V	**Core Course**	HCC-V	**Total Marks**	60+10+5=75

THEORY OF REAL FUNCTIONS AND INTRODUCTION TO METRIC SPACE

Unit 1 : Theory of Real Functions

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

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, absolute extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials.

Unit 3

Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of reminder, application of Taylor's theorem to convex functions. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, $\log(1+x)$, $1/(ax+b)$ and $(x + 1)^n$. Application of Taylor's theorem to inequalities.

Unit 4 : Introduction to Metric Space

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

Reference 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
- S Shirali and H. L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumareasan, Topology of Metric Spaces, 2^{nd} Ed., Narosa Publishing House, 2011.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.

Semester 3					
Course Name	Group Theory – I			**Total Credit**	5+1=6
Subject Course No.	MATH 31 HCC-VI	**Core Course**	HCC-VI	**Total Marks**	60+10+5=75

GROUP THEORY-I

Unit 1

Groupoid, semigroup, monoid, groups, commutative groups, elementary properties of groups, finite semigroup with cancellation properties is a group, semigroup containing unique solution of $ax = b$ and $xa = b$ is a group. Particularly, $\mathbb{Z}_n$ group, U_n group, Klein's 4 group, symmetric group S_n, alternating group A_n, matrix group $M_n(R)$, multiplicative group of n-th roots of unity, Dihedral group, quaternion group (through matrices) etc.

Unit 2

Subgroups and examples of subgroups, necessary and sufficient conditions for a subset of a group to be a subgroup, union and intersection of subgroups, centralizer, normalizer, center of a group, product of two subgroups.

Unit 3

Order of an element and a group. Generators, cyclic group and its properties, necessary and sufficient condition. Cosets, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem, normal subgroups, factor/quotient groups, Cauchy's theorem for finite abelian groups, necessary and sufficient conditions for a subgroup of a group to be a normal subgroup.

Unit 4

Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.

Reference 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.

Semester 3					
Course Name	Riemann Integration and Series of Functions			**Total Credit**	5+1=6
Subject Course No.	MATH 31 HCC-VII	**Core Course**	HCC-VII	**Total Marks**	60+10+5=75

RIEMANN INTEGRATION AND SERIES OF FUNCTIONS

Unit 1

Riemann integration: inequalities of upper and lower sums, Darbaux integration, Darbaux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two definitions. Riemann integrability of monotone and continuous functions, properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals; Fundamental theorem of Integral Calculus.

Improper integrals. Convergence of Beta and Gamma functions.

Unit 2

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions.

Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.

Unit 3

Fourier series: Definitions of Fourier coefficients and series, Riemann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition. Examples of Fourier expansions and summation results for series.

Unit 4

Power series, radius of convergence, Cauchy Hadamard theorem. Differentiation and integration of power series, Abel's theorem, Weierstrass approximation theorem.

Reference Books

- K. A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- 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.

Semester 3					
Course Name	Logic and Sets			**Total Credit**	2
Subject Course No.	MATH 34 SEC-I	**Skill Enhancement Course**	SEC-I	**Total Marks**	60+10+5=75

LOGIC AND SETS

Unit 1 : Logic

Introduction, propositions, truth table, logical connectives: Negation, conjunction, disjunction, implications. Biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, quantifiers, binding variables and negations.

Unit 2 : Sets

The natural number sequence, Proof and definition by induction, cardinal numbers, countable sets, cardinal arithmetic, order types, well-ordered sets and ordinal numbers, the axiom of choice, the well-ordering theorem, and Zorn's lemma, further properties of cardinal numbers, Some theorems equivalent to the axiom of choice.

Reference Books

- R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998.
- P.R. Halmos, Naive Set Theory, Springer, 1974.
- E. Kamke, Theory of Sets, Dover Publishers, 1950.
- R. P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Educ., 1998.
- R. R. Stoll, Set Theory and Logic, Dover Publishers, 1979.

OR

<table>
<tr><th colspan="6">Semester 3</th></tr>
<tr><td>Course Name</td><td colspan="3">Graph Theory</td><td>Total Credit</td><td>2</td></tr>
<tr><td>Subject Course No.</td><td>MATH 34 SEC-I</td><td>Skill Enhancement Course</td><td>SEC-I</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

GRAPH THEORY

Unit 1

Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs, isomorphism of graphs. Trees and forests, paths and cycles.

Unit 2

Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles,theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph.

Unit 3

Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm. Connectivity, matching in bipartite graphs, matching in general graphs.

Reference Books

- 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, 2ndEdition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- R. Lidl and G. Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India Ptv. Ltd., New Delhi.
- R. Diestel, Graph Theory, Springer-Verlag, 2000.

Semester 4					
Course Name	Multivariate Calculus			**Total Credit**	5+1=6
Subject Course No.	MATH 41 HCC-VIII	**Core Course**	HCC-VIII	**Total Marks**	60+10+5=75

MULTIVARIATE CALCULUS

Unit 1

Functions of several variables, limit and continuity of functions of two or more variables

Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems.

Unit 2

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

Unit 3

Definition of vector field, divergence and curl.

Line integrals, applications of line integrals: mass and work. Fundamental theorem for line integrals, conservative vector fields, independence of path.

Unit 4

Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, Divergence theorem.

Reference 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., D. K. (India) Pvt. Ltd., Delhi, 2007.
- E. Marsden, A. J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), 2005.
- J. Stewart, Multivariable Calculus, Concepts and Contexts, Brooks/ Cole, Learning, USA, 2001.
- T. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer.
- W. Rudin, Principles of Mathematical Analysis, Tata 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).
- T. Tao, Analysis II, Hindustan Book Agency, 2006.
- M. R. Speigel, Schaum's outline of Vector Analysis.

Semester 4					
Course Name	Ring Theory and Linear Algebra-I			**Total Credit**	5+1=6
Subject Course No.	MATH 41 HCC-IX	**Core Course**	HCC-IX	**Total Marks**	60+10+5=75

RING THEORY AND LINEAR ALGEBRA-I

Unit 1 : Ring Theory

Definition and examples of rings, properties of rings, subrings, integral domains and fields. Necessary and sufficient conditions for subrings and subfields. Characteristics of a ring. Ideal, ideal generated by a subset of a ring, operations on ideals, prime and maximal ideals, factor/ quotient rings.

Unit 2

Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III.

Unit 3 : Linear Algebra

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, existence; extension and replacement theorems for basis of a finite dimensional vector space.

Unit 4

Linear transformations, null space, range space, rank and nullity of a linear transformation, matrix representation of a linear transformation relative to ordered bases, algebra of linear transformations, correspondence between LTs and matrices. Linear transformation is non-singular if its representation matrix is non-singular. Invertibility and isomorphisms, isomorphism theorems, change of coordinate matrix.

Reference Books

- J. B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- S. H. Friedberg, A. J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- J. A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- 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.
- D. A. R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
- D. S. Malik, J. M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra.

Semester 4					
Course Name	Metric Spaces and Complex Analysis			**Total Credit**	5+1=6
Subject Course No.	MATH 41 HCC-X	**Core Course**	HCC-X	**Total Marks**	60+10+5=75

METRIC SPACES AND COMPLEX ANALYSIS

Unit 1 : **Metric Spaces**

Continuous mapping, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of $\mathbb{R}$.

Compactness: Sequential compactness, Heine-Borel property, totally bounded spaces, finite intersection property and continuous functions on compact sets.

Homeomorphism. Contraction mappings. Banach fixed point theorem and its application to ordinary differential equation.

Unit 2 : Complex Analysis

Limits, limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings.

Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.

Unit 3

Analytic functions, examples of analytic functions, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy-Goursat theorem, Cauchy integral formula.

Unit 4

Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples.

Unit 5

Laurent series and its examples, absolute and uniform convergence of power series.

Reference Books

- S. Shirali and H. L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- J. W. Brown and R. V. Churchill, Complex Variables and Applications, McGraw-Hill Int. Edi. 2009.
- J. Bak and D. J. Newman, Complex Analysis, 2nd Ed., Undergraduate texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
- S. Ponnusamy, Foundations of Complex analysis.
- E. M. Stein and R. Shakrachi, Complex Analysis, Princeton University Press.

<table>
<tr><th colspan="6">Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">C Programming Language</td><td>Total Credit</td><td>2</td></tr>
<tr><td>Subject Course No.</td><td>MATH 44 SEC-II</td><td>Skill Enhancement Course</td><td>SEC-II</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

C PROGRAMMING LANGUAGE

Unit 1

An overview of history of computers and architecture of computer. Concept of compiler, assembler, machine language, high level language, object-oriented language, programming language and importance of C programming.

Unit 2

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 3

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 4

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. Library functions, e.g. stdio.h, math.h, string.h, stdlib.h, etc. No arguments and no return values, arguments but no return values, arguments with return values, no arguments but returns a value.

Reference Books

- B. W. Kernighan and D. M. Ritchi : The C-Programming Language, 2nd Edi.(ANSI Refresher), 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.

OR

<table>
<tr><th colspan="6">Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">Operating System: Linux</td><td>Total Credit</td><td>2</td></tr>
<tr><td>Subject Course No.</td><td>MATH 44 SEC-II</td><td>Skill Enhancement Course</td><td>SEC-II</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

OPERATING SYSTEM: LINUX

Unit 1

Linux – The operating system: Linux history, Linux features, Linux distributions, Linux's relationship to Unix, overview of Linux architecture, installation, start up scripts, system processes (an overview), Linux security.

Unit 2

The Ext2 and Ext3 file systems: General characteristics of the Ext3 file system, file permissions. User management: types of users, the powers of root, managing users (adding and deleting): using the command line and GUI tools.

Unit 3

Resource management in Linux: file and directory management, system calls for files process Management, signals, IPC: Pipes, FIFOs, System V IPC, message queues, system calls for processes, memory management.

Reference Books

- A. Robbins, Linux Programming by Examples The Fundamentals, 2nd Ed., Pearson Education, 2008.
- K. Cox, Red Hat Linux Administrator's Guide, PHI, 2009.
- R. Stevens, UNIX Network Programming, 3rd Ed., PHI, 2008.
- S. Das, UNIX Concepts and Applications, 4th Ed., TMH, 2009.
- E. Siever, S. Figgins, R. Love, A. Robbins, Linux in a Nutshell, 6th Ed.,O'Reilly Media, 2009.
- N. Matthew, R. Stones, A. Cox, Beginning Linux Programming, 3rd Ed., 2004.

Semester 5					
Course Name	Group Theory-II			**Total Credit**	5+1=6
Subject Course No.	MATH 51 HCC-XI	**Core Course**	HCC-XI	**Total Marks**	60+10+5=75

GROUP THEORY-II

Unit 1

Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.

Unit 2

External and internal direct product of groups and its properties. The group of units modulo n as an external direct product, converse of Lagrange's theorem for finite Abelian group, Fundamental theorem of finite abelian groups.

Unit 3

Group actions, stabilizers and kernels, permutation representation associated with a given group action. Applications of group actions. Generalized Cayley's theorem. Index theorem.

Unit 4

Groups acting on themselves by conjugation, class equation and consequences, conjugacy in S_n, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of A_n for $n \geq 5$, non-simplicity tests.

Reference 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.
- D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
- J. R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
- D. A. R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.
- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.

Semester 5					
Course Name	Numerical Methods			**Total Credit**	4
Subject Course No.	MATH 51 HCC-XII	**Core Course**	HCC-XII	**Total Marks**	40+10+5=55

NUMERICAL METHODS

Unit 1

Algorithms. Convergence. Errors: Absolute, relative, percentage, inherent, round off, truncation errors. Significant figures approximate number. Operators: Δ, ∇, μ, E, δ.

Unit 2

Transcendental and polynomial equations: Bisection method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method for simple and multiple roots. Rate of convergence and conditions of convergence of these methods.

Unit 3

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

Unit 4

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations, methods based on finite differences.

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule, Simpsons 3/8th rule, Weddle's rule, Composite trapezoidal rule, composite Simpson's 1/3rd rule, Gauss quadrature formula, Romberg integration.

The algebraic eigen value problem: Power method.

Unit 6

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).

Reference 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.

Semester 5					
Course Name	Numerical Methods LAB			**Total Credit**	2
Subject Course No.	MATH 51 HCC-XII	**Core Course**	HCC-XII	**Total Marks**	20

NUMERICAL METHODS LAB (PRACTICAL)

1. Solution of transcendental and algebraic equations by

   a) Bisection method

   b) Newton Raphson method (for simple root).

   c) Secant method.

   d) Regula Falsi 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 Forword and Backward Interpolation

4. Numerical Integration

   a) Trapezoidal Rule

   b) Simpson's one third rule

   c) Weddle's Rule

   d) Gauss Quadrature

5. Solution of ordinary differential equations

   a) Euler method

   b) Modified Euler method

   c) Runge-Kutta method (4^{th} order only)

Semester 5					
Course Name	Probability and Statistics			**Total Credit**	5+1=6
Subject Course No.	MATH 52 DSE-I	**Discipline Specific Electives**	DSE-I	**Total Marks**	60+10+5=75

PROBABILITY AND STATISTICS

Unit 1 : Probability

Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function. Discrete distributions: Uniform, binomial, Poisson, geometric, negative binomial. Continuous distributions: Uniform, normal, exponential.

Unit 2

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

Unit 3

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

Unit 4 : Statistics

Sampling Distributions: Sample moments. Sample variance, Sampling from the normal distributions, Chi-square and t-distributions.

Estimation of parameters: Point estimation. Interval Estimation: Confidence intervals for mean and variance of normal population. Method of Maximum likelihood: Likelihood function, ML estimators for discrete and continuous models.

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

Reference 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, 7^{th} Ed., 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, 3rd Ed., Tata McGraw- Hill, Reprint 2007.
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

OR

Semester 5					
Course Name	Differential Geometry			**Total Credit**	5+1=6
Subject Course No.	MATH 52 DSE-I	**Discipline Specific Electives**	DSE-I	**Total Marks**	60+10+5=75

DIFFERENTIAL GEOMETRY

Unit 1

Theory of curves: Parametrization and reparametrization of curves, plane curves, space curves, regular curves, curvature, torsion and relation between curvature and torsion, Serret-Frenet formula. Osculating plane, osculating circles and osculating spheres. Evolutes and involutes of curves.

Unit 2

Theory of surfaces: Regular surfaces, tangent plane, First and second Fundamental forms. Principal and Gaussian curvatures. Rodrigue's formula. Conjugate and asymptotic lines.

Unit 3

Developable: Developable associated with space curves and curves on surfaces. Minimal surfaces. Geodesics: Canonical geodesic equations. Nature of geodesics on a surface of revolution. Clairaut's theorem. Normal property of geodesics. Geodesic curvature. Gauss-Bonnet theorem.

Reference Books

- A. Pressley, Elementary Differential Geometry, Springer, 2012.
- T. J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
- B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
- C. E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press2003.
- D. J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
- S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
- B. Spain, Tensorhj. Calculus: A Concise Course, Dover Publications, 2003.

Semester 5					
Course Name	Mechanics			**Total Credit**	5+1=6
Subject Course No.	MATH 52 DSE-II	**Discipline Specific Electives**	DSE-II	**Total Marks**	60+10+5=75

MECHANICS

Unit 1

Co-planar forces. Astatic equilibrium. Friction. Equilibrium of a particle on a rough curve. Virtual work. Forces in three dimensions. General conditions of equilibrium. Centre of gravity for different bodies. Stable and unstable equilibrium.

Unit 2

Equations of motion referred to a set of rotating axes. Motion of a projectile in a resisting medium. Stability of nearly circular orbits. Motion under the inverse square law. Slightly disturbed orbits. Motion of artificial satellites. Motion of a particle in three dimensions. Motion on a smooth sphere, cone and on any surface of revolution.

Unit 3

Degrees of freedom. Moments and products of inertia. Momental Ellipsoid. Principal axes. D'Alembert's principle. Motion about a fixed axis. Compound pendulum. Motion of a rigid body in two dimensions under finite and impulsive forces. Conservation of momentum and energy.

Reference Books

- I. H. Shames and G. Krishna Mohan Rao, Engineering Mechanics: Statics and Dynamics, (4th Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- R. C. Hibbeler and Ashok Gupta, Engineering Mechanics: Statics and Dynamics, 11th Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi.
- F. Chorlton, Textbook of Dynamics.
- S. L. Loney, An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press.
- S. L. Loney, S. L., Elements of Statics and Dynamics I and II.

OR

Semester 5					
Course Name	Number Theory			**Total Credit**	5+1=6
Subject Course No.	MATH 52 DSE-II	**Discipline Specific Electives**	DSE-II	**Total Marks**	60+10+5=75

NUMBER THEORY

Unit 1

Euclidean Algorithm for GCD, linear representation of GCD. Prime numbers, Fundamental Theorem of Arithmetic and its consequences. Linear Diophantine Equation. Gaussian integers, Divisibility and primes in $\mathbb{Z}$ and $\mathbb{Z}[i]$.

Unit 2

Linear congruences, Chinese Remainder Theorem. Inverse modulo a prime, Fermats' Little Theorem, congruence theorem of Wilson and Lagrange.

Unit 3

Primitive roots, Quadratic residues, Legendre symbol, Quadratic reciprocity law, Pythagorean triples, Fermat's Two Square Theorem.

Reference 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.

<table>
<tr><th colspan="6">Semester 6</th></tr>
<tr><td>Course Name</td><td colspan="3">Ring Theory and Linear Algebra-II</td><td>Total Credit</td><td>5+1=6</td></tr>
<tr><td>Subject Course No.</td><td>MATH 61 HCC-XIII</td><td>Core Course</td><td>HCC-XIII</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

RING THEORY AND LINEAR ALGEBRA-II

Unit 1

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

Polynomial rings over commutative rings, division algorithm and consequences, factorization of polynomials, irreducibility tests, Eisenstein criterion and unique factorization in $\mathbb{Z}[x]$.

Unit 2

Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms.

Unit 3

Inner product spaces and norms, Gram-Schmidt orthogonalisation process, orthogonal complements, Bessel's inequality, the adjoint of a linear operator. Least squares approximation, minimal solutions to systems of linear equations. Normal and self-adjoint operators. Orthogonal projections and Spectral theorem.

Reference 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.
- S. H. Friedberg, A. J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- 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.

Semester 6					
Course Name	Partial Differential Equations and Applications			**Total Credit**	5+1=6
Subject Course No.	MATH 61 HCC-XIV	**Core Course**	HCC-XIV	**Total Marks**	60+10+5=75

PARTIAL DIFFERENTIAL EQUATIONS AND APPLICATIONS

Unit 1

Partial differential equations – Basic concepts and definitions. Mathematical problems. First- order equations: classification, construction and geometrical interpretation. Method of characteristics for obtaining general solution of quasi linear equations. Canonical forms of first order linear equations. Method of separation of variables for solving first order partial differential equations.

Unit 2

Derivation of heat equation, wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.

Unit 3

The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial boundary value problems. Semi-infinite string with a fixed end, semi-infinite string with a free end. Equations with non-homogeneous boundary conditions. Non-homogeneous wave equation. Method of separation of variables, solving the vibrating string problem. Solving the heat conduction problem

Unit 4

Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law.

Reference Books

- T. Myint-U and L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.
- 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.
- I. N. Sneddon, Elements of Partial Differential Equations, McGraw Hill.
- F. H. Miller, Partial Differential Equations, John Wiley and Sons.
- S. L. Loney, An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press.

Semester 6					
Course Name	Linear Programming			**Total Credit**	5+1=6
Subject Course No.	MATH 62 DSE-III	**Discipline Specific Electives**	DSE-III	**Total Marks**	60+10+5=75

LINEAR PROGRAMMING

Unit 1

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

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 4

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

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.

Reference 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, 9th Ed., 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.

OR

Semester 6					
Course Name	Point Set Topology			**Total Credit**	5+1=6
Subject Course No.	MATH 62 DSE-III	**Discipline Specific Electives**	DSE-III	**Total Marks**	60+10+5=75

POINT SET TOPOLOGY

Unit 1

Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal numbers and cardinal arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice. Well-ordered sets, Hausdorff's maximal principle.

Unit 2

Topological spaces, basis and Sub basis for a topology, subspace topology, interior points, limit points, derived set, boundary of a set, closed sets, closure and interior of a set. Continuous functions, open maps, closed maps and homeomorphisms. Product topology, metric topology, Baire category theorem.

Unit 3

Connectedness. Distinguishing topological spaces via connectedness, intermediate value theorem, path connectedness, compact spaces, compact subspaces of the real line, limit point compactness.

Reference Books

- J. R. Munkres, Topology: A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
- J. Dugundji, Topology, Allyn and Bacon, 1966.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
- J. L. Kelley, General Topology, Van Nostrand Reinhold Co., New York,1995.
- J. Hocking, G. Young, Topology, Addison-Wesley Reading, 1961.
- L. Steen, J. Seebach, Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970.
- Adams and Franzosa, Introduction to topology, Pearson 2008.

Semester 6					
Course Name	Mathematical Modelling			**Total Credit**	5+1=6
Subject Course No.	MATH 62 DSE-IV	**Discipline Specific Electives**	DSE-IV	**Total Marks**	60+10+5=75

MATHEMATICAL MODELLING

Unit 1

Functions, modelling with linear and exponential functions. Average rate of change, linear functions with applications, Piecewise-linear functions with applications. Fitting linear models to data. Exponential growth functions with applications, Growth factors and rates, doubling time. Compound interest, Exponential decay functions with applications. Fitting exponential models to data, Decay factors and rates, Half-life. Modeling with logarithmic and polynomial functions, Logarithmic functions with applications, Fitting logarithmic models to data, Maxima and minima applications.

Unit 2

Introduction to continuous time models, limitations & advantages of the discrete-time model, the need for continuous time models, Continuous time models: the model for the growth of microorganisms, chemostat; Stability and linearization methods for system of ODE's.

Unit 3

Power series solution of Bessel's equation and Legendre's equation, Laplace transform and inverse transform, application to initial value problem up to second order.

Unit 4

Monte Carlo simulation modelling: simulating deterministic behavior (area under a curve, volume under a surface), generating random numbers: middle square method, queuing models. Overview of optimization modelling.

References Books

- T. Myint and L. Debnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2008.
- J. N. Kapoor, Mathematical Modelling, New Age International Pvt Ltd Publishers, 2011.
- K. Kamalanand and P. M. Jawahar, Mathematical Modelling of Systems and Analysis, PHI Learning Pvt Ltd, 2018.
- F. R. Giordano, W. P. Fox, S. B. Horton, A First Course in Mathematical Modeling, Brooks/Cole Cengage Learning, USA, 2013.

OR

Semester 6					
Course Name	Boolean Algebra and Automata Theory			**Total Credit**	5+1=6
Subject Course No.	MATH 62 DSE-IV	**Discipline Specific Electives**	DSE-IV	**Total Marks**	60+10+5=75

BOOLEAN ALGEBRA AND AUTOMATA THEORY

Unit 1 : Boolean Algebra

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.

Unit 2

Boolean algebra, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams. Logic gates, switching circuits and applications of switching circuits.

Unit 3 : Automata Theory

Introduction: Alphabets, strings and languages. Finite automata and regular languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.

Unit 4

Context free grammars and pushdown automata: Context free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non deterministic PDA, properties of context free languages, normal forms, pumping lemma, closure properties, decision properties.

Unit 5

Turing Machines: Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence.

References Books

- 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.
- R. Lidl and G. Pilz, Applied Abstract Algebra, 2nd Edition, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages and Computation, 2nd Ed., Addison-Wesley, 2001.
- H. R. Lewis, C. H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997.
- J. A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006.

ANNEXURE

Generic Elective (GE) Course only taken by the Honours Students other than Mathematics Honours

Semester 1					
Course Name	Calculus, Geometry and Differential Equation (GE-1) **OR** Group Theory (GE-4)			**Total Credit**	5+1=6
Subject Course No.	MATH 13 GE-I	**Generic Electives**	GE-I	**Total Marks**	60+10+5=75
Semester 2					
Course Name	Algebra (GE-2) **OR** Differential Equation and Vector Calculus (GE-3) **OR** Numerical Methods (GE-5)			**Total Credit**	5+1=6
Subject Course No.	MATH 23 GE-II	**Generic Electives**	GE-II	**Total Marks**	60+10+5=75
Semester 3					
Course Name	Calculus, Geometry and Differential Equation (GE-1) **OR** Group Theory (GE-4)			**Total Credit**	5+1=6
Subject Course No.	MATH 33 GE-III	**Generic Electives**	GE-III	**Total Marks**	60+10+5=75
Semester 4					
Course Name	Algebra (GE-2) **OR** Differential Equation and Vector Calculus (GE-3) **OR** Numerical Methods (GE-5)			**Total Credit**	5+1=6
Subject Course No.	MATH 43 GE-IV	**Generic Electives**	GE-IV	**Total Marks**	60+10+5=75

	Course Subcode	Course	Credit	Page No.
Generic Electives Course	GE-1	Calculus, Geometry and Differential Equation	5 + 1	28
	GE-2	Algebra	5 + 1	29
	GE-3	Differential Equation and Vector Calculus	5 + 1	30
	GE-4	Group Theory	5 + 1	31
	GE-5	Numerical Methods	5 + 1	32

Semester 1 & Semester 3						
Course Name	Calculus, Geometry and Differential Equation			**Total Credit**	5+1=6	
Subject Course No.	MATH 13 GE-I MATH 33 GE-III	**Course Subcode**	GE-1	**Total Marks**	60+10+5=75	

CALCULUS, GEOMETRY AND DIFFERENTIAL EQUATION

Unit 1 : Calculus

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to the problems of the type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n \sin x$, $(ax+b)^n \cos x$. L'Hospital's rule and it's applications. Concept of plane, simple and closed curves, parameterizing a curve. Pedal equation, envelopes, evolute, asymptotes, radius of curvature, curve tracing in Cartesian and polar coordinates of standard curves. Concavity, convexity, cusps and inflection points.

Unit 2

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n x\, dx, \int \cos^n x\, dx, \int \sec^n x\, dx, \int \tan^n x\, dx,\ \int (logx)^n\, dx, \int\ \sin nx\, cos\, mx\, dx$ etc. Arc length of a curve, arc length of parametric curves, area enclosed by a curve, area between two curves, area and volume of revolution.

Unit 3 : Geometry

2D: Properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics.

3D: Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics.

Unit 4 : Differential Equation

Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

Reference 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 York, Inc., 1989.
- S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- D. Murray, Introductory Course in Differential Equations, Longmans Green and Co.
- G. F. Simmons, Differential Equations, Tata Mcgraw Hill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.

<table>
<tr><th colspan="7">Semester 2 & Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">Algebra</td><td>Total Credit</td><td colspan="2">5+1=6</td></tr>
<tr><td rowspan="2">Subject Course No.</td><td>MATH 23 GE-II</td><td rowspan="2">Course Subcode</td><td rowspan="2">GE-2</td><td rowspan="2">Total Marks</td><td colspan="2" rowspan="2">60+10+5=75</td></tr>
<tr><td>MATH 43 GE-IV</td></tr>
</table>

ALGEBRA

Unit 1

Complex numbers: Polar representation, De Moivre’s theorem for rational indices and its applications. Trigonometric, logarithm, exponential and hyperbolic functions of complex variable.

Theory of equations: Fundamental theorem of Classical Algebra (statement only), relation between roots and coefficients, symmetric functions of roots, transformation of equation, Descartes’ rule of signs, Sturms’ theorem, cubic equation (Cardan’s method), biquadratic equation (Ferrari’s method), graphical representation of a polynomial.

Inequality: $AM \geq GM \geq HM$, theorem of weighted means and m-th power theorem (statement only), Cauchy-Schwartz inequality (statements only) and its application.

Unit 2

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

Well-ordering property of positive integers, principles of mathematical induction, division algorithm, divisibility and Euclidean algorithm, congruence relation between integers, Fundamental Theorem of Arithmetic (statement only), solution of linear congruence equations.

Unit 3

Matrices: Inverse of a matrix, characterizations of invertible matrices, elementary operations and matrices, echelon matrix, row/column reduced echelon matrix, rank of matrix, normal forms, equivalency and congruency of matrices. Eigen values and eigen vectors of a square matrix, characteristic equation of a matrix, Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Unit 4

Systems of linear equations: Consistency, the matrix equation $AX = B$ of a system of linear equations, solution sets of linear systems, solution of linear systems using row reduced form.

Reference Books

- T. Andreescu and D. Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- E. G. Goodaire and M. M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
- D. C. Lay, Linear Algebra and its Applications, Pearson Education Asia, Indian Reprint, 2007.
- K. B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- W. S. Burnstine and A. W. Panton, Theory of equations

<table>
<tr><th colspan="6">Semester 2 & Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">Differential Equation and Vector Calculus</td><td>Total Credit</td><td>5+1=6</td></tr>
<tr><td rowspan="2">Subject Course No.</td><td>MATH 23 GE-II</td><td rowspan="2">Course Subcode</td><td rowspan="2">GE-3</td><td rowspan="2">Total Marks</td><td rowspan="2">60+10+5=75</td></tr>
<tr><td>MATH 43 GE-IV</td></tr>
</table>

DIFFERENTIAL EQUATION AND VECTOR CALCULUS

Unit 1 : Differential Equations

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Unit 2

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 3

Power series solution of a differential equation about an ordinary point, solution about a regular singular point.

Unit 4 : Vector Calculus

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.

Reference Books

- B. Barnes and G. R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, 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.
- 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).

Semester 1 & Semester 3					
Course Name	Group Theory			**Total Credit**	5+1=6
Subject Course No.	MATH 13 GE-I MATH 33 GE-III	**Course Subcode**	GE-4	**Total Marks**	60+10+5=75

GROUP THEORY

Unit 1

Groupoid, semigroup, monoid, groups, commutative groups, elementary properties of groups, finite semigroup with cancellation properties is a group, semigroup containing unique solution of $ax = b$ and $xa = b$ is a group. Particularly, $\mathbb{Z}_n$ group, U_n group, Klein's 4 group, symmetric group S_n, alternating group A_n, matrix group $M_n(R)$, multiplicative group of n-th roots of unity, Dihedral group, quaternion group (through matrices) etc.

Unit 2

Subgroups and examples of subgroups, necessary and sufficient conditions for a subset of a group to be a subgroup, union and intersection of subgroups, centralizer, normalizer, center of a group, product of two subgroups.

Unit 3

Order of an element and a group. Generators, cyclic group and its properties, necessary and sufficient condition. Cosets, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem, normal subgroups, factor/quotient groups, Cauchy's theorem for finite abelian groups, necessary and sufficient conditions for a subgroup of a group to be a normal subgroup.

Unit 4

Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems (statement only).

Reference 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, 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, J. M. Mordeson and M. K. Sen, Fundamentals of abstract algebra.

<table>
<tr><th colspan="7">Semester 2 & Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">Numerical Methods</td><td>Total Credit</td><td>5+1=6</td></tr>
<tr><td rowspan="2">Subject Course No.</td><td>MATH 23 GE-II</td><td rowspan="2">Course Subcode</td><td rowspan="2">GE-5</td><td rowspan="2">Total Marks</td><td rowspan="2">60+10+5=75</td></tr>
<tr><td>MATH 43 GE-IV</td></tr>
</table>

NUMERICAL METHODS

Unit 1

Algorithms. Convergence. Errors: Absolute, relative, percentage, inherent, round off, truncation errors. Significant figures approximate number. Operators: Δ, ∇, μ, E, δ.

Unit 2

Transcendental and polynomial equations: Bisection method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method for simple and multiple roots. Rate of convergence and conditions of convergence of these methods.

Unit 3

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

Unit 4

Interpolation: Lagrange and Newton’s methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations; methods based on finite differences.

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson’s 1/3rd rule, Simpsons 3/8th rule, Weddle’s rule, Composite trapezoidal rule, composite Simpson’s 1/3rd rule.

Unit 6

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).

Reference 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.

Dr. Paltu Sarkar (Chairman)
UG Board of Studies in Mathematics
University of North Bengal

REVISED B.SC. MATHEMATICS PROGRAMME COURSE SYLLABUS UNDER CBCS SYSTEM 2023

CREDIT DISTRIBUTION

Sl. No.	Course Type	Total Papers	Credits	Marks
			Theory + Tutorial	
1	Discipline Specific Core (**DSC**)	12	$(12 \times 5) + (12 \times 1) = 72$	75 $(60 + 10 + 5)$
2	Discipline Specific Electives (**DSE**)	6	$(6 \times 5) + (6 \times 1) = 36$	75 $(60 + 10 + 5)$
3	Skill Enhancement Courses (**SEC**)	4	$4 \times 2 = 8$	75 $(60 + 10 + 5)$
4	Ability Enhancement Compulsory Courses (**AECC**)	2	$2 \times 2 = 4$	100 (AE-I) $(80 + 15 + 5)$ 50 (AE-II) $(35 + 10 + 5)$
	Total	**24**	**120**	**1800**

SEMESTER-1				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATP 14 AE-I	AE-I	Eng Com/EVS	2	----
MATP 11 DSC	DSC Paper 1	Calculus and Geometry	5 + 1	33
	DSC	Other Department	----	----
	DSC	Other Department	----	----
SEMESTER-2				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATP 24 AE-I	AE-I	Eng Com/EVS	2	----
MATP 21 DSC	DSC Paper 2	Real Analysis	5 + 1	34
	DSC	Other Department	----	----
	DSC	Other Department	----	----
SEMESTER-3				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATP 31 DSC	DSC Paper 3	Algebra	5 + 1	35
	DSC	Other Department	----	----
	DSC	Other Department	----	----
MATP 33 SEC	SEC SEM 3 Paper 1	Logic & Sets / Graph Theory	2	36 - 37
SEMESTER-4				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATP 41 DSC	DSC Paper 4	Differential Equation and Vector Calculus	5 + 1	38
	DSC	Other Department	----	----
	DSC	Other Department	----	----
MATP 43 SEC	SEC SEM 4 Paper 2	Theory of Equations/ C Programming Language	2	39 - 40
SEMESTER-5				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATP 52 DSE	DSE Paper 1	Numerical Methods + LAB/ Group Theory and Linear Algebra	4 + 2 5 + 1	41 - 43
	DSE	Other Department	----	----
	DSE	Other Department	----	----
MATP 53 SEC	SEC SEM 5 Paper 1	Theory of Probability / Differential Geometry	2	44 - 45
SEMESTER-6				
Subject Course No.	**Syllabus Code**	**Course**	**Credit**	**Page No.**
MATP 62 DSE	DSE Paper 2	Metric Spaces & Complex Analysis / Linear Programming	5 + 1	46 - 47
	DSE	Other Department	----	----
	DSE	Other Department	----	----
MATP 63 SEC	SEC SEM 6 Paper 2	Mechanics / Boolean Algebra & Automata Theory	2	48 - 49

DETAILED PROGRAMME SYLLABUS

Semester 1					
Course Name	Calculus and Geometry			**Total Credit**	5+1=6
Subject Course No.	MATP 11 DSC	**Discipline Specific Core**	DSC Paper 1	**Total Marks**	60+10+5=75

CALCULUS AND GEOMETRY

Unit 1 : Calculus

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to the problems of the type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$. L'Hospital's rule and it's applications. Concept of plane, simple and closed curves, parameterizing a curve. Pedal equation, envelopes, evolute, asymptotes, radius of curvature, curve tracing in Cartesian and polar coordinates of standard curves. Concavity, convexity, cusps and inflection points.

Unit 2

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n x\, dx, \int \cos^n x\, dx, \int \sec^n x\, dx, \int \tan^n x\, dx,\ \int (logx)^n\, dx, \int\ \sin nx\ cos\, mx\, dx$ etc. Arc length of a curve, arc length of parametric curves, area enclosed by a curve, area between two curves, area and volume of revolution.

Unit 3 : Geometry

2D: Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics.

Unit 4

3D: Spheres, cylindrical surfaces, central conicoids, paraboloids, hyperboloids, plane sections of conicoids, generating lines, classification of quadrics.

Reference 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 York, Inc., 1989.
- S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- G. F. Simmons, Differential Equations, Tata Mcgraw Hill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.

Semester 2					
Course Name	Real Analysis			**Total Credit**	5+1=6
Subject Course No.	MATP 21 DSC	**Discipline Specific Core**	DSC Paper 2	**Total Marks**	60+10+5=75

REAL ANALYSIS

Unit 1

Review of Algebraic and order properties of ℝ, ε-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. Suprema and infima. Completeness property of ℝ and its equivalent properties. Archimedean property, density of rational (and irrational) numbers in ℝ, intervals. Limit points of a set, isolated points, open set, closed set, derived set, illustrations of Bolzano-Weierstrass theorem for sets, compact sets in ℝ, Heine-Boreal Theorem.

Unit 2

Sequences: Sequence, bounded sequence, convergent sequence, limit of a sequence, lim inf, lim sup. 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.

Unit 3

Series: 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.

Reference Books

- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- G. G. Bilodeau, P. R. Thie, G. E. Keough, An Introduction to Analysis, 2nd ed., Jones & Bartlett, 2010.
- B. S. Thomson, A. M. Bruckner and J. B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S. K. Berberian, a First Course in Real Analysis, Springer Verlag, New York, 1994.
- T. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, Vol I, Springer.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill.
- T. Tao, Analysis I, Hindustan Book Agency, 2006 .
- S. Goldberg, Calculus and mathematical analysis.

Semester 3					
Course Name	Algebra			**Total Credit**	5+1=6
Subject Course No.	MATP 31 DSC	**Discipline Specific Core**	DSC Paper 3	**Total Marks**	60+10+5=75

ALGEBRA

Unit 1

Complex numbers: Polar representation, De Moivre's theorem for rational indices and its applications. Trigonometric, logarithm, exponential and hyperbolic functions of complex variable.

Theory of equations: Fundamental theorem of Classical Algebra (statement only), relation between roots and coefficients, symmetric functions of roots, transformation of equation, Descartes' rule of signs, Sturms' theorem, cubic equation (Cardan's method), biquadratic equation (Ferrari's method), graphical representation of a polynomial.

Inequality: $AM \geq GM \geq HM$, theorem of weighted means and m-th power theorem (statement only), Cauchy-Schwartz inequality (statements only) and its application.

Unit 2

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

Well-ordering property of positive integers, principles of mathematical induction, division algorithm, divisibility and Euclidean algorithm, congruence relation between integers, Fundamental Theorem of Arithmetic (statement only), solution of linear congruence equations.

Unit 3

Matrices: Inverse of a matrix, characterizations of invertible matrices, elementary operations and matrices, echelon matrix, row/column reduced echelon matrix, rank of matrix, normal forms, equivalency and congruency of matrices. Eigen values and eigen vectors of a square matrix, characteristic equation of a matrix, Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Unit 4

Systems of linear equations: Consistency, the matrix equation $AX = B$ of a system of linear equations, solution sets of linear systems, solution of linear systems using row reduced form.

Reference Books

- T. Andreescu and D. Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- E. G. Goodaire and M. M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
- D. C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K. B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- W. S. Burnstine and A. W. Panton, Theory of equations

Semester 3					
Course Name	Logic and Sets			**Total Credit**	2
Subject Course No.	MATP 33 SEC	**Skill Enhancement Courses**	SEC SEM 3 Paper 1	**Total Marks**	60+10+5=75

LOGIC AND SETS

Unit 1 : Logic

Introduction, propositions, truth table, logical connectives: Negation, conjunction, disjunction, implications. Biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, quantifiers, binding variables and negations.

Unit 2 : Sets

The natural number sequence, Proof and definition by induction, cardinal numbers, countable sets, cardinal arithmetic, order types, well-ordered sets and ordinal numbers, the axiom of choice, the well-ordering theorem, and Zorn's lemma, further properties of cardinal numbers, Some theorems equivalent to the axiom of choice.

Reference Books

- R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998.
- P.R. Halmos, Naive Set Theory, Springer, 1974.
- E. Kamke, Theory of Sets, Dover Publishers, 1950.
- R. P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Educ., 1998.
- R. R. Stoll, Set Theory and Logic, Dover Publishers, 1979.

OR

<table>
<tr><th colspan="6">Semester 3</th></tr>
<tr><td>Course Name</td><td colspan="3">Graph Theory</td><td>Total Credit</td><td>2</td></tr>
<tr><td>Subject Course No.</td><td>MATP 33 SEC</td><td>Skill Enhancement Courses</td><td>SEC SEM 3 Paper 1</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

GRAPH THEORY

Unit 1

Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs, isomorphism of graphs. Trees and forests, paths and cycles.

Unit 2

Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles, theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph.

Unit 3

Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm.

Reference Books

- 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, 2ndEdition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- R. Lidl and P. Gunter, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India Ptv. Ltd., New Delhi.
- R. Diestel, Graph Theory, Springer-Verlag, 2000.

<table>
<tr><th colspan="6">Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">Differential Equation and Vector Calculus</td><td>Total Credit</td><td>5+1=6</td></tr>
<tr><td>Subject Course No.</td><td>MATP 41 DSC</td><td>Skill Enhancement Courses</td><td>DSC Paper 4</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

DIFFERENTIAL EQUATION AND VECTOR CALCULUS

Unit 1 : Differential Equation

Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Unit 2

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 3

Lipschitz condition and Picard's Theorem (Statement only). Equilibrium points, Interpretation of the phase plane.

Unit 4 : Vector Calculus

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.

Reference Books

- B. Barnes and G. R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, Taylor and Francis group, 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 4					
Course Name	Theory of Equations			**Total Credit**	2
Subject Course No.	MATP 43 SEC	**Skill Enhancement Courses**	SEC SEM 4 Paper 2	**Total Marks**	60+10+5=75

THEORY OF EQUATIONS

Unit 1

General properties of polynomials, Graphical representation of a polynomial, maximum and minimum values of a polynomials, General properties of equations, Descarte's rule of signs positive and negative rule, Relation between the roots and the coefficients of equations.

Unit 2

Symmetric functions. Applications of symmetric function of the roots. Transformation of equations. Solutions of reciprocal and binomial equations. Algebraic solutions of the cubic and biquadratic. Properties of the derived functions, Newton's theorem on the sums of powers of roots, homogeneous products, limits of the roots of equations.

Unit 3

Separation of the roots of equations, Strums theorem. Applications of Strum's theorem, conditions for reality of the roots of an equation. Solution of numerical equations.

Reference Books

- W.S. Burnside and A.W. Panton, The Theory of Equations, Dublin University Press, 1954.
- C. C. MacDuffee, Theory of Equations, John Wiley & Sons Inc., 1954.

OR

<table>
<tr><th colspan="6">Semester 4</th></tr>
<tr><td>Course Name</td><td colspan="3">C Programming Language</td><td>Total Credit</td><td>2</td></tr>
<tr><td>Subject Course No.</td><td>MATP 43 SEC</td><td>Skill Enhancement Courses</td><td>SEC SEM 4 Paper 2</td><td>Total Marks</td><td>60+10+5=75</td></tr>
</table>

C PROGRAMMING LANGUAGE

Unit 1

An overview of history of computers and architecture of computer. Concept of compiler, assembler, machine language, high level language, object-oriented language, programming language and importance of C programming.

Unit 2

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 3

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 4

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. Library functions, e.g. stdio.h, math.h, string.h, stdlib.h, etc. No arguments and no return values, arguments but no return values, arguments with return values, no arguments but returns a value.

Reference Books

- B. W. Kernighan and D. M. Ritchi, The C-Programming Language, 2nd Edi. (ANSI Refresher), 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 5					
Course Name	Numerical Methods			**Total Credit**	4
Subject Course No.	MATP 52 DSE	**Core Course**	DSE Paper 1	**Total Marks**	40+10+5=55

NUMERICAL METHODS

Unit 1

Algorithms. Convergence. Errors: Absolute, relative, percentage, inherent, round off, truncation errors. Significant figures, approximate number. Operators: Δ , ∇ , μ, E, δ .

Unit 2

Transcendental and polynomial equations: Bisection method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method for simple and multiple roots. Rate of convergence and conditions of convergence of these methods.

Unit 3

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

Unit 4

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations methods based on finite differences.

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule, Simpsons 3/8th rule, Weddle's rule, Composite trapezoidal rule, composite Simpson's 1/3rd rule.

Unit 6

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

Reference 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.

Semester 5					
Course Name	Numerical Methods LAB			**Total Credit**	2
Subject Course No.	MATP 52 DSE	**Core Course**	DSE Paper 1	**Total Marks**	20

NUMERICAL METHODS LAB (PRACTICAL)

1. Solution of transcendental and algebraic equations by
   a) Bisection method
   b) Newton Raphson method (for simple root).
   c) Regula-Falsi method.
2. Interpolation
   a) Lagrange Interpolation
   b) Newton Forward Interpolation
   c) Newton Backward Interpolation
3. Numerical Integration by
   a) Trapezoidal Rule
   b) Simpson's one third rule
4. Solution of ordinary differential equations by
   a) Euler method
   b) Runge-Kutta method (4^{th} order only)

OR

Semester 5					
Course Name	Group Theory and Linear Algebra			**Total Credit**	5+1=6
Subject Course No.	MATP 52 DSE	**Discipline Specific Electives**	DSE Paper 1	**Total Marks**	60+10+5=75

GROUP THEORY AND LINEAR ALGEBRA

Unit 1 : **Group Theory**

Groupoid, semigroup, monoid, groups, commutative groups, elementary properties of groups, finite semigroup with cancellation properties is a group, semigroup containing unique solution of $ax = b$ and $xa = b$ is a group. Particularly, $\mathbb{Z}_n$ group, U_n group, Klein's 4 group, symmetric group S_n, alternating group A_n, matrix group $M_n(R)$, multiplicative group of n-th roots of unity, Dihedral group, quaternion group (through matrices) etc.

Unit 2

Subgroups and examples of subgroups, necessary and sufficient conditions for a subset of a group to be a subgroup, union and intersection of subgroups, centralizer, normalizer, center of a group, product of two subgroups.

Unit 3

Order of an element and a group. Generators, cyclic group and its properties, necessary and sufficient condition. Cosets, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.

Unit 4 : Linear Algebra

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension of a vector space, dimension of subspaces.

Unit 4

Linear transformations, null space, range space, rank and nullity of a linear transformation, matrix representation of a linear transformation relative to ordered bases, algebra of linear transformations, correspondence between LTs and matrices. Isomorphisms.

Reference Books

- J. B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- I. Herstein, Abstract Algebra.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- S. H. Friedberg, A. J. Insel, L. E. Spence, Linear Algebra, PHI Pvt. Ltd., New Delhi, 2004.
- J. A. Gallian, Contemporary Abstract Algebra, Narosa Publishing House, New Delhi, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- 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., 1997.

Semester 5					
Course Name	Theory of Probability			**Total Credit**	2
Subject Course No.	MATP 53 SEC	**Skill Enhancement Courses**	SEC SEM 5 Paper 1	**Total Marks**	60+10+5=75

THEORY OF PROBABILITY

Unit 1

Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function. Discrete distributions: Uniform, binomial, Poisson distribution. Continuous distributions: uniform, normal, exponential distribution.

Unit 2

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

Unit 3

Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central limit theorem for independent and identically distributed random variables with finite variance.

Reference 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, 7th Ed., Pearson Education, Asia, 2006.
- S. Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
- A. M. Mood, F. A. Graybill and D. C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007.
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

OR

Semester 5					
Course Name	Differential Geometry			**Total Credit**	2
Subject Course No.	MATP 53 SEC	**Skill Enhancement Courses**	SEC SEM 5 Paper 1	**Total Marks**	60+10+5=75

DIFFERENTIAL GEOMETRY

Unit 1

Theory of curves: Parametrization and reparametrization of curves, plane curves, space curves, regular curves, curvature, torsion and relation between curvature and torsion, Serret-Frenet formula. Osculating plane, osculating circles and osculating spheres. Evolutes and involutes of curves.

Unit 2

Theory of surfaces: Regular surfaces, tangent plane, First and second Fundamental forms. Principal and Gaussian curvatures. Rodrigue's formula. Conjugate and asymptotic lines.

Unit 3

Developable: Developable associated with space curves and curves on surfaces, minimal surfaces, canonical geodesic equations.

Reference Books

- A. Pressley, Elementary Differential Geometry, Springer, 2012.
- T. J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
- B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
- C. E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press2003.
- D. J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
- S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
- B. Spain, Tensor Calculus: A Concise Course, Dover Publications, 2003.

Semester 6					
Course Name	Metric Spaces and Complex Analysis			**Total Credit**	5+1=6
Subject Course No.	MATP 62 DSE	**Discipline Specific Electives**	DSE Paper 2	**Total Marks**	60+10+5=75

METRIC SPACES AND COMPLEX ANALYSIS

Unit 1 : Metric Spaces

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

Unit 2 : Complex Analysis

Limits, limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings.

Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.

Unit 3

Analytic functions, examples of analytic functions. Derivatives of functions and definite integrals of functions. Contours, Contour integrals and its examples. Upper bounds for moduli of contour integrals. Cauchy- Goursat theorem, Cauchy integral formula.

Unit 4

Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples.

Reference Books

- S. Shirali and H. L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- J. W. Brown and R. V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
- J. Bak and D. J. Newman, Complex Analysis, 2nd Ed., Undergraduate texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
- S. Ponnusamy, Foundations of Complex analysis.
- E. M. Stein and R. Shakrachi, Complex Analysis, Princeton University Press.

OR

Semester 6					
Course Name	Linear Programming			**Total Credit**	5+1=6
Subject Course No.	MATP 62 DSE	**Discipline Specific Electives**	DSE Paper 2	**Total Marks**	60+10+5=75

LINEAR PROGRAMMING

Unit 1

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

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

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

Unit 4

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.

Reference 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, 9th Ed., 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.

Semester 6					
Course Name	Mechanics			**Total Credit**	2
Subject Course No.	MATP 63 SEC	**Skill Enhancement Courses**	SEC SEM 6 Paper 2	**Total Marks**	60+10+5=75

MECHANICS

Unit 1

Co-planar forces. Astatic equilibrium. Friction. Equilibrium of a particle on a rough curve. Virtual work. Forces in three dimensions. General conditions of equilibrium. Centre of gravity for different bodies. Stable and unstable equilibrium.

Unit 2

Equations of motion referred to a set of rotating axes. Motion of a projectile in a resisting medium. Stability of nearly circular orbits. Motion under the inverse square law. Slightly disturbed orbits. Motion of artificial satellites. Motion of a particle in three dimensions. Motion on a smooth sphere, cone and on any surface of revolution.

Unit 3

Degrees of freedom. Moments and products of inertia. Momental Ellipsoid. Principal axes. D'Alembert's principle. Motion about a fixed axis. Compound pendulum. Motion of a rigid body in two dimensions under finite and impulsive forces. Conservation of momentum and energy.

Reference Books

- I. H. Shames and G. K. Mohan Rao, Engineering Mechanics: Statics and Dynamics, (4^{th} Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- R. C. Hibbeler and A. Gupta, Engineering Mechanics: Statics and Dynamics, 11th Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi.
- F. Chorlton, Textbook of Dynamics.
- S. L. Loney, An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press.
- S. L. Loney, Elements of Statics and Dynamics I and II.
- M. C. Ghosh, Analytical Statics.

OR

Semester 6					
Course Name	Boolean Algebra and Automata Theory			**Total Credit**	2
Subject Course No.	MATP 63 SEC	**Skill Enhancement Courses**	SEC SEM 6 Paper 2	**Total Marks**	60+10+5=75

BOOLEAN ALGEBRA AND AUTOMATA THEORY

Unit 1 : Boolean Algebra

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.

Unit 2

Boolean algebra: Definition of Boolean algebra, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams. Logic gates, switching circuits and applications of switching circuits.

Unit 3 : Automata Theory

Introduction: Alphabets, strings and languages. Finite automata and regular languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.

References Books

- B. A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge 1990.
- E. G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, (2nd Ed.), Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- R. Lidl and G. Pilz, Applied Abstract Algebra, 2nd Edition, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages and Computation, 2nd Ed., Addison-Wesley, 2001.
- H. R. Lewis, C. H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997.
- J. A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006.

Dr. Paltu Sarkar
Chairman
UG Board of Studies in Mathematics
University of North Bengal

B.Sc. Three Year Hons. /Prog. Course in Mathematics under CBCS (2023) NBU

Honours Course			Programme Course		
Subject Course No.	**Syllabus Code**	**Course**	**Subject Course No.**	**Syllabus Code**	**Course**
1ST SEMESTER					
MATH 11 HCC-I	HCC-I	Calculus and Geometry	MATP 11 DSC	DSC Paper 1	Calculus and Geometry
MATH 11 HCC-II	HCC-II	Algebra			
MATH 13 GE-I	GE-I	Other Department			
2ND SEMESTER					
MATH 21 HCC-III	HCC-III	Real Analysis	MATP 21 DSC	DSC Paper 2	Real Analysis
MATH 21 HCC-IV	HCC-IV	Differential Equation & Vector Calculus			
MATH 23 GE-II	GE-II	Other Department			
3RD SEMESTER					
MATH 31 HCC-V	HCC-V	Theory of Real Functions & Introduction of the Metric Space	MATP 31 DSC	DSC Paper 3	Algebra
MATH 31 HCC-VI	HCC-VI	Group Theory-I			
MATH 31 HCC-VII	HCC-VII	Riemann Integration & Series of Functions	MATP 33 SEC	SEC SEM 3 Paper 1	Logic & Sets / Graph Theory
MATH 33 GE-III	GE-III	Other Department			
MATH 34 SEC-I	SEC-I	Logic & Sets/Graph Theory			
4TH SEMESTER					
MATH 41 HCC-VIII	HCC-VIII	Multivariate Calculus	MATP 41 DSC	DSC Paper 4	Differential Equation and Vector Calculus
MATH 41 HCC-IX	HCC-IX	Ring Theory & Linear Algebra-I			
MATH 41 HCC-X	HCC-X	Metric Spaces & Complex Theory	MATP 43 SEC	SEC SEM 4 Paper 2	C Programming Language/ Theory of Equations
MATH 43 GE-IV	GE-IV	Other Department			
MATH 44 SEC-II	SEC-II	C Programming Language/ Operating System: Linux			
5TH SEMESTER					
MATH 51 HCC-XI	HCC-XI	Group Theory-II	MATP 52 DSE	DSE Paper 1	Numerical Methods + LAB / Group Theory and Linear Algebra
MATH 51 HCC-XII	HCC-XII	Numerical Methods + Lab			
MATH 52 DSE-I	DSE-I	Probability & Statistics/ Differential Geometry	MATP 53 SEC	SEC SEM 5 Paper 1	Theory of Probability/ Differential Geometry
MATH 52 DSE-II	DSE-II	Mechanics/ Number Theory			
6TH SEMESTER					
MATH 61 HCC-XIII	HCC-XIII	Ring Theory & Linear Algebra-II	MATP 62 DSE	DSE Paper 2	Metric Spaces & Complex Analysis / Linear Programming
MATH 61 HCC-XIV	HCC-XIV	Partial Differential Equations & Applications			
MATH 62 DSE-III	DSE-III	Linear Programming/ Point Set Topology/	MATP 63 SEC	SEC SEM 6 Paper 2	Mechanics / Boolean Algebra & Automata Theory
MATH 62 DSE-IV	DSE-IV	Mathematical Modelling/ Boolean Algebra & Automata Theory			

B.Sc. Three Year Hons. /Prog. Course in Mathematics under CBCS (2018) NBU

Honours Course			Programme Course		
Subject Course No.	**Syllabus Code**	**Course**	**Subject Course No.**	**Syllabus Code**	**Course**
1ST SEMESTER					
MATH 11 HCC-I	HCC-I	Cal, Geo & D.E.	MATP 11 DSC	DSC Paper 1	Calculus and Geometry
MATH 11 HCC-II	HCC-II	Algebra			
MATH 13 GE-I	GE-I	Other Department			
2ND SEMESTER					
MATH 21 HCC-III	HCC-III	Real Analysis	MATP 21 DSC	DSC Paper 2	Algebra
MATH 21 HCC-IV	HCC-IV	D.E & Vector Calculus			
MATH 23 GE-II	GE-II	Other Department			
3RD SEMESTER					
MATH 31 HCC-V	HCC-V	Theory Of Real Functions & Introduction of the Metric Space	MATP 31 DSC	DSC Paper 3	Real Analysis
MATH 31 HCC-VI	HCC-VI	Group Theory-I			
MATH 31 HCC-VII	HCC-VII	Riemann Integration & Series of Functions	MATP 33 SEC	SEC SEM 3 Paper 1	Logic & Sets / C++
MATH 33 GE-III	GE-III	Other Department			
MATH 34 SE-I	SE-I	Logic & Sets/ C++			
4TH SEMESTER					
MATH 41 HCC-VIII	HCC-VIII	Multivariate Calculus	MATP 41 DSC	DSC Paper 4	Differential Equation and Vector Calculus
MATH 41 HCC-IX	HCC-IX	Ring Theory & Linear Algebra-I			
MATH 41 HCC-X	HCC-X	Metric Spaces & Complex Theory	MATP 43 SEC	SEC SEM 4 Paper 2	Theory of Equations/ Number Theory
MATH 43 GE-IV	GE-IV	Other Department			
MATH 44 SE-II	SE-II	Graph Theory/ Operating System: Linux			
5TH SEMESTER					
MATH 51 HCC-XI	HCC-XI	Group Theory-II	MATP 52 DSE	DSE Paper 1	Mechanics / Group Theory and Linear Algebra
MATH 51 HCC-XII	HCC-XII	Numerical Methods + Lab			
MATH 52 DSE-I	DSE-I	Probability & Statistics / Linear Programming	MATP 53 SEC	SEC SEM 5 Paper 1	Probability & Statistics/ Differential Geometry
MATH 52 DSE-II	DSE-II	Number Theory/ Mechanics			
6TH SEMESTER					
MATH 61 HCC-XIII	HCC-XIII	Ring Theory & Linear Algebra-II	MATP 62 DSE	DSE Paper 2	Metric Space & Complex Analysis / Linear Programming
MATH 61 HCC-XIV	HCC-XIV	Partial Differential Equations & Applications			
MATH 62 DSE-III	DSE-III	Point Set Topology/ Boolean Algebra & Automata Theory	MATP 63 SEC	SEC SEM 6 Paper 2	Graph Theory/ Boolean Algebra & Automata Theory
MATH 62 DSE-IV	DSE-IV	Differential Geometry/ Theory of Equation			

QUESTION PATTERN

THEORY

For 60 Marks paper:

Group	Total Questions	Question to be answered	Mark of each Question	Total Marks
A	6	4	3	$12 = 4 \times 3$
B	6	4	6	$24 = 4 \times 6$
C	4	2	12	$24 = 2 \times 12$
			Total Marks	60

For 35 Marks paper:

Group	Total Questions	Question to be answered	Mark of each Question	Total Marks
A	8	5	1	$5 = 5 \times 1$
B	3	2	5	$10 = 2 \times 5$
C	4	2	10	$20 = 2 \times 10$
			Total Marks	35

For 40 Marks paper:

Group	Total Questions	Question to be answered	Mark of each Question	Total Marks
A	8	5	1	$5 = 5 \times 1$
B	5	3	5	$15 = 3 \times 5$
C	4	2	10	$20 = 2 \times 10$
			Total Marks	40

PRACTICAL

For 20 Marks Honours Paper:

Course	Note Book + Viva	6 Marks
Numerical Methods LAB HCC-XII	2 Problems $\times$ 7 Marks Each	14 Marks

For 20 Marks Programme Paper:

Course	Note Book + Viva	6 Marks
Numerical Methods LAB DSE Paper 1	2 Problems $\times$ 7 Marks Each	14 Marks

Dr. Paltu Sarkar (Chairman)
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University of North Bengal

ANNEXURE

Further Reference Book List for Mathematics Honours/ Programme Course

Algebra, Linear Algebra, Group Theory, Ring Theory, Boolean Algebra

1. Topics in Algebra: I. N. Herstein (*Wiley Eastern Ltd.*)
2. Topics in Abstract Algebra: M. K. Sen, S. Ghosh, P. Mukhopadhyay and S. K. Maity (*Universities Press)*
3. Abstract Algebra: N. P. Chaudhuri *(Tata McGraw Hill)*
4. A First Course in Abstract Algebra: J. B. Fraleigh *(Pearson Education)*
5. Algebra: R. M. Khan *(New Central Book Agency)*
6. Higher Algebra: Classical: S. K. Mapa *(Sarat Book House)*
7. Higher Algebra: Abstract & Linear: S. K. Mapa (*Sarat BookHouse*)
8. University Algebra: N. S. Gopala Krishnan (*New Age International*)

Integral and Differential Calculus

9. Introduction to Real Analysis, S. K. Mapa *(Sarat Book House)*
10. Mathematical Analysis: S. C. Malik and S. Arora *(New Age International)*
11. Introduction to Real Analysis: D. R. Sherbert and R. G. Bartle *(Wiley)*
12. Advanced Mathematical Analysis: Utpal Chatterjee *(Academic Publishers)*
13. Mathematical Analysis: Problems and Solutions: S. Bandyopadhyay *(Academic Publishers)*
14. Mathematical Analysis: S. N. Mukhopadhyay and A. K. Layek (*U. N. Dhur and Sons*)
15. A Course of Mathematical Analysis: S. Narayan *(S. Chand & Co.)*
16. Problems in Mathematical Analysis: B. P. Demidovich *(Mir Publication)*
17. An Introduction to Analysis-Differential Calculus, Part I & II: R. K. Ghosh and K. C. Maity *(New Central Book Agency)*
18. Integral Calculus & Differential Equations: B. C. Das and B. N. Mukherjee *(U.N. Dhur and Sons)*
19. Differential Calculus: B. C. Das & B. N. Mukherjee *(U.N. Dhur and Sons)*
20. Differential Calculus: S. Narayan (*S. Chand & Co.)*
21. Application of Calculus: S. K. Maity & S. Bandyopadhyay *(Academic Publishers)*
22. Application of Calculus: D. Sengupta *(Books & Allied)*
23. Calculus and its Applications: Goldstein, Lay, Schneider, Asmar *(Pearson Education)*
24. Integral Calculus: S. Narayan *(S. Chand & Co.)*
25. An Introduction to Analysis-Integral Calculus: R. K. Ghosh and K. C. Maity *(New Central Book Agency)*
26. Integral Calculus and Differential Equations: D. Chatterjee *(Tata McGraw Hill)*
27. Calculus: Volume I and II: T. Apstol *(Narosa Publishing House)*

Differential Equation

28. An Introduction to Differential Equations: R. K. Ghosh and K. C. Maity *(New Central Book Agency)*
29. Differential Equations: J. G. Chakravorty and P. R. Ghosh *(U. N. Dhur and Sons)*

30. Differential Equation and Laplace Transform: A. N. Das *(New Central Book Agency)*
31. Differential Equations: G. F. Simmons *(Tata McGraw)*
32. Ordinary and Partial Differential Equations: M. D. Risinghania *(S. Chand & Co.)*

Complex Analysis and Metric Spaces

33. Complex Analysis: S. Ganguly *(Academic Publishers)*
34. Theory of Functions of a Complex Variable: S. Narayan and P. K. Mittal *(S. Chand & Co.)*
35. Complex Variables: M. R. Spiegel *(McGraw Hill)*
36. Complex Analysis: U. C. De *(U. N. Dhur and Sons)*
37. Complex Analysis and Metric Spaces: U.C. De and J. Sengupta *(U. N. Dhur and Sons)*
38. Elements of Metric Spaces: M. N. Mukherjee *(Academic Publishers)*
39. Topology of Metric Spaces: S. Kumareasan (*Narisa Publishing House*)

Analytical Geometry (Two & Three Dimension) and Vector Analysis

40. Analytical Geometry and Vector Algebra: N. Datta and R. N. Jana *(Shreedhar Prakashani)*
41. Co-ordinate Solid Geometry: B. Nand, B. S. Tyagi and B. D. Sharma (*Kedar Nath Ram Nath*)
42. Analytical Geometry of two and three Dimensions: A. N. Das *(New Central Book Agency)*
43. Advanced Analytical Geometry of Two and Three Dimensions: U. Chatterjee and N. Chatterjee (*Academic Publishers*)
44. Analytical Geometry of Two and Three Dimensions & Vector Analysis: R.M. Khan *(New Central Book Agency)*
45. Vector Analysis: R. K. Ghosh and K. C. Maity *(New Central Book Agency)*
46. Vector Analysis: J. G. Chakravorty and P. R. Ghosh *(U.N. Dhur and Sons)*
47. Vector Analysis- Introduction to Tensor Analysis: A. N. Das *(U.N. Dhur and Sons)*
48. Vector Analysis and An Introduction to Tensor Analysis: M. R. Spiegel *(McGraw Hill)*

Particle Dynamics, Rigid Dynamics, Analytical Static and Classical Mechanics

49. Dynamics of a Particle: N. Datta and R. N. Jana *(Shreedhar Prakashani)*
50. Analytical Dynamics of a Particle: S. Ganguly and S. Saha *(New Central Book Agency)*
51. Advanced Analytical Dynamics: J. G. Chakravorty and P. R. Ghosh *(U.N. Dhur and Sons)*
52. Dynamics of a Particle and of Rigid Bodies: S. L. Loney *(Indian Edition-Radha Publishing House)*
53. Dynamics of Rigid Bodies: S. Mollah *(Books &Allied)*
54. Rigid Dynamics: M. M. Rahaman *(New Central Book Agency)*
55. Analytical Statics: M. C. Ghosh *(Shreedhar Prakashani)*
56. Analytical Statics: S. A. Mollah *(Books &Allied)*
57. Statics: B. C. Das and B. N. Mukherjee *(U.N. Dhur and Sons)*
58. Statics: S. L. Loney (*Radha Publishing House*)
59. Advanced Analytical Statics: S. Mondal *(U.N. Dhur and Sons)*
60. Classical Mechanics: H. Goldstein *(Narosa Publishing House)*

61. Classical Mechanics: S. L. Gupta, V. Kumar and H. V. Sharma *(Pragati Prakashan)*
62. Theoretical Mechanics: M. R. Spiegel *(McGraw Hill)*
63. Classical Mechanics: R. N. Tiwari and B. S. Thakur *(Prentice Hall of India)*

Linear Programming

64. Linear Programming: P. M. Karak *(New Central Book Agency)*
65. Linear Programming: J. G. Chakravorty and P. R. Ghosh *(U.N. Dhur & Sons)*
66. Introduction to Linear Programming: D. C. Sanyal and K. Das *(Dhur & Sons)*

Probability and Statistics

67. Groundwork of Mathematical Probability and Statistics: A. Gupta *(Academic Publishers)*
68. Mathematical Probability: A. Banerjee, S. K. De and S. Sen *(U.N. Dhur & Sons)*
69. Probability & Statistics-volume I & II: D. Biswas *(New Central Book Agency)*
70. Statistical Methods-part I & II: N. G. Das *(M. Das & Co.)*
71. Fundamentals of Mathematical Statistics: S. C. Gupta & V. K. Kapoor *(Sultan Chand & Sons)*
72. Mathematical Statistics S. K. De and S. Sen *(U.N. Dhur and Sons)*
73. A First Course in Probability: Sheldon Ross (*Pearson*)
74. Introduction to Probability and Statistics: Lipschutz (*Tata McGraw Hill*)

Numerical Analysis and C Programming Language

75. An Introduction to Numerical Analysis: Atkinson (*John Wiley and Sons*)
76. Numerical Analysis: N. Datta and R. N. Jana *(Shreedhar Prakashani)*
77. Numerical Analysis: S. A. Mollah *(Books & Allied)*
78. A Textbook of Numerical Analysis: D. C. Sanyal and K. Das *(U.N. Dhur and sons)*
79. Numerical Analysis: A. N. Das *(U.N. Dhur and Sons)*
80. Let us C: Y. Kanetkar *(BPB Publications)*
81. Programming in ANSI C: E. Balagurusamy *(Tata McGraw-Hill)*
82. Programming in C: V. Krishnamoorthy and K. R. Radhakrishnan *(Tata McGraw Hill)*

Discrete Mathematics and Graph Theory

83. Introduction to Graph Theory: D. B. West *(Prentice Hall of India)*
84. Discrete Mathematics: J. K. Sharma *(Macmillan)*
85. Introduction to Discrete Mathematics: M. K. Sen and B. C. Chakraborty *(Books & Allied)*
86. Graphic Theory with Applications to Engineering and Computer Science: N. Deo *(Prentice-Hall of India)*
87. Discrete Mathematics with Graph Theory: E. G. Goodaire and M. M. Parmenter (*Pearson Education*)

*********THE END*********