VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE WITH MATHEMATICS (MULTIDISCIPLINARY STUDIES)

3-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

VIDYASAGAR UNIVERSITY

BACHELOR OF SCIENCE IN MATHEMATICAL & COMPUTER SCIENCES with MATHEMATICS

(*Under CCFUP, 2023*)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. in Math. Comp. Sc. with Mathematics	3rd	V	**SEMESTER-V**							
			Major-A4	**MATPMJ04**	**T: Numerical Methods; P:** Practical ***(To be studied by students taken* Mathematics *as Discipline- A)***	**4**	**3-0-1**	**15**	**60**	**75**
			Major-A5	**MATPMJ05**	**T: Multivariate Calculus** ***(To be studied by students taken* Mathematics *as Discipline- A)***	**4**	**3-1-0**	**15**	**60**	**75**
			Major-A6	**MATPMJ06**	**T: Probability and Statistics; P:** Practical ***(To be studied by students taken* Mathematics. *as Discipline- A)***	**4**	**3-1-0**	**15**	**60**	**75**
			Major (Elective) -2	**MATMJE-02**	Logic, Sets, and Graph Theory **Or** Number Theory **Or** Real Analysis ***(To be studied by students taken* Mathematics *as Discipline- A)***	**4**	**3-1-0**	**15**	**60**	**75**
			Minor-5 (Disc.-C5)	**MATMIN05**	**T: Multivariate Calculus** ***(To be studied by students taken* Mathematics *as Discipline- C)***	**4**	**3-1-0**	**15**	**60**	**75**
		Semester-V Total				**20**				**375**
		VI	**SEMESTER-VI**							
			Major-B4		***To be decided*** ***(Same as MajorA4 for* Mathematics. *taken as Discipline-B)***	**4**	**3-0-1**	**15**	**60**	**75**
			Major-B5		***To be decided*** ***(Same as Major–A5 for* Mathematics *taken as Discipline-B)***	**4**	**3-1-0**	**15**	**60**	**75**
			Major-B6		***To be decided*** ***(Same as Major–A6 for* Mathematics *taken as Discipline-B)***	**4**	**3-1-0**	**15**	**60**	**75**
			Major (Elective) -3	**MATMJE03**	Assignment Writing ***(To be studied by students taken* Mathematics *as Discipline- A)***	**4**	**0-0-4**	**15**	**60**	**75**
			Minor -6 (Disc.-C6)	**MATMIN06**	**T: Probability and Statistics** ***(To be studied by students taken* Mathematics *as Discipline- C)***	**4**	**3-1-0**	**15**	**60**	**75**
		Semester-VI Total				**20**				**375**
		TOTAL of YEAR-3				**40**	**-**	**-**	**-**	**700**
		Eligible to be awarded Bachelor of Science in Multidisciplinary Studies with Mathematics *on Exit*				**126**	**Marks (Year: I+II+III)**			**2325**

MJP = Major Programme (Multidisciplinary), MI = Minor, A/B = Choice of Major Discipline; C= Choice of Minor Discipline; CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical

MAJOR (MJ)

MJ A4/B4: Numerical Methods **Credits 04 (Full Marks: 75)**

MJ A4/B4T: Numerical Methods (Theory) **Credits 02** **[30L]**

Course contents:

Unit 1:
Algorithms. Convergence. Errors: relative, absolute. Round off. Truncation.

Unit 2
Transcendental and polynomial equations: Bisection method, Newton's method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.

Unit 3
System of linear algebraic equations: Gaussian elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method.

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 $1/3^{rd}$ rule, Composite trapezoidal rule, composite Simpson's $1/3^{rd}$ rule, Gauss quadrature formula.
The algebraic eigenvalue problem: Power method. Approximation: Least square polynomial approximation.

Unit 6
Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, and the Runge-Kutta methods of orders two and four.

Reference Books

1. Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
3. Computation, 6th Ed., New age International Publisher, India, 2007.
4. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
5. Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
6. John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
7. Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH Publishing Co.

8. Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
9. M. Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa, New Delhi, 2007.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand the fundamentals of numerical algorithms, including convergence, types of errors, and their impact on computational methods.
b) Solve transcendental and polynomial equations using numerical methods such as Bisection, Newton-Raphson, Secant, Regula - Falsi, and Fixed Point Iteration, and analyze their rate of convergence.
c) Apply numerical techniques like Gaussian elimination, Gauss-Jordan, Gauss-Seidel,to solve systems of linear algebraic equations, along with their convergence analysis.
d) Utilize interpolation techniques, including Lagrange and Newton's methods, finite difference operators, and numerical differentiation techniques based on interpolation and finite differences.
e) Perform numerical integration using Newton-Cotes formulas, Trapezoidal, Simpson's,, and apply least square polynomial approximation for solving algebraic eigenvalue problems.
f) Solve ordinary differential equations using numerical methods such as Euler's method, Modified Euler's method, and Runge-Kutta methods of different orders.

MJ A4/B4 P: Numerical Methods (Using MATLAB/C++ or any software) - Practical) Credits 02 (60hrs.)

List of practical:

1. Solution of transcendental and algebraic equations by
   a) Bisection method
   b) Newton Raphson method.
   c) Regula Falsi method.
2. Solution of system of linear equations
   a) Gaussian elimination method
   b) Gauss-Seidel method
3. Interpolation
   a) Lagrange Interpolation
   b) Newton Interpolation
4. Numerical Integration
   a) Trapezoidal Rule
   b) Simpson's one third rule
5. Fitting a Polynomial Function
6. Solution of ordinary differential equations
   a) Euler method
   b) Modified Euler method
   c) Runge Kutta method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Compute the sum of a harmonic series up to a given integer **N** using computational techniques.
b) Implement sorting algorithms to arrange an array of 100 integers in ascending order.
c) Solve transcendental and algebraic equations using numerical methods, including **Bisection, Newton-Raphson, Secant, and Regula-Falsi methods**.
d) Solve systems of linear equations using **LU decomposition, Gaussian elimination, Gauss-Jacobi, and Gauss-Seidel methods**.
e) Apply **Lagrange and Newton interpolation methods** to estimate values between data points.
f) Perform numerical integration using **Trapezoidal Rule, Simpson's One-Third Rule, Weddle's Rule, and Gauss Quadrature** for approximating definite integrals.
g) Determine eigenvalues of matrices using the **Power Method**.
h) Fit a polynomial function to given data points for approximation and curve fitting.
i) Solve ordinary differential equations using **Euler's method, Modified Euler's method, and Runge-Kutta methods** of different orders.

MJ A5/B5: Multivariate Calculus **Credits 04 (FM: 75)**

MJ A5/B5T: Multivariate Calculus **Credits 04 [60L]**

Course contents:

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 coordinates. Change of variables in double integrals and triple integrals.

Unit 3

Definition of vector field, divergence and curl.

Line integrals, applications of line integrals: 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, The Divergence theorem.

Reference Books

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
3. E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.
4. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
5. T. Apostol, Mathematical Analysis, Narosa Publishing House
6. Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
7. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
8. Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
9. Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
10. Terence Tao, Analysis II, Hindustan Book Agency, 2006
11. M.R. Speigel, Schaum's outline of Vector Analysis.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand functions of several variables, their limits, continuity, and differentiability, including total and partial derivatives.
b) Apply optimization techniques using **gradient, directional derivatives, and Lagrange multipliers** for constrained and unconstrained problems.
c) Evaluate **double and triple integrals** in Cartesian, polar, cylindrical, and spherical coordinates and apply them to compute areas and volumes.
d) Analyze vector fields by computing **divergence, curl, and line integrals**, and understand their physical significance.
e) Apply **Green's theorem, Stoke's theorem, and the Divergence theorem** to relate different integral forms in vector calculus.
f) Utilize multiple integration and vector calculus concepts in real-world applications involving physics and engineering.

MJ A6/B6: Probability and Statistics **Credits 04 (FM: 75)**

MJ A6/B6T: Probability and Statistics **Credits 04 [60L]**

Course contents:

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, 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

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, Markov chains, Chapman-Kolmogorov equations, classification of states.

Unit 4

Random Samples, Sampling Diatributions, Estimation of parameters, Testing of hypothesis.

Reference Books

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
2. Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
4. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007
5. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand fundamental probability concepts, including probability axioms, random variables, and probability distributions.
b) Analyze discrete and continuous probability distributions, including binomial, Poisson, normal, and exponential distributions.
c) Evaluate joint distributions, conditional expectations, and correlation coefficients, and apply regression analysis for two variables.

d) Apply statistical theorems such as **Chebyshev's inequality, laws of large numbers, and the central limit theorem** in real-world scenarios.
e) Understand the fundamentals of Markov chains, including **state classification and Chapman-Kolmogorov equations**.
f) Perform statistical inference through **sampling distributions, parameter estimation, and hypothesis testing**.

Major Elective

(To be studied by students taken Mathematics as Discipline- A)

Major Elective (MJE)-2

Credits 04 (FM: 75)

Elective 2A: Logic, Sets, and Graph Theory **Credits 04**

Unit 1

Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, quantifiers, binding variables and negations.

Unit 2

Difference and Symmetric difference of two sets. Set identities, generalized union and intersections. Relation: Product set. Composition of relations, types of relations, partitions, equivalence Relations with example of congruence modulo relation. Partial ordering relations, n- ary relations.

Unit 3

Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs isomorphism of graphs.

Unit 4

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 5

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

Reference Books

1. R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998.
2. P.R. Halmos, Naive Set Theory, Springer, 1974.
3. E. Kamke, Theory of Sets, Dover Publishers, 1950.
4. B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
5. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
6. Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
7. N. Deo, Graph Theory with Applications to Engineering & Computer Science, Prentice Hall India Learning Private Limited; New edition (1 January 1979).
8. D. B. West, Introduction to Graph Theory, Pearson. 2000.

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Understand and apply** propositional logic, truth tables, logical equivalences, predicates, and quantifiers to formulate and analyze logical statements.
b) **Demonstrate knowledge** of set operations, set identities, relations, equivalence relations, partial ordering relations, and their applications in mathematical structures.
c) **Analyze and interpret** different types of graphs, including pseudo graphs, complete graphs, bipartite graphs, and understand graph isomorphism.
d) **Apply graph theory concepts** to Eulerian and Hamiltonian circuits, adjacency and incidence matrices, and weighted graphs to solve real-world problems.
e) **Utilize algorithms** such as Dijkstra's and Warshall's to solve shortest path problems, spanning tree problems, and the Traveling Salesman Problem (TSP).

These outcomes will provide students with a solid foundation in discrete mathematics, essential for computer science, optimization, and theoretical research.

Elective 2B: Number Theory **Credits 04**

Unit 1

Linear diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues. Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.

Unit 2

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi- function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.

Unit 3

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation $x^2 + y^2 = z^2$, Fermat's Last theorem.

Reference Books

1. David M. Burton, Elementary Number Theory, 6th Ed., Tata McGraw- Hill, Indian reprint, 2007.
2. Neville Robinns, Beginning Number Theory, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Solve and analyze** linear Diophantine equations, linear congruences, and apply key theorems such as the Chinese Remainder Theorem, Fermat's Little Theorem, and Wilson's Theorem in number theory problems.
b) **Understand and compute** number-theoretic functions, including the sum and number of divisors, Dirichlet product, Möbius inversion formula, Euler's phi-function, and explore their fundamental properties.
c) **Apply modular arithmetic concepts** such as order of an integer modulo nn, primitive roots, and quadratic congruences using Euler's criterion, the Legendre symbol, and the quadratic reciprocity theorem.
d) **Explore cryptographic applications** of number theory, including RSA encryption and decryption, and analyze its security implications.
e) **Investigate classical number theory problems**, including the Prime Number Theorem, Goldbach's conjecture, and Fermat's Last Theorem, developing a deeper understanding of mathematical conjectures and proofs.

These outcomes provide students with essential problem-solving skills in number theory, preparing them for further research and applications in cryptography, computer science, and advanced mathematics.

Elective 2C: Real Analysis

Course contents:

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. The 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-Borel Theorem.

Unit 2:

Sequences, bounded sequence, convergent sequence, limit of a sequence, liminf, lim sup. Limit theorems. Monotone sequences, monotone convergence theorem. Subsequences, divergence criteria. Monotone subsequence theorem (statement only), Bolzano Weierstrass theorem for sequences. Cauchy sequenc, Cauchy's convergence criterion.

Unit 3:

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

Suggested Readings:

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. T. Apostol, Mathematical Analysis, Narosa Publishing House
6. Courant and John, Introduction to Calculus and Analysis, Vol I, Springer
7. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
8. Terence Tao, Analysis I, Hindustan Book Agency, 2006.
9. S. Goldberg, Calculus and mathematical analysis.

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Understand and analyze** the algebraic and order properties of real numbers, including the completeness and Archimedean properties, as well as the density of rational and irrational numbers in R\mathbb{R}.
b) **Apply fundamental concepts** of set topology in R\mathbb{R}, such as limit points, open and closed sets, compact sets, and the Heine-Borel Theorem, to solve real analysis problems.

c) **Examine and determine** the behavior of sequences, including bounded, monotone, and Cauchy sequences, and apply the Bolzano-Weierstrass Theorem and Cauchy's convergence criterion for analyzing sequence convergence.
d) **Evaluate and classify** the convergence and divergence of infinite series using various tests, such as the comparison test, ratio test, root test, and integral test.
e) **Differentiate between absolute and conditional convergence** and apply the alternating series test (Leibniz test) to study the nature of alternating series.

These outcomes equip students with a strong foundation in real analysis, preparing them for advanced mathematical studies and applications in research and problem-solving.

Major Elective (MJE)-3:

Elective 3A: Mechanics

Course contents:

Unit 1
Conditions of equilibrium of a particle and coplanar forces acting on a rigid body. Laws of friction, problems of equilibrium under forces including friction. Centre of gravity, work, and potential energy.

Unit 2
Velocity and acceleration of a particle along a curve: radial and transverse components (plane curve), tangential and normal components (space curve).

Unit 3
Newton's laws of motion, simple harmonic motion, simple pendulum, projectile motion.

Suggested Readings:

1. A.S. Ramsay, *Statics*, CBS Publishers and Distributors (Indian Reprint), 1998.
2. A.P. Roberts, *Statics and Dynamics with Background in Mathematics*, Cambridge University Press, 2003.
3. S. L. Loney. An elementary treaties on the dynamics of a particle and rigid body, New Age International Pvt. Ltd.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Analyze the equilibrium conditions of particles and rigid bodies under coplanar forces, including the effects of friction and potential energy.
b) Apply the laws of friction to solve real-world equilibrium problems and determine the center of gravity for various objects.
c) Understand and compute velocity and acceleration components along plane and space curves using radial, transverse, tangential, and normal components.
d) Apply Newton's laws of motion to solve problems in kinematics and dynamics, including simple harmonic motion and projectile motion.
e) Develop mathematical models for physical phenomena such as pendulum motion and projectile trajectory, enhancing problem-solving skills in mechanics.

Elective 3B: Mathematical Modeling

Course contents:

Unit 1

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 2

Monte Carlo simulation modelling: simulating deterministic behavior (area under a curve, volume under a surface), generating random numbers: middle square method, linear congruence, queuing models: harbor system, morning rush hour, Overview of optimization modelling. Linear programming model: geometric solution algebraic solution, simplex method, sensitivity analysis

Reference Books

1. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006.
2. Frank R. Giordano, Maurice D. Weir and William P. Fox, A First Course in Mathematical Modeling, Thomson Learning, London and New York, 2003.

Graphical demonstration as Teaching Aid using any software

1. Plotting of Legendre polynomial for n = 1 to 5 in the interval [0,1].
2. Verifying graphically that all the roots of $P_n(x)$ lie in the interval [0,1].
3. Automatic computation of coefficients in the series solution near ordinary points.
4. Plotting of the Bessel's function of first kind of order 0 to 3.
5. Automating the Frobenius Series Method.
6. Random number generation and then use it for one of the following (a) Simulate area under a curve (b) Simulate volume under a surface.
7. Programming of either one of the queuing model (a) Single server queue (e.g. Harbor system) (b) Multiple server queue (e.g. Rush hour).

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Solve differential equations** using power series methods, particularly for Bessel's and Legendre's equations, and apply Laplace transforms to initial value problems up to the second order.
b) **Understand and implement** Monte Carlo simulation techniques to model deterministic behavior and generate random numbers using methods such as the middle square and linear congruence methods.
c) **Analyze and develop** queuing models, including single-server (harbor system) and multiple-server (rush hour) models, to study real-world systems involving waiting lines.
d) **Formulate and solve** linear programming problems using graphical and simplex methods, and perform sensitivity analysis for optimization problems.

e) **Apply computational tools** to visualize mathematical concepts, including plotting Legendre polynomials, Bessel functions, and automating the Frobenius series method.
f) **Implement numerical simulations** for computing areas under curves, volumes under surfaces, and solving optimization problems using programming-based approaches.

These outcomes prepare students for advanced applications in mathematical modeling, optimization, and computational simulations.

Elective 3C: Ring theory & Linear Algebra -1

Course contents:

Unit 1

Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.

Unit 2

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

Unit 3

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

Unit 4

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

Reference Books

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra,4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
4. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
5. S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
6. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
7. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
8. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
9. D.A.R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
10. D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Understand fundamental concepts of rings and fields**, including subrings, integral domains, and the characteristic of a ring, and apply these concepts to construct examples and counterexamples.
b) **Analyze ideals and factor rings**, including operations on ideals, prime and maximal ideals, and the structure of quotient rings.

c) **Comprehend ring homomorphisms and their properties**, apply the three isomorphism theorems, and determine the field of quotients of an integral domain.
d) **Develop a strong foundation in vector spaces**, including subspaces, quotient spaces, linear span, and the basis-dimension theorem, and apply these to solve problems in linear algebra.
e) **Explore linear transformations**, including concepts of null space, range, rank, and nullity, and represent linear transformations using matrices.
f) **Apply isomorphism theorems in linear algebra**, understand invertibility, and perform changes of coordinate matrices in vector spaces.

These outcomes equip students with the essential theoretical and computational skills required for further studies in abstract algebra and linear algebra.

MINOR (MI)

(To be studied by students taken Mathematics as Discipline- C)

C5 / MI-5: Multivariate Calculus **Credits 04 (Full Marks: 75**

C5 / MI-5T: Multivariate Calculus **Credits 04**

Course contents:

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 coordinates. Change of variables in double integrals and triple integrals.

Unit 3

Definition of vector field, divergence and curl.

Line integrals, applications of line integrals: 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, The Divergence theorem.

Reference Books

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
3. E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.
4. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
5. T. Apostol, Mathematical Analysis, Narosa Publishing House
6. Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
7. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
8. Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
9. Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
10. Terence Tao, Analysis II, Hindustan Book Agency, 2006
11. M.R. Speigel, Schaum's outline of Vector Analysis.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand functions of several variables, their limits, continuity, and differentiability, including total and partial derivatives.
b) Apply optimization techniques using **gradient, directional derivatives, and Lagrange multipliers** for constrained and unconstrained problems.
c) Evaluate **double and triple integrals** in Cartesian, polar, cylindrical, and spherical coordinates and apply them to compute areas and volumes.
d) Analyze vector fields by computing **divergence, curl, and line integrals**, and understand their physical significance.
e) Apply **Green's theorem, Stoke's theorem, and the Divergence theorem** to relate different integral forms in vector calculus.
f) Utilize multiple integration and vector calculus concepts in real-world applications involving physics and engineering.

C6 / MI-6: Probability and Statistics **Credits 04 (Full Marks: 75**

C6 / MI-6T: Probability and Statistics **Credits 04**

Course contents:

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, 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
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, Markov chains, Chapman-Kolmogorov equations, classification of states.

Unit 4
Random Samples, Sampling Diatributions, Estimation of parameters, Testing of hypothesis.

Reference Books

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
2. Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
4. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007
5. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand fundamental probability concepts, including probability axioms, random variables, and probability distributions.
b) Analyze discrete and continuous probability distributions, including binomial, Poisson, normal, and exponential distributions.
c) Evaluate joint distributions, conditional expectations, and correlation coefficients, and apply regression analysis for two variables.

d) Apply statistical theorems such as **Chebyshev's inequality, laws of large numbers, and the central limit theorem** in real-world scenarios.
e) Understand the fundamentals of Markov chains, including **state classification and Chapman-Kolmogorov equations**.
f) Perform statistical inference through **sampling distributions, parameter estimation, and hypothesis testing**.