National Curriculum and Credit Framework (NCCF)

Syllabus

for

3 YEARS DEGREE WITH MATHEMATICS/4 YEARS DEGREE WITH MATHEMATICS HONOURS/4 YEARS DEGREE WITH MATHEMATICS HONOURS WITH RESEARCH

w.e.f. Academic Session 2023-24

Kazi Nazrul University
Asansol, Paschim Bardhaman
West Bengal-713340

SEMESTER-I

MAJOR COURSE-1

Course Name: Classical Algebra, Calculus and Analytical Geometry

Course Code: BSCMTMMJ101

Course Type: **MAJOR (Theoretical)**	Course Details: **MJC-1**			L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **100**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**30**	……	**70**

Course Learning Outcomes:

After the completion of course, the students will have ability to:

- Understand the importance of roots of real and complex polynomials and learn various methods of obtaining roots.
- Employ De Moivre's theorem in a number of applications to solve numerical problems.
- Understand various kinds of standard functions and graphs, techniques of integrations and limits.
- Understand the concepts on two-dimensional and three-dimensional geometry.

Classical Algebra

Unit 1: Polar representation of complex numbers, n^{th} roots of unity, De Moivre's theorem for rational indices and its applications, complex functions and their applications.

Unit 2: Theory of equations: Relation between roots and coefficients, Transformation of equation, Descartes rule of signs, Cubic and biquadratic equations. Reciprocal equation, separation of the roots of equations, Strum's theorem.

Unit 3: Inequality: The inequality involving $AM \geq GM \geq HM$ and simple theorems, Cauchy-Schwartz inequality, Weierstrass inequality, Problems on maxima-minima.

(25 Classes)

Calculus

Unit 4: Hyperbolic functions, higher order derivatives, Successive differentiation, Leibnitz rule and its applications to problems of type $(ax+b)^n; e^{ax}\sin(bx+c)$; $e^{ax}\cos(bx+c)$; $log_e(ax+b)$ etc. L'Hospital's rule. concavity and inflection points, envelopes, asymptotes, Maxima and Minima, Curvature. (13 Classes)

Unit 5: Reduction formulae, derivations and illustrations of reduction formulae for the integration of $sin^n x, cos^n x, tan^n x, sec^n x, (logx)^n, sinnx.sinmx$, etc. parametric equations,

parametrizing a curve, arc length, arc length of parametric curves, areas and volumes of surfaces of revolution. (12 Classes)

Analytical Geometry

Unit 6: Reflection properties of conics, translation, rotation and rigid motion of axes and second degree equations, classification of conics using the discriminant, Tangent, Normal, pole, polar, Diameter and conjugate diameters, Asymptotes. Polar equations of conics. (12 Classes)

Unit 7: Planes, Straight lines in 3D, Spheres. Cylindrical surfaces, Cone. Central conicoids, paraboloids, plane sections of conicoids, Generating lines, classification of quadrics, Tangent plane, Normal. (13 Classes)

References:

1. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
2. W. S. Burnstine and A.W. Panton, Theory of equations, 2007.
3. J. G. Chakravorty & P. R. Ghosh, Advanced Higher Algebra, U. N. Dhur& Sons Pvt. Ltd.
4. A. N. Das, Advanced Higher Algebra, Books & Allied (P) Ltd.
5. S. K. Mapa, Higher Algebra: Classical, Sarat Book House.
6. G. B. Thomas and R. L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
7. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
8. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
9. T. Apostol, Calculus, Volumes I and II. Vol-I, 1966, Vol-II, 1968.
10. S. Goldberg, Calculus and Mathematical analysis, 1989.
11. R. K. Ghosh & K. C. Maity, An Introduction to Analysis: Differential Calculus: Part I, New Central Book Agency (P) Ltd. Kolkata (India).
12. D. Sengupta, Application of Calculus, Books and Allied (P) Ltd (1st edition, 2012).
13. S. Bandyopadhyay and S. K. Maity, Application of Calculus, Academic Publishers (2nd edition, 2011).
14. R. M. Khan, Analytical Geometry of Two and Three Dimensions and Vector Analysis, New Central Book Agency (2010).
15. A. Mukherjee and N. K. Bej, Analytical Geometry of Two and Three Dimensions, Books and Allied (P) Ltd. (2013).

SKILL ENHANCEMENT COURSE-1

Course Name: Graph Theory

Course Code: BSCMTMSE101

Course Type: **SEC (Theoretical)**	Course Details: **SEC-1**			L-T-P: **2-1-0**	
Credit: **3**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	**.....**	**35**

Course Learning Outcomes*:* This course will enable the students to

- Appreciate the definition and basics of graphs along with types and their examples.
- Understand the Eulerian circuits, Eulerian graphs, Hamiltonian cycles, representation of a graph by matrix.
- Relate the graph theory to the real-world problems.

Unit -1: Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs isomorphism of graphs. (10 Classes)

Unit -2: Paths and circuits, Eulerian circuits, Eulerian graph, semi-Eulerian graph and theorems, Hamiltonian cycles and theorems. Representation of a graph by a matrix, the adjacency matrix, incidence matrix, weighted graph, Königsberg bridge problem; Subgraphs. (20 Classes)

Unit -3: Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Shortest path and Dijkstra's algorithm, Warshall algorithm. (15 Classes)

References:

1. J. Clark and D. A. Holton: A First Look at Graph Theory, Allied Publishers Ltd., 1995.
2. D. S. Malik, M. K. Sen and S. Ghosh: Introduction to Graph Theory, Cengage Learning Asia, 2014.
3. Nar Sing Deo: *Graph Theory,* Prentice-Hall, 1974.
4. J. A. Bondy and U.S.R. Murty: Graph Theory with Applications, Macmillan, 1976.
5. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
6. D.N.Ghosh, Discrete Mathematics, Academic Publishers.
7. D.K.Ghosh, Introduction to Graph Theory, New Central Book Agency(P) Ltd.

SEMESTER-II

MAJOR COURSE-2

Course Name: Linear Algebra I, Ordinary Differential Equations and Vector Calculus

Course Code: BSCMTMMJ201

Course Type: **MAJOR (Theoretical)**	Course Details: **MJC-2**			L-T-P: **4-1-0**	
Credit: **5**	Full Marks:**100**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**30**	……	**70**

Course Learning Outcomes: This course will enable the students to

- Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.
- Find eigenvalues and corresponding eigenvectors for a square matrix.
- Understand the genesis of ordinary differential equations.
- Understand the various techniques of getting exact solutions of solvable first order differential equations and linear differential equations of higher order.
- Know how to solve linear homogeneous and non-homogeneous equations of higher order with constant coefficients.
- Understand the system of linear differential equations and the solution techniques.
- Understand the theory and applications of vector analysis.

Linear Algebra I

Unit 1: Systems of linear equations, vector equations, the matrix equation $Ax=b$, vectors in R^2 and R^3 row reduction (column reduction) and echelon forms, congruent operations and congruence of matrices, matrices and matrix operations, inverse of a matrix, rank of a matrix, determinants and their properties, Cramer's rule, solution sets of linear systems and their geometrical interpretation, applications of linear systems, linear independence, characteristic equations, eigenvalues and eigenvectors of a matrix, geometrical interpretations and related theorems, algebraic and geometric multiplicity, Cayley Hamilton's theorem. (15 Classes)

Ordinary Differential Equations

Unit 2: Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Lipschitz condition and Picard's Theorem (Statement only). Existence and uniqueness of the solution of first order ODE (IVP). Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and

transformations, oblique and orthogonal trajectories, equations of first order but not first degree, Clairaut's form, Extraneous loci. (15 Classes)

Unit 3: 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. Reduction of order of ODE and solution. (15 Classes)

Unit 4: Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Matrix Method. Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions. Stability analysis: Equilibrium points, Interpretation of the phase plane and phase portrait. Solution of simultaneous equations of the form $dx/P = dy/Q = dz/R$. Pfaffian Differential Equation $Pdx+Qdy+Rdz = 0$, Necessary and sufficient condition for existence of integrals of the above (proof not required), Total differential equation.
(15 Classes)

Vector Calculus

Unit 5: Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, vector equations and its simple applications, differentiation and integration of vector functions. Differential operators: gradient, divergence, curl. (15 Classes)

References:

1. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
2. K. B. Dutta, Matrix and linear algebra, 2004.
3. P. K. Nayak, Linear Algebra, Books & Allied (P) Ltd.
4. S. K. Mapa, Higher Algebra: Abstract and Linear, Sarat Book House.
5. K. Hoffman, R. Kunze, Linear algebra, 1971.
6. H. Anton & C. Rorres, Elementary Linear Algebra, Wiley, 2017.
7. S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
8. D. Murray, Introductory Course in Differential Equations, Longmans Green and Co.
9. G. F. Simmons, Differential Equations, Tata Mcgraw Hill, 1991.
10. P. R. Ghosh & J. G. Chakraborty, Differential Equations, U. N. Dhur and Sons.
11. R. K. Ghosh and K. C. Maity, Introduction to Differential Equations, New Central
12. M. D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand.
13. N. Mandal & B. Pal, Differential Equations, Books and Allied (P) Ltd., 2022.
14. D. Sengupta, Introduction to Differential Equations, Books and Allied (P) Ltd., 2019.

15. J. Marsden & Tromba, Vector Calculus, McGraw Hill, 1987
16. K. C. Maity& R. K. Ghosh, Vector Analysis, New Central Book Agency (P) Ltd.
17. J. G. Chakravorty & P. R. Ghosh, Vector Analysis, U. N. Dhur& Sons Private Ltd.
18. Shanti Narayan & P. K. Mittal, A Textbook of Vector Calculus, S. Chand & Company.
19. M. R. Speigel, Schaum's outline of Vector Analysis, McGraw Hill, 1980.

SKILL ENHANCEMENT COURSE-2

Course Name: Mathematical Tools and Latex

Course Code: BSCMTMSE201

Course Type: **SE(Theoretical)**	Course Details: **SEC-2**			L-T-P: **2-1-0**	
Credit: **3**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	**.....**	**35**

Course Learning Outcomes: This course will enable the students to

- Familiar with open-source mathematical tools.
- Utilize Scilab for displaying graphs, plots, etc.
- Get acquainted with LaTex software
- Prepare resume, question paper, project report, etc. using LaTeX

Unit 1: Open-Source Mathematical tool. Introduction to Scilab and its benefits, the general environment, editor, command window, graphics window, Variables assignments, functions, conditional statements, loops, display of array in terms of matrices and vectors, displaying graphs, plots, output data, data file. The following programs need to be completed in Scilab:

(i) Computation of addition and multiplication of matrices.
(ii) Computation of Trace and Transpose of Matrix
(iii) Computation of Rank of matrix and Row reduced Echelon form.
(iv) Computation of Inverse of a Matrix.
(v) Solving the system of homogeneous and non-homogeneous linear equations.
(vi) Finding the nth Derivative of algebraic and logarithmic functions.
(vii) Computation of maxima and minima of functions.
(viii) Definite and indefinite integration.
(ix) Solution of algebraic and transcendental equations.
(x) Solution of ODEs.

(15 Classes)

Unit 2: Graphical demonstration

(Conceptual Discussion and Practical using Scilab)

Plotting of graphs of function exp(ax + b), log(ax + b), 1/(ax + b), sin(ax + b), cos(ax + b), |ax + b| and to illustrate the effect of a and b on the graph. Plotting the graphs of polynomials, the derivative graph, the second derivative graph and comparing them. Sketching parametric curves (eg. Trochoid, cycloid). Obtaining surface of revolution of curves. Tracing of conics in Cartesian coordinates/polar coordinates. Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic paraboloid, and hyperbolic paraboloid using Cartesian coordinates. (15 Classes)

Unit 3: LaTeX. Installation of MikTeX, Basic Syntex, Understanding Latex compilation. Use of templates, using various Classes and Packages, Latex Preamble, Latex commands and debugging errors, formatting text, symbols, indenting, paragraphs, line-spacing, titles and subtitles. Mathematical environment: mathematical symbols, functions and equations, theorem declarations, drawing matrices. Inserting figures, tables with captions, in-text references to figures and tables. Creating contents, citation and bibliography. Preparing resume, question paper, project report, etc. in LaTeX. (15 Classes)

References:

1. Sandeep Nagar, Introduction to Scilab: For Engineers and Scientists. Apress publisher, New York, USA, 2017.
2. A.S.Nair, SCILAB (A free software to MATLAB), S. Chand Publishing, New Delhi, India, 2012.
3. Stefan Kottwitz, LaTeX Beginner's Guide, Packt Publishing; 2nd ed. edition (October 6, 2021).
4. Ms Firuza Karmali Aibara, A short introduction to LaTeX: A book for beginners, Create Space Independent Publishing Platform (January 3, 2019)
5. WEB REFERENCES: https://www.scilab.org/; https://onlinecourses.swayam2.ac.in/aic20_sp38/preview

SEMESTER-III

MAJOR COURSE-3

Course Name: Real Analysis I

Course Code: BSCMTMMJ301

Course Type: **MAJOR (Theoretical)**	Course Details: **MJC-3**			L-T-P: 4-1-0	
Credit: 5	Full Marks: 100	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			30		70

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Understand the various basic information and importance of the set of real numbers which will help them to build up preliminary ideas about the higher dimensional spaces.
- Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a sequence.
- Understand various kinds of standard functions and their graphs and behaviours.
- Judge the discontinuities of the real valued functions with the help of the ideas about sequences and subsequences.
- Enrich their previous knowledge about limits, continuities and differentiability's of real valued functions.
- Expand the different type of functions with the help of appropriate theorem and also the remainder term of the expansion.

Unit - 1: Review of Algebraic and Order Properties of $\mathbb{R}$, ε-neighbourhood of a point in $\mathbb{R}$. Idea of countable sets, uncountable sets and uncountability of $\mathbb{R}$. Bounded above& Bounded below sets, Bounded Sets, Unbounded sets. Suprema and Infima. Completeness Property of $\mathbb{R}$ and its equivalent properties. The Archimedean Property, Density of Rational (and Irrational) numbers in $\mathbb{R}$, Intervals. Limit points of a set, Isolated points, Open set, closed set, derived set, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in $\mathbb{R}$, Heine-Borel Theorem. (15 Classes)

Unit- 2: Sequences, Bounded sequence, Convergent sequence, Limit of a sequence, Limit Theorems. Monotone Sequences, Convergence criterion on Monotone sequence. Subsequence and its convergence, Divergence Criterion of sequences and subsequences. Bolzano-Weierstrass theorem for sequences. Limit superior and Limit inferior of a sequence, Cauchy sequence, Cauchy's Convergence Criterion. Sequence of functions: pointwise convergence, uniform convergence, consequences of uniform convergence. (20 Classes)

Unit – 3: ε - δ definition of limit of a real-valued function, Algebra of limits, Limit at infinity and infinite limits; Continuity of a real-valued function, Algebra of continuity, sequential criteria for continuity, Properties of continuous functions, Bolzano's theorem, Fixed point property. Intermediate value theorem, Geometrical interpretation of continuity, Types of discontinuity; Uniform continuity, Relation between continuity and uniform continuity.

(20 Classes)

Unit – 4: Differentiability of a real-valued function, Geometrical interpretation of differentiability, Relation between differentiability and continuity, Differentiability and monotonicity, Chain rule of differentiation; Darboux's theorem, Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Geometrical interpretation of mean value theorems; Maclaurin's and Taylor's theorems for expansion of a function in an infinite series, Taylor's theorem in finite form with Lagrange, Cauchy and Schlomilch- Roche forms of remainder. (20 Classes)

References:

1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Gerald G. Bilodeau, Paul R. Thie, G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
3. Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
4. S. K. Berberian, A First Course in Real Analysis, Springer Verlag, New York, 1994.
5. Tom M. Apostol, Mathematical Analysis, Narosa Publishing House, 1981.
6. Courant and John, Introduction to Calculus and Analysis, Vol I, Springer, 1999.
7. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill, 1953.
8. Terence Tao, Analysis I, Hindustan Book Agency, 2006
9. S. Goldberg, Calculus and mathematical analysis, 1989.
10. S. K. Mukherjee, First Course in Real Analysis, Academic Publishers.
11. S. Bandyopadhyay & B. Guhathakurta, Mathematical Analysis, Academic Publishers.
12. R. K. Ghosh & K. C. Maity, An Introduction to Analysis: Differential Calculus: Part I, New Central Book Agency (P) Ltd. Kolkata (India).
13. S. N. Mukhopadhyay & A. K. Layek, Mathematical Analysis Volume-I, U. N. Dhur & Sons Pvt. Ltd.
14. B. K. Kar (2013), An Introduction to Modern Analysis (Volume I), Books & Allied Ltd.
15. S. C. Malik and S. Arora, Mathematical Analysis, New Age International (P) Ltd publishers (3rd edition, 2009).
16. S. K. Mapa, Real Analysis, Sarat Book Distributors (5th edition, 2008).
17. Shanti Narayan & M. D. Raisinghania, Elements of Real Analysis, S. Chand & Company Ltd. (14th edition, 2013).
18. Thomas and Finney, Calculus and Analytic Geometry, Addison-Wesley publishing co. 9th Edition. 1996.
19. S. Ponnusamy, Foundations of Mathematical Analysis, Birkhauser. 2011.

MAJOR COURSE-4

Course Name: Abstract Algebra-I and Number Theory

Course Code: BSCMTMMJ302

Course Type: MAJOR **(Theoretical)**	Course Details: **MJC-4**			L-T-P: 4-1-0	
Credit: 5	Full Marks: 100	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			30		70

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Link the fundamental concepts of groups and symmetries of geometrical objects.
- Explain the significance of the notions of cosets, normal subgroups, and factor groups.
- Analyse consequences of Lagrange's theorem.
- Learn about structure preserving maps between groups and their consequences
- Learn about some important results in the theory of numbers including the prime number theorem, Chinese remainder theorem, Wilson's theorem and their consequences.
- Learn about number theoretic functions, modular arithmetic and their applications.
- Familiarize with modular arithmetic and find primitive roots of prime and composite numbers.
- Know about open problems in number theory, namely, the Goldbach conjecture and twin-prime conjecture etc.

Unit – 1: Equivalence relations and partitions, Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Binary Compositions; Groupoids, Semigroups, Monoids, Groups: Examples & elementary Properties; Abelian group; Permutation groups; Finite groups: symmetric group, alternating group, Klein's 4-group, group of all n-th roots of unity; Examples of infinite groups; Order of an element, symmetry and dihedral groups.(15 Classes)

Unit-2: Subgroups: definitions, examples and elementary properties; Centre of a group; Centraliser of an element in a group; Cyclic groups: definitions, examples and elementary properties; Properties of Cosets; Lagrange's theorem. Normal Subgroups and their properties; Simple group; Normaliser of a subgroup; Self-conjugate subgroup; Quotient group; Conjugacy relation in a group; Class equation of a group.(20 Classes)

Unit – 3: Well-ordering property of positive integers, Principles of Mathematical Induction, Division algorithm, Divisibility and Euclidean algorithm. Linear Diophantine equation. statement of Fundamental Theorem of Arithmetic. Prime counting function, Theorems on Prime numbers, Goldbach conjecture, Twin-prime conjecture, Odd perfect numbers conjecture, Fermat and Mersenne primes. (15 Classes)

Unit – 4: Congruence relation between integers, modular arithmetic. Linear congruence and Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Number theoretic functions for sum and number of divisors, Multiplicative function, The Möbius inversion formula, Greatest integer function, Euler's phi-function and properties, Euler's theorem.
. (15 Classes)

References:

1. Michael Artin (2014). Algebra (2nd edition). Pearson.
2. John B. Fraleigh (2007). A First Course in Abstract Algebra (7th edition). Pearson.
3. Joseph A. Gallian (2017). Contemporary Abstract Algebra (9th edition). Cengage.
4. I. N. Herstein (2006). Topics in Algebra (2nd edition). Wiley India.
5. Nathan Jacobson (2009). Basic Algebra I (2nd edition). Dover Publications
6. Ramji Lal (2017). Algebra 1: Groups, Rings, Fields and Arithmetic. Springer.
7. I.S. Luthar & I.B.S. Passi (2013). Algebra: Volume 1: Groups. Narosa.
8. M. K. Sen, S. Ghosh, P. Mukhopadhyay& S. K. Maity. Topics in Abstract Algebra. Universities Press.
9. S. K. Mapa. Higher Algebra: Abstract and Linear. Levant Books.
10. V. K. Khanna & S. K. Bhambri. A Course in Abstract Algebra. Vikash Publishing.
11. David M. Burton (2007), Elementary Number Theory (7th edition), McGraw-Hill.
12. I. Niven (2012), An Introduction to the Theory of Numbers (5th edition), John Wiley & Sons.
13. Neville Robbins (2007), Beginning Number Theory (2nd edition), Narosa.
14. Gareth A. Jones & J. Mary Jones (2005), Elementary Number Theory, Springer.
15. Neal Koblitz (1994), A Course in Number Theory and Cryptography (2nd edition), Springer-Verlag.

SEMESTER-IV

MAJOR COURSE-5

Course Name: Multivariate Calculus

Course Code: BSCMTMMJ401

Course Type: MAJOR **(Theoretical)**	Course Details: **MJC-5**			L-T-P: 4-1-0	
Credit: 5	Full Marks: 100	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			30		70

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Understand the basic concepts and know the basic techniques of differential and integral calculus of functions of several variables.
- Learn conceptual differences while advancing from one variable to several variables in calculus
- Apply multivariable calculus in various optimization problems. Solve problems involving maxima and minima, line integral and surface integral, and vector calculus.
- Visualise the structure of curves and surfaces in plane and space etc.
- Learn the applications of multivariable calculus in different fields like Physics, Economics, Medical Sciences, Animation & Computer Graphics etc.
- Realize importance of Green, Gauss and Stokes' theorems in other branches of Mathematics.
- Understand inter-relationship amongst the line integral, double and triple integral formulations.
- Develop mathematical maturity to undertake higher level studies in mathematics and related fields.

Unit- 1: Functions of several variables, Level curves and surfaces, Limits: repeated limits and double limits, continuity of functions of several variables, Partial differentiation, Linear approximation and tangent planes, Chain rule, Directional derivatives, The gradient, Maximal and normal properties of the gradient, Tangent planes and normal lines. (14 Classes)

Unit- 2: Differentiability and Total Differentiation, Higher order and mixed partial derivatives, Total differential and differentiability, Sufficient condition for differentiability, Jacobians, Change of variables, Young's theorem, Schwarz theorem, Implicit function theorem (Statement only), Functional dependence, Inverse function theorem (Statement only), Euler's theorem for homogeneous functions (upto three variables), Taylor's theorem for functions of two variables, Envelopes and evolutes. (18 Classes)

Unit-3: Extrema of Functions, Critical points and extrema of functions of two and three variables, Local extrema and absolute extrema, Constrained optimization problems, Method of Lagrange multipliers with various applications, Definition of vector field, Vector operators such as divergence, curl, gradient and the related vector identities. (14 Classes)

Unit-4: Double and Triple Integrals: Double integration over rectangular and non-rectangular regions, Double integrals in polar coordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals, Dirichlet integral. (14 Classes)

Unit-5: Line integrals, Applications of line integrals, Fundamental theorem on line integrals, Path independence, Conservative vector fields, Area as a line integral, Surface integrals, Integrals over parametric surfaces, Green's theorem, Stokes' theorem, Volume as a surface integral, Gauss divergence theorem. (15 Classes)

References:

1. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein (2009), Basic Multivariable Calculus, Springer India Pvt. Limited.
2. James Stewart (2012). Multivariable Calculus (7th edition), Brooks/Cole, Cengage.
3. Monty J. Strauss, Gerald L. Bradley & Karl J. Smith (2011), Calculus (3rd edition), Pearson Education, Dorling Kindersley (India) Pvt. Ltd.
4. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018), Thomas' Calculus (14th edition), Pearson Education.
5. Sudhir R. Ghorpade & Balmohan V. Limaye (2009), A Course in Multivariable Calculus and Analysis, Springer.
6. Terence Tao (2015), Analysis II (3rd edition), Hindustan Book Agency.
7. Susan Jane Colley (2012), Vector Calculus (4th edition), Pearson Education.
8. R. K. Ghosh & K. C. Maity, An Introduction to Analysis: Differential Calculus: Part I, New Central Book Agency (P) Ltd. Kolkata (India).
9. B. K. Kar (2013), An Introduction to Modern Analysis (Volume I), Books & Allied Pvt. Ltd.
10. Subir Kumar Mukherjee (2019), Advanced Differential Calculus of Several Variables (5th edition), Academic Publishers.
11. Debasish Sengupta, Elementary Multivariate Calculus, Books & Allied Pvt. Ltd.

MAJOR COURSE-6

Course Name: Linear Algebra-II and Tensor Calculus

Course Code: BSCMTMMJ402

Course Type: **(Theoretical)**	Course Details: **MJC-6**			L-T-P: 4-1-0	
MAJOR Credit: 5	Full Marks: 100	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			30		70

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Extend their previous knowledge about matrices and different form of matrixes
- Understand the concepts of vector spaces, subspaces, bases, dimension and their properties
- Relate matrices and linear transformations, compute eigenvalues and eigenvectors of linear transformations.
- Learn properties of inner product spaces and determine orthogonality in inner product spaces.
- Classify different standard conics and coincided by reducing the equations into it normal or canonical form with the help of ideas on matrices.
- Realize the further study of inner product spaces and linear transformations.
- Explain the basic concepts of tensors.
- Understand role of tensors in different fields.

Unit 1: Diagonalization of a matrix, Jordan canonical form, Normal form, Triangular form. (5 Classes)

Unit-2: Vector Spaces: Definition and examples, Subspaces, Linear span, Linearly independent and dependent sets, Bases and dimension, Replacement theorem, Deletion theorem, Extension theorem, Quotient space and direct sum of subspaces. (12 Classes)

Unit-3: Linear Transformations, Algebra of linear transformations, Matrix representation of a linear transformation, Change of coordinates, Rank and nullity of a linear transformation and rank-nullity theorem. (10 Classes)

Unit-4: Isomorphism theorems of finite dimensional vector spaces, Dual of a vector space, Transpose of a linear transformation, Eigenvalues and eigenvectors of a linear transformation, Eigen space, Characteristic polynomial and Cayley-Hamilton theorem, Minimal polynomial. Invariant subspaces. (10 Classes)

Unit-5: Inner product space, Norm, Cauchy-Schwarz inequality, Paralelogram Law, Polarization identity, Orthogonal and orthonormal vectors, Gram-Schmidt Process, Pythagorean theorem. . (10 Classes)

Unit-6: Real quadratic form and reduction to its normal form, Rank, Index, Signature, Sylvester's law, Classification of conics. (10 Classes)

Unit-7: Tensor: Contravariant and Covariant vectors, Different transformation laws, Tensor product of two vector spaces, Properties of tensors, Symmetric and Skew symmetric Tensors, Contraction of Tensors, Kronecker delta, Quotient law, Metric tensor, Associated Covariant and Contravariant vectors, Christoffel Symbols and their laws of transformation, (18 Classes)

References:

1. Stephen H. Friedberg, Arnold J. Insel & Lawrence E. Spence (2003). Linear Algebra (4thedition). Prentice-Hall of India Pvt. Ltd.
2. Serge Lang (2005). Introduction to Linear Algebra (2nd edition). Springer India.
3. Gilbert Strang (2014). Linear Algebra and its Applications (2nd edition). Elsevier.
4. Kenneth Hoffman & Ray Kunze (2015). Linear Algebra (2nd edition). Prentice-Hall.
5. Nathan Jacobson (2009). Basic Algebra I & II (2nd edition). Dover Publications.
6. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
7. Vivek Sahai & Vikas Bist (2013). Linear Algebra (2nd Edition). Narosa Publishing House.
8. Mapa, Higher Algebra(Abstract and linear), Sarat Book Distributors.
9. P. K. Nayak, Linear Algebra, Books & Allied (P) Ltd.
10. H. Anton & C. Rorres, Elementary Linear Algebra, Wiley, 2017.
11. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
12. S.K. Berberian, Linear Algebra, Dover Publication, 2014.
13. B. Spain, Tensor Calculus: A Concise Course, Dover Publications, 2003.
14. P. K. Nayak, Textbook of Tensor Calculus and Differential Geometry, PHI Learning Private Limited, 2012.
15. R. S. Mishra, A Course in Tensors with Applications to Riemannian Geometry, Pothishala Pvt Ltd., 1965.
16. P.P. Gupta, G.S. Malik & S.K. Pundir, Tensors and Differential Geometry, Anu Books, 2020.
17. S.S. Gupta J.K. Goyal, K.P. Gupta, G.S. Gupta, Tensor Calculus and Riemannian Geometry, Anu Books, 2020.
18. M.C. Chaki, A Textbook of Tensor Calculus, Calcutta Publisher, 1994.
19. A. A. Shaikh, U.C. De, J. Sengupta, Tensor Calculus, Narosa.
20. U. Chatterjee & N. Chatterjee, Vector & Tensor Analysis, Academic Publishers.

SKILL ENHANCEMENT COURSE-3

Course Name: C Programming

Course Code: BSCMTMSE401

Course Type: SE **(Theoretical)**	Course Details: **SEC-3**			L-T-P: 2-1-0	
Credit: 3	Full Marks: 50	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			15		35

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Acquire knowledge of different computer languages.
- Understand basic structures, characters, identifier etc. in C language.

- Write flow chart and corresponding C-program for solving problems requiring decision making, branching, looping and other control statements.
- Learn to implement arrays and functions in C programming.
- Familiarise with the concepts of structure, union and pointers.

Unit 1: Introduction to C Language – Background, C Programs, Identifiers, Types, Variables, Constants, Input / Output, Operators (Arithmetic, relational, logical, bitwise etc.), Expressions, Precedence and Associativity, Expression Evaluation, Type conversions. (7 Classes)

Unit 2: Statements- Selection Statements (making decisions) – if, if-else, nested if, ladder if, else-if, and switch statements. Repetition statements (loops)-while, for, do-while statements, Loop examples, other statements related to looping – break, continue and goto. Some simple programs. (8 Classes)

Unit 3: One Dimensional Arrays: Array Manipulation; Searching, Insertion, Deletion of an element from an Array; Sorting an array (bubble sort and selection sort). Two Dimensional Arrays: Addition and Multiplication of two matrices, Transpose of a square matrix, representation of Sparse matrices. Some simple programs. (10 Classes)

Unit 4: Functions: Elements of User-Defined Functions, Definition of Functions, Return Values and their Types, Function Calls: call by value, call by reference, Function Declaration, Category of Functions, Nesting of Functions, Recursion, Passing Arrays to Functions, Scope of variables. Some simple programs. (10 Classes)

Unit 5: Structures, Unions and Pointers: Structure variables, Initialization, Structure Assignment, Structures and Functions, Structures and Arrays, Unions. Pointers: Address operators, Pointer Type Declaration, Pointer Assignment, Pointer Initialization, Pointer Arithmetic. Some simple programs. (10 Classes)

References:

1. B. W. Kernighan and D. M. Ritchi: The C-Programming Language, 2nd Edi. (ANSI Refresher), Prentice Hall, 1977.
2. E. Balagurnsamy: Programming in ANSI C, Tata McGraw Hill, 2004.
3. Y. Kanetkar: Let Us C; BPB Publication, 1999.
4. C. Xavier: C-Language and Numerical Methods, New Age International.
5. V. Rajaraman: Computer Oriented Numerical Methods, Prentice Hall of India, 1980.

Pool of Minor Courses offered by Mathematics Discipline

SEMESTER-I

MINOR COURSE-1

Course Name: Classical Algebra, Calculus and Analytical Geometry

Course Code: BSCMTMMN101

Course Type: **MINOR (Theoretical)**	Course Details: **MNC-1**			L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **100**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**30**	……	**70**

Course Learning Outcomes:

After the completion of course, the students will have ability to:

- Understand the importance of roots of real and complex polynomials and learn various methods of obtaining roots.
- Employ De Moivre's theorem in a number of applications to solve numerical problems.
- Understand various kinds of standard functions and graphs, techniques of integrations and limits.
- Understand the concepts on two-dimensional and three-dimensional geometry.

Classical Algebra

Unit 1: Polar representation of complex numbers, n^{th} roots of unity, De Moivre's theorem for rational indices and its applications, complex functions and their applications.

Unit 2: Theory of equations: Relation between roots and coefficients, Transformation of equation, Descartes rule of signs, Cubic and biquadratic equations. Reciprocal equation, separation of the roots of equations, Strum's theorem.

Unit 3: Inequality: The inequality involving $AM \geq GM \geq HM$ and simple theorems, Cauchy-Schwartz inequality, Weierstrass inequality, Problems on maxima-minima.

(25 Classes)

Calculus

Unit 4: Hyperbolic functions, higher order derivatives, Successive differentiation, Leibnitz rule and its applications to problems of type $(ax+b)^n; e^{ax}\sin(bx+c)$; $e^{ax}\cos(bx+c)$; $log_e(ax+b)$ etc. L'Hospital's rule. concavity and inflection points, envelopes, asymptotes, Maxima and Minima, Curvature. (13 Classes)

Unit 5: Reduction formulae, derivations and illustrations of reduction formulae for the integration of $sin^n x, cos^n x, tan^n x, sec^n x, (logx)^n, sinnx.sinmx$, etc. parametric equations, parametrizing a curve, arc length, arc length of parametric curves, areas and volumes of surfaces of revolution. (12 Classes)

Analytical Geometry

Unit 6: Reflection properties of conics, translation, rotation and rigid motion of axes and second degree equations, classification of conics using the discriminant, Tangent, Normal, pole, polar, Diameter and conjugate diameters, Asymptotes. Polar equations of conics.

(12 Classes)

Unit 7: Planes, Straight lines in 3D, Spheres. Cylindrical surfaces, Cone. Central conicoids, paraboloids, plane sections of Conicoids, Generating lines, classification of quadrics, Tangent plane, Normal. (13 Classes)

References:

1. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
2. W. S. Burnstine and A.W. Panton, Theory of equations, 2007.
3. J. G. Chakravorty & P. R. Ghosh, Advanced Higher Algebra, U. N. Dhur& Sons Pvt. Ltd.
4. A. N. Das, Advanced Higher Algebra, Books & Allied (P) Ltd.
5. S. K. Mapa, Higher Algebra: Classical, Sarat Book House.
6. G. B. Thomas and R. L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
7. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
8. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
9. T. Apostol, Calculus, Volumes I and II. Vol-I, 1966, Vol-II, 1968.
10. S. Goldberg, Calculus and Mathematical analysis, 1989.
11. R. K. Ghosh & K. C. Maity, An Introduction to Analysis: Differential Calculus: Part I, New Central Book Agency (P) Ltd. Kolkata (India).
12. D. Sengupta, Application of Calculus, Books and Allied (P) Ltd (1st edition, 2012).
13. S. Bandyopadhyay and S. K. Maity, Application of Calculus, Academic Publishers (2nd edition, 2011).
14. R. M. Khan, Analytical Geometry of Two and Three Dimensions and Vector Analysis, New Central Book Agency (2010).
15. A. Mukherjee and N. K. Bej, Analytical Geometry of Two and Three Dimensions, Books and Allied (P) Ltd. (2013).

SEMESTER-II

MINOR COURSE-2

Course Name: Linear Algebra I, Ordinary Differential Equations and Vector Calculus

Course Code: BSCMTMMN201

Course Type: **MINOR (Theoretical)**	Course Details: **MNC-2**			L-T-P: **4-1-0**	
Credit: **5**	Full Marks:**100**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**30**	……	**70**

Course Learning Outcomes: This course will enable the students to

- Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.
- Find eigenvalues and corresponding eigenvectors for a square matrix.
- Understand the genesis of ordinary differential equations.
- Understand the various techniques of getting exact solutions of solvable first order differential equations and linear differential equations of higher order.
- Know how to solve linear homogeneous and non-homogeneous equations of higher order with constant coefficients.
- Understand the system of linear differential equations and the solution techniques.
- Understand the theory and applications of vector analysis.

Linear Algebra I

Unit 1: Systems of linear equations, vector equations, the matrix equation $Ax=b$, vectors in R^2 and R^3 row reduction (column reduction) and echelon forms, congruent operations and congruence of matrices, matrices and matrix operations, inverse of a matrix, rank of a matrix, determinants and their properties, Cramer's rule, solution sets of linear systems and their geometrical interpretation, applications of linear systems, linear independence, characteristic equations, eigenvalues and eigenvectors of a matrix, geometrical interpretations and related theorems, algebraic and geometric multiplicity, Cayley Hamilton's theorem.(15 Classes)

Ordinary Differential Equations

Unit 2: Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Lipschitz condition and Picard's Theorem (Statement only). Existence and uniqueness of the solution of first order ODE (IVP). Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations, oblique and orthogonal trajectories, equations of first order but not first degree, Clairaut's form, Extraneous loci. (15 Classes)

Unit 3: 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. Reduction of order of ODE and solution. (15 Classes)

Unit 4: Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Matrix Method. Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions. Stability analysis: Equilibrium points, Interpretation of the phase plane and phase portrait. Solution of simultaneous equations of the form $dx/P = dy/Q = dz/R$. Pfaffian Differential Equation $Pdx+Qdy+Rdz = 0$, Necessary and sufficient condition for existence of integrals of the above (proof not required), Total differential equation. (15 Classes)

Vector Calculus

Unit 5: Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, vector equations and its simple applications, differentiation and integration of vector functions. Differential operators: gradient, divergence, curl. (15 Classes)

References:

1. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
2. K. B. Dutta, Matrix and linear algebra, 2004.
3. P. K. Nayak, Linear Algebra, Books & Allied (P) Ltd.
4. S. K. Mapa, Higher Algebra: Abstract and Linear, Sarat Book House.
5. K. Hoffman, R. Kunze, Linear algebra, 1971.
6. H. Anton & C. Rorres, Elementary Linear Algebra, Wiley, 2017.
7. S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
8. D. Murray, Introductory Course in Differential Equations, Longmans Green and Co.
9. G. F. Simmons, Differential Equations, Tata Mcgraw Hill, 1991.
10. P. R. Ghosh & J. G. Chakraborty, Differential Equations, U. N. Dhur and Sons.

11. R. K. Ghosh and K. C. Maity, Introduction to Differential Equations, New Central
12. M. D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand.
13. N. Mandal & B. Pal, Differential Equations, Books and Allied (P) Ltd., 2022.
14. D. Sengupta, Introduction to Differential Equations, Books and Allied (P) Ltd., 2019.
15. J. Marsden & Tromba, Vector Calculus, McGraw Hill, 1987
16. K. C. Maity& R. K. Ghosh, Vector Analysis, New Central Book Agency (P) Ltd.
17. J. G. Chakravorty & P. R. Ghosh, Vector Analysis, U. N. Dhur& Sons Private Ltd.
18. Shanti Narayan & P. K. Mittal, A Textbook of Vector Calculus, S. Chand & Company.
19. M. R. Speigel, Schaum's outline of Vector Analysis, McGraw Hill, 1980.

SEMESTER-III

MINOR COURSE-3

Course Name: Real Analysis and Complex Analysis

Course Code: BSCMTMMN301

Course Type: MINOR **(Theoretical)**	Course Details: **MNC-3**			L-T-P: 4-1-0	
Credit: 5	Full Marks: 100	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			30		70

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Understand the various basic information and importance of the set of real numbers which will help them to build up preliminary ideas about the higher dimensional spaces.
- Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a sequence.
- Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.
- Understand various kinds of standard functions and their graphs and behaviours.
- Judge the discontinuities of the real valued functions with the help of the ideas about sequences and sub sequences.
- Enrich their previous knowledge about limit, continuities and differentiability of real valued functions.
- Expand the different types of function with the help of appropriate theorem and also the remainder term of the expansion.
- Visualize complex numbers as points of $\mathbb{R}^2$ and stereographic projection of complex plane on the Riemann sphere.
- Understand the significance of differentiability and analyticity of complex functions leading to the Cauchy-Riemann equations.
- Learn the role of Cauchy-Goursat theorem and Cauchy integral formula in evaluation of contour integrals.

Unit - 1: Sequences, Bounded sequence, Convergent sequence, Limit of a sequence, Limit Theorems. Monotone Sequences, Convergence criterion on Monotone sequence. Subsequence and its convergence, Divergence Criterion of sequences and subsequences Bolzano Weierstrass Theorem for Sequences (statement only),. Limit superior and Limit inferior of a sequence of real numbers, Cauchy sequence, Cauchy's Convergence Criterion. (15 Classes)

Unit-2: Infinite series, convergence and divergence of infinite series, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Raabe's test, Gauss test, Cauchy condensation test, Integral test. Alternating series, Leibniz test. (8 Classes)

Unit – 3: ε - δ definition of limit of a real-valued function, Algebra of limits, Limit at infinity and infinite limits; Continuity of a real-valued function, Algebra of continuous functions, sequential criteria for continuity, Properties of continuous functions, Intermediate value theorem, Geometrical interpretation of continuity, Types of discontinuity; Uniform continuity. (12 Classes)

Unit-4: Differentiability of a real valued function, Geometrical interpretation of differentiability, Relation between differentiability and continuity, Chain rule of differentiation; Darboux's theorem, Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Geometrical interpretation of mean value theorems; Maclaurin's and Taylor's theorems for expansion of a function in an infinite series, Taylor's theorem in finite form with Lagrange and Cauchy forms of remainder. (15 Classes)

Unit-5: Complex numbers and their representations, algebra of complex numbers; Complex plane, Open set, Domain and region in complex plane; Stereographic projection and Riemann mapping; complex functions, limits & continuity. Differentiability of a complex valued function, Cauchy-Riemann equations, Harmonic functions, Analytic functions, necessary and sufficient conditions for analyticity. Transformations, Examples of isogonal and conformal transformations, some general transformations: translation, rotation, magnification, inversion; Bilinear transformation, fixed points of a bilinear transformation, cross ratio.(20 Classes)

Unit-6: Complex line integrals, Cauchy's theorem on line integral, evaluations of line integrals using Cauchy's integral formula. (5 Classes)

References:

1. S. Bandyopadhyay & B. Guhathakurta, Mathematical Analysis, Academic Publishers.
2. R. K. Ghosh & K. C. Maity, An Introduction to Analysis: Integral Calculus: Part II, New Central Book Agency (P) Ltd. Kolkata (India).
3. S. N. Mukhopadhyay & A. K. Layek, Mathematical Analysis Volume-I &II, U. N. Dhur & Sons Pvt. Ltd.
4. B. K. Kar (2013), An Introduction to Modern Analysis (Volume I &II), Books & Allied Ltd.
5. S. C. Malik and S. Arora, Mathematical Analysis, New Age International (P) Ltd publishers (3rd edition, 2009).
6. S. K. Mapa, Real Analysis, Sarat Book Distributors (5th edition, 2008).
7. Shanti Narayan & M. D. Raisinghania, Elements of Real Analysis, S. Chand & Company Ltd. (14th edition, 2013).
8. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
9. S. Goldberg, Calculus and mathematical analysis, 1989.
10. S. K. Mukherjee, First Course in Real Analysis, Academic Publishers.

11. Lars V. Ahlfors (2017). Complex Analysis (3rd edition). McGraw-Hill Education.
12. Joseph Bak & Donald J. Newman (2010). Complex Analysis (3rd edition). Springer.
13. James Ward Brown & Ruel V. Churchill (2009). Complex Variables and Applications(9th edition). McGraw-Hill Education.
14. John B. Conway (1973). Functions of One Complex Variable. Springer-Verlag.
15. E.T. Copson (1970). Introduction to Theory of Functions of Complex Variable. Oxford University Press.
16. Theodore W. Gamelin (2001). Complex Analysis. Springer-Verlag.
17. George Polya & Gordon Latta (1974). Complex Variables. Wiley.
18. H. A. Priestley (2003). Introduction to Complex Analysis. Oxford University Press.
19. S. Ponnuswamy, Foundations of Complex Analysis, Narosa.
20. S. Ponnuswamy & H. Silverman, Complex Variables with Applications, Birkhauser.
21. H.S. Kasana, Complex Variables, 2nd Edition, PHI. 2005,

SEMESTER-IV

MINOR COURSE-4

Course Name: Abstract Algebra and Linear Algebra-II

Course Code: BSCMTMMN401

Course Type: MINOR**(Theoretical)**	Course Details: **MNC-4**			L-T-P: 4-1-0	
Credit: 5	Full Marks: 100	CA		ESE	
		Practical	Theoretical	Practical	Theoretical
			30		70

Course Learning Outcomes:

After successful completion of this course, the students will be able to:

- Link the fundamental concepts of groups and symmetries of geometrical objects.
- Understand the concepts of different types of groups, rings and field.
- Extend their previous knowledge about matrices and different form of matrixes
- Explain the significance of the notions of normal subgroups and their properties.
- Understand the concepts of vector spaces, subspaces, bases, dimension and their properties
- Relate matrices and linear transformations, compute eigen values and eigen vectors of linear transformations.
- Find different polynomials associated with the matrix of linear transforms

Unit-1: Binary Compositions; Groupoid, Semigroups, Monoids, Groups: Examples & elementary Properties; Abelian group; Permutation groups; Finite groups: symmetric group, alternating group, Klein's 4-group, group of all n-th roots of unity; Examples of infinite groups; Order of an element, symmetry and dihedral groups. (15 Classes)

Unit-2: Subgroups: definitions, examples and elementary properties; Cyclic groups: definitions, examples and elementary properties; Normal Subgroups and their properties.
Rings: Definition, examples and elementary properties of rings, Commutative rings, Integral domain, Division rings and fields. (20 Classes)

Unit 3: Diagonalization of a matrix, Jordan canonical form, Normal form, Triangular form. (5 Classes)

Unit-4: Vector Spaces: Definition and examples, Subspace, Linear span, Linearly independent and dependent sets, Bases and dimension. (10 Classes)

Unit-5: Linear Transformations: Algebra of linear transformations, Matrix of a composite & inverse linear transformation, Change of coordinates, Rank and nullity of a linear transformation and rank-nullity theorem. Transpose of a linear transformation, Eigenvectors

and eigenvalues of a linear transformation, Characteristic polynomial and Cayley-Hamilton theorem, Minimal polynomial. (25 Classes)

References:

1. John B. Fraleigh (2007). A First Course in Abstract Algebra (7th edition). Pearson.
2. Joseph A. Gallian (2017). Contemporary Abstract Algebra (9th edition). Cengage.
3. M. K. Sen, S. Ghosh, P. Mukhopadhyay & S. K. Maity. Topics in Abstract Algebra. Universities Press.
4. S. K. Mapa. Higher Algebra: Abstract and Linear. Levant Books.
5. V. K. Khanna & S. K. Bhambri. A Course in Abstract Algebra. Vikash Publishing.
6. Stephen H. Friedberg, Arnold J. Insel & Lawrence E. Spence (2003). Linear Algebra (4thedition). Prentice-Hall of India Pvt. Ltd.
7. Serge Lang (2005). Introduction to Linear Algebra (2nd edition). Springer India.
8. Gilbert Strang (2014). Linear Algebra and its Applications (2nd edition). Elsevier.
9. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
10. Vivek Sahai & Vikas Bist (2013). Linear Algebra (2nd Edition). Narosa Publishing House.
11. Mapa, Higher Algebra(Abstract and linear), Sarat Book Distributors.
12. P. K. Nayak, Linear Algebra, Books & Allied (P) Ltd.
13. H. Anton & C. Rorres, Elementary Linear Algebra, Wiley, 2017.
14. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.

Pool of Multidisciplinary Courses offered by Mathematics Discipline

SEMESTER-I

MULTI DISCIPLINARY COURSE-1

Course Name: Business Mathematics
Course Code: MD113

Course Type: **MD (Theoretical)**		Course Details: **MDC-1**		L-T-P: 2-1-0	
Credit: 3	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		.....	15	**----**	35

Course Learning Outcomes*:* This course will enable the students to

- Learn the concepts of AP and GP Series, logarithm, Permutation & Combination and Set Theory
- Learn the concepts of Matrix and determinant.
- Understand the concepts of limit, continuity, differentiability and integration of functions.

Algebra

A.P. and G.P Series, Convergence and Divergence of G.P. series

Logarithms: Definition-Base and index of logarithm, general properties of logarithm.

Permutations: Definition, Factorial notation, Theorems on permutation - Permutations with repetitions, Restricted permutations, Combinations: Definition, Theorems on combination; Basic identities - Restricted combinations. Binomial Theorem: Statement of the theorem for positive integral index, General term, middle term, Equidistant terms – Simple properties of binomial coefficients.

Sets and subsets – set operations -Venn diagram – De Morgan's Law.

Definition of matrix – Different types of Matrix, Symmetric and skew symmetric matrices, Equality, Addition, Subtraction and Multiplication of matrices – Transpose of a matrix, Determinant of a square matrix (upto third order), properties of determinants – minors and co-factors – Inverse of a matrix. Solution of a system of simultaneous equations in 2 and 3 unknowns using Cramer's rule and matrix rule.

Differential and Integral Calculus

Function: Type, Domain (Trigonometric functions excluded). Limit of a function, Existence, Evaluation by factorization and rationalization, limit when $x \to \infty$, Standard limits (L'Hospital's rule excluded): $\lim_{x \to a} \frac{x^n - a^n}{x-a} = na^{n-1}$, $lim_{x \to 0} \frac{\log(1+x)}{x} = 1$, $\lim_{x \to 0} \frac{a^x - 1}{x} = \log_e a \ (a > 0)$, $\lim_{x \to 0} \frac{e^x - 1}{x} = 1$

Continuity of a function: Continuity at a point and in an interval, geometrical interpretation, Simple examples. Derivative of a function, Geometrical interpretation, Derivatives of composite and parametric functions, Logarithmic differentiation, Second order derivative, Convexity, concavity and point of inflexion, Maximum and minimum values of a function.

Function of several variables, Partial differentiation of simple algebraic functions, Homogeneous functions and their properties, Euler's theorem (without proof), The concept of total differential of a function, Differentiation of implicit function with the help of total differential.

Integration, Indefinite integration as the inverse process of differentiation, Illustration with integral of simple algebraic functions, Definite integral (for simple algebraic and exponential functions).

References:

1. R.G.D. Allen, *Mathematical Analysis for Economists*, Macmillan
2. S.N. Dey, *Business Mathematics and Statistics*, Chhaya Prakashani.
3. J. Chakrabarti, *Business Mathematics and Statistics*, Dey Book Concern.
4. V.K. Kapoor, *Essential Mathematics for Commerce and Economics*, Sultan Chand
5. K. C. Maity and R.K. Ghosh, *Calculus*, New Central Book Agency.
6. R. K. Ghosh and S. Saha, *Business Mathematics and Statistics*, New Central Book Agency.
7. N. K. Nag, *Advanced Business Mathematics and Statistics*, Kalyani Publishers.

SEMESTER-II

MULTI DISCIPLINARY COURSE-2

Course Name: Mathematical Science
Course Code: MD201

Course Type: **MD (Theoretical)**		Course Details: **MDC-2**		L-T-P: 2-1-0	
Credit: 3	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		.....	15	**----**	35

Course Learning Outcomes*:* This course will enable the students to

- Understand the concept of complex number and its algebra
- Understand the concept of two-dimension
- Learn the concepts of vector algebra
- Understand the solution methods of differential equations
- Understand the basic concepts on probability and statistics

Algebra

Complex numbers, Algebra of complex numbers, The modulus and the conjugate of a Complex number, Argand plane and polar representation, Cube roots of unity, De Moiver's theorem (statement only) and its elementary applications.

Permutations and combinations, Binomial theorem for positive integral indices.

Geometry in two-dimension

Sections of a Cone, Circle, Parabola, Ellipse, Hyperbola and basic information of these conic sections, general second degree equation and its Classification.

Differential Equations

Basic definitions, Formation, General, particular and singular solution, solution of first order and first degree differential equations, integrating factors, homogeneous, reducible to homogeneous, exact, linear differential equations.

Vector Algebra

Vectors and linear combinations, Vectors in three dimensions, Dot products, Lengths and unit vectors**,** The angle between two vectors, Cross product of vectors, Dependent and independent vectors, collinear and co-planar vectors.

Probability and Statistics

Events, Types of events, Sample space, Classical and axiomatic definition of probability, Total and compound probability - theories with examples, Conditional probability, Statistical independence, Baye's theorem, Random variables discrete and continuous probability, mass functions, and probability density function, Distribution function, Expectation of sum and product of independent random variables, Bernoulli theorem, Binomial, Poisson, Normal distribution.

Sampling, Sample, Random sample, Frequency distributions, graphical representations of it, Measures of location: Mean, Median, Quartiles, Mode for group and un-grouped frequency distributions.

References:

1. S.N. De, Mathematics, Chhaya Prakasani Pvt. Ltd.
2. A.P. Baisnab, B.N. Ghatak, Elements of Mathematics, Oriental Book Company Pvt. Ltd.

3. B. C. Das and B.N. Mukherjee, Integral Calculus-Differential Equations, U. N. Dhur and Sons Private Ltd.
4. J. G. Chakravorty & P. R. Ghosh, Advanced Higher Algebra, U. N. Dhur & Sons Pvt. Ltd.
5. J. G. Chakravorty & P. R. Ghosh, Vector Analysis.
6. N. G. Das, Statistical Methods, M. Das & CO., 2001.
7. A. M. Goon, M. K. Gupta, B. Dasgupta, Fundamentals of Statistics- II, World Press.

SEMESTER-III

MULTI DISCIPLINARY COURSE-3

Course Name: Indian Mathematics
Course Code: MD305

Course Type: **MD (Theoretical)**		Course Details: **MDC-3**		L-T-P: 2-1-0	
Credit: 3	Full Marks: 50	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		.....	15	**----**	35

Course Learning Outcomes*:* This course will enable the students to

- Understand the fastest calculations in arithmetic.
- learn some of the important mathematical results and techniques given by Indian mathematicians
- Understand the work of Ancient Indian mathematician in context

Unit-I: Multiplication: Ekadhiken Purven method (multiplication of two numbers of two digits, multiplication of two numbers of three digits), Urdhva Tiragbhyam method (multiplication of two numbers of three digits), Nikhilam Navtashchramam Dashtaha (multiplication of two numbers of three digits), Combined Operations.

Unit-2: Division and Divisibility:
Part A: Division: Nikhilam Navtashchramam Dashtaha (two digits divisor), Paravartya Yojyet method (three digit divisor)
Part B: Divisibility: Ekadhikenpurven method (two digits divisor), Eknunenpurven method (two digit divisor),

Unit-3: LCM and HCF

Unit-4: Power and Root:
Power: (i) Square (two-digit number), (ii) Cube (two-digit number).
Root: (i) Square root (four-digit number) (ii) Cube root (six-digit number)

Unit-5: Work of Indian Mathematicians in Arithmetic

1. Aryabhata
2. Brahmagupta

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6. Bharatiya Mathematicians, Sharda Sanskrit Sansthan, Varanasi.