DEBRA THANA SAHID KSHUDIRAM SMRITI MAHAVIDYALAYA (AUTONOMOUS)

Gangaram Chak, Chak Shyampur, Paschim Midnapore,
West Bengal

PROPOSED CURRICULUM & SYLLABUS OF

BACHELOR OF SCIENCE (HONOURS) MAJOR IN MATHEMATICS

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 (HONOURS) MAJOR IN MATHEMATICS
(Under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	2nd	III	**SEMESTER-III**							
			Major-A2	MATHMJ03	T: Algebra	4	3-1-0	15	60	75
			Major-A3	MATHMJ04	T: Differential Equations and Vector Calculus	4	3-1-0	15	60	75
			SEC	MATSEC03	P: Object Oriented Programming in C++ /Introduction to Python programming (Practical)	3	0-0-3	10	40	50
			AEC	AEC03	Communicative English -2 (*common for all programmes*)	2	2-0-0	10	40	50
			MDC	MDC03	Multidisciplinary Course -3 (*to be chosen from the list*)	3	3-0-0	10	40	50
			Minor-C3 (Disc.-I)	MATMIN03	T: Differential Equations and Vector Calculus	4	3-1-0	15	60	75
					Semester-III Total	20				375
		IV	**SEMESTER-IV**							
			Major-B2	MATHMJ05	T: Algebra	4	3-1-0	15	60	75
			Major-B3	MATHMJ06	T: Differential Equations and Vector Calculus	4	3-1-0	15	60	75
			AEC	AEC04	MIL-2 (*common for all programmes*)	2	2-0-0	10	40	50
			Minor-C4	MATMNI04	T: Numerical Analysis	4	3-1-0	15	60	75
			Elective 1		Linear Programming / Partial Differential Equations & Applications / Group Theory-1	4	0-0-4	-	-	50
					Semester-IV Total	22				400
					TOTAL of YEAR-2	42				775

MJ = Major, MI = Minor Course, SEC = Skill Enhancement Course, AEC = Ability Enhancement Course, MDC = Multidisciplinary Course, CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical, MIL = Modern Indian Language

MAJOR (MJ)

Semester – 3 & 4

A2, B2: MJ-2: Algebra **Credits 04 (Full Marks: 75)**

A2, B2: MJ-2T: Algebra **Credits 04**

Course contents:

UNIT-1:

Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.

Theory of equations: Relation between roots and coefficients, transformation of equation, Descartes rule of signs, cubic and biquadratic equation.

Inequality: The inequality involving AM$\geq$ GM$\geq$ HM, Cauchy-Schwartz inequality.

UNIT-2:

Equivalence relations. Functions, composition of functions, Invertible functions, one-to-one correspondence and cardinality of a set. Well-ordering property of positive integers, division algorithm, divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical induction, statement of Fundamental Theorem of Arithmetic.

UNIT-3:

Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.

UNIT-4:

Definition of vector space of $R^{n:}$,–inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n, rank of a matrix, eigenvalues, eigenvectors and characteristic equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Marking scheme on question paper:

UNIT	Marks	QUESTION PATTERN	
		Mark of each question	Number of Question to be attempted
UNIT-I (Classical Algebra)	22	2 5 10	1 2 1
UNIT-II (Sets and Integers)	15	2 5	5 1

UNIT-III (System of Linear Functions)	9	2 5	2 1
UNIT-IV (Linear Transformation and Eigen Values)	14	2 10	2 1

Suggested Readings:

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

Course Outcomes (COs):

After completing this course, students will be able to:

a) Represent complex ns in polar form, apply De Moivre's theorem, and analyze the properties of polynomial equations, including root-coefficient relationships and transformations.
b) Apply fundamental inequalities, such as AM-GM-HM and Cauchy-Schwarz, to mathematical problems and proofs.
c) Understand equivalence relations, functions, and cardinality, and apply the division algorithm, Euclidean algorithm, and congruence relations in number theory.
d) Solve systems of linear equations using row reduction, echelon forms, and matrix methods, and apply them to real-world problems.
e) Analyze vector spaces, linear transformations, and matrix properties, including invertibility, subspaces, and rank.
f) Compute eigenvalues, eigenvectors, and characteristic equations, and apply the Cayley-Hamilton theorem to matrix operations.

A3, B3: MJ-3: Differential Equations & Vector Calculus Credits 04 (Full Marks:

75

A3, B3: MJ-3T: Differential Equations & Vector Calculus Credits 04

Course contents:

Unit 1

Lipschitz condition and Picard's Theorem (Statement only). The general solution of the homogeneous equation of second order, principle of superposition for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Unit 2

Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.

Unit 3

Equilibrium points, Interpretation of the phase plane, Power series solution of a differential equation about an ordinary point, solution about a regular singular point.

Unit 4

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

Marking scheme on question paper:

UNIT	*Marks*	*QUESTION PATTERN*	
		Mark of each question	***Number of Question to be attempted***
UNIT-I	***22***	***2*** ***5*** ***10***	***1*** ***2*** ***1***
UNIT-II	***13***	***2*** ***5***	***4*** ***1***
UNIT-III	***9***	***2*** ***5***	***2*** ***1***
UNIT-IV	***16***	***3*** ***10***	***3*** ***1***

Suggested Readings:

1. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case
2. Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
3. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
4. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
5. Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand the Lipschitz condition, Picard's Theorem, and the fundamental concepts of second-order differential equations, including the principle of superposition and Wronskian properties.
b) Solve linear homogeneous and non-homogeneous differential equations using methods such as undetermined coefficients and variation of parameters.
c) Analyze systems of linear differential equations, apply the operator method, and solve homogeneous linear systems with constant coefficients.
d) Interpret equilibrium points and phase plane analysis and apply power series methods to solve differential equations around ordinary and regular singular points.

e) Perform vector operations, understand vector functions, and compute their limits, derivatives, and integrals.
f) Demonstrate the graphical representation of solutions to second- and third-order differential equations to visualize their behavior.

MINOR (MI)

Semester – 3

C3: MJ-3: Differential Equations & Vector Calculus **Credits 04 (Full Marks:**

C3: MJ-3T: Differential Equations & Vector Calculus **Credits 04**

Course contents:

Unit 1
Lipschitz condition and Picard's Theorem (Statement only). The general solution of the homogeneous equation of second order, principle of superposition for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Unit 2
Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.

Unit 3
Equilibrium points, Interpretation of the phase plane, Power series solution of a differential equation about an ordinary point, solution about a regular singular point.

Unit 4
Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.

Marking scheme on question paper:

Suggested Readings:

6. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case
7. Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and

Francis group, London and New York, 2009.
8. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
9. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
10. Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.

Course Outcomes (COs):

After completing this course, students will be able to:

a) Understand the Lipschitz condition, Picard's Theorem, and the fundamental concepts of second-order differential equations, including the principle of superposition and Wronskian properties.
b) Solve linear homogeneous and non-homogeneous differential equations using methods such as undetermined coefficients and variation of parameters.
c) Analyze systems of linear differential equations, apply the operator method, and solve homogeneous linear systems with constant coefficients.
d) Interpret equilibrium points and phase plane analysis and apply power series methods to solve differential equations around ordinary and regular singular points.
e) Perform vector operations, understand vector functions, and compute their limits, derivatives, and integrals.
f) Demonstrate the graphical representation of solutions to second- and third-order differential equations to visualize their behavior.

Semester – 4

C4: MI-4: Numerical Methods **Credits 04 (Full Marks: 75)**

C4: MI-4T: Numerical Methods (Theory) **Credits 04**

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 and their convergence analysis. LU decomposition

Unit 4

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.

Numerical differentiation: Methods based on interpolations, methods based on finite differences.

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons 3/8th rule, Weddle's rule, Boole's Rule. midpoint rule, Composite trapezoidal rule, composite Simpson's $1/3^{rd}$ rule, Gauss quadrature formula.

The algebraic eigen value 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, Runge-Kutta methods of orders two and four.

Marking scheme on question paper:

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, 4^{th} 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, and LU decomposition 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, Weddle's, Boole's, and Gauss quadrature methods, 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.

SKILL ENHANCEMENT COURSE (SEC)

Semester – 3

SEC 3: Object-Oriented Programming in C++/Introduction to Python programming

[Students will opt for either Object Oriented Programming in C++ or Introduction to Python programming]

Credits 03

SEC3P: Object Oriented Programming in C++ (Practical) **Full Marks: 50**
Course Outline of Object-Oriented Programming in C++:

Unit 1
Programming paradigms, characteristics of object-oriented programming languages, brief history of C++, structure of C++ program, differences between C and C++, basic C++ operators, Comments, working with variables, enumeration, arrays and pointers.

Unit 2
Objects, classes, constructors and destructors, friend function, inline function, encapsulation, data abstraction, inheritance, polymorphism, dynamic binding, operator overloading, method overloading, overloading arithmetic operator and comparison operators.

Unit 3
Working with files. Template class in C++, copy constructor, subscript and function call operator, concept of namespace and exception handling.

Unit 4: Problems to be solved:

1. Generate a list of 50 random numbers between 1 and 100. Find the maximum and minimum values in the list. Calculate the mean and variance of the numbers.
2. Write a function to determine if a given integer is prime or not.
3. Implement the following sorting algorithms:

- Bubble Sort ○ Insertion Sort
- Selection Sort

4. Write a program to calculate the sum of the sine, cosine, or exponential series up to a given number of decimal places.
5. Write a function to check if a given square matrix is an identity matrix.
6. Calculate and print the sum of each row and each column of a given matrix.
7. Write a function that checks whether a given string is a palindrome.
8. Count and display the frequency of each word in a given string.
9. Write a function that removes duplicate characters from a given string.
10. Write a program to compare two strings lexicographically and check if they are equal.
11. Write a function to check if a substring exists in a given string.
12. Write a program to find the longest word in a given sentence.
13. Reverse each word in a given string but keep the original word order intact.
14. Write a program to count the number of vowels and consonants in a given string.
15. Write a program to generate Fibonacci sequence using overloading of ++ operator.
16. Write a class for complex numbers and use it to find the sum, difference, multiplication and division of complex numbers. Use operator overloading.
17. Write a class for matrices and use it to find the sum, difference and multiplication matrices. Use operator overloading.

Suggested Readings:

1. A. R. Venugopal, Rajkumar, and T. Ravishanker, Mastering C++, TMH, 1997.
2. S. B. Lippman and J. Lajoie, C++ Primer, 3rd Ed., Addison Wesley, 2000.
3. Bruce Eckel, Thinking in C++, 2nd Ed., President, Mindview Inc., Prentice Hall.
4. D. Parasons, Object Oriented Programming with C++, BPB Publication.
5. Bjarne Stroustrup, The C++ Programming Language, 3rd Ed., Addison Welsley. 6. E. Balaguruswami, Object Oriented Programming In C++, Tata McGraw Hill

7. Herbert Scildt, C++, The Complete Reference, Tata McGraw Hill.

SEC3P: Introduction to Python programming (Practical) (Practical) Full Marks: 50

Course Outline of Introduction to Python programming:

Unit 1:

Python interpreter as a calculator, variable types: int, float, complex, list, tuple, set, string, type() function, , basic mathematical operations, logical conditions (if, elif, else), loops (for, while), user defined functions,, lambda function, importing modules with math, c math, random, help and dir commands, name spaces-local and global.

Python scripts, I/O operations, opening and writing to files.

Unit 2:

List: reading, changing elements, slicing, concatenation, list comprehension. 2D list. range(), len(), sum(), min(), max(), append(), extend(), count(), index(), sort(), insert(), pop(), remove(), reverse().
Array: Difference between Python lists and arrays, array module, NumPy, Insertion, deletion, and modification.
Tuples: compare with lists, packing/unpacking.
Sets: update(), pop(), remove(), union, intersection, difference, symmetric difference.
Strings: single, double, triple quotes, len(). Indexing, slicing, concatenation, strip(), split), join(), find(), count(), replace(), matting with % operator
Dictionary: Make a dictionary, built-in functions, and dictionary methods. NumPy
library

Unit 3:
Matplotlib, basics of XY-plotting of function, exponential functions, trigonometric functions. Define a Python function, plot in a domain, bar chart, histograms, polar plots, pie plots, plot from data file, save, subplots, and multiple plots.

Unit 4: Problems to be solved:

1. Generate a List of Random Numbers:
    - Generate a list of 50 random numbers between 1 and 100.
    - Find the maximum and minimum values in the list. o Calculate the mean and variance of the numbers.
2. Prime Number Check: o Write a function to determine if a given integer is prime or not.
3. Sorting Algorithms:
    - Implement and compare the performance of the following sorting algorithms:
        - Bubble Sort
        - Insertion Sort
        - Selection Sort
4. Sum of Series (Trigonometric or Exponential Functions):
    - Write a program to calculate the sum of the sine, cosine, or exponential series up to a given number of decimal places. (Example: sin(x)\sin(x), cos(x)\cos(x), exe^x).
5. Matrix Operations using NumPy:
    - Perform matrix addition, multiplication, and find the inverse using NumPy.
6. Finding Determinant of a Matrix:
    - Use NumPy or implement your own logic to find the determinant of a square matrix.
7. Solving a System of Linear Equations:
    - Use the Gaussian elimination method or NumPy to solve a system of linear equations.
8. Checking Identity Matrix:
    - Write a function to check if a given square matrix is an identity matrix.
9. Sum of Each Row and Column of a Matrix:
    - Calculate and print the sum of each row and each column of a given matrix.
10. Matrix Rotation by 90 Degrees:
    - Write a program to rotate a matrix by 90 degrees clockwise.
11. Palindrome Check:
    - Write a function that checks whether a given string is a palindrome.
12. Word Frequency Counter in a String:

- Count and display the frequency of each word in a given string.

13. Removing Duplicates from a String:
    - Write a function that removes duplicate characters from a given string.
14. String Comparison:
    - Write a program to compare two strings lexicographically and check if they are equal.
15. Substring Search:
    - Write a function to check if a substring exists in a given string.
16. Longest Word in a Sentence:
    - Write a program to find the longest word in a given sentence.
17. Reverse Each Word in a String:
    - Reverse each word in a given string but keep the original word order intact.
18. Counting Vowels and Consonants in a String:
    - Write a program to count the number of vowels and consonants in a given string.
19. Plotting a Polynomial Function: ○ Plot a polynomial (or any transcendental) function. Identify the real roots by plotting.
20. Plotting Sine and Cosine Functions: ○ Plot the graphs of sine and cosine functions for $x \in [0,2\pi]$. Use different line styles, colors, and a legend.
21. Plotting $y = x$ and $y = \sqrt{x}$:
    - Plot the graphs of $y = x$ and $y = \sqrt{x}$ on the same figure for $x \in [0, 10]$. Use different colors and add a legend.
22. Bar Chart of Student Grades: ○ Create a bar chart to display the grades of five students in three subjects (Math, Science, and English). Label the axes and provide a title.
23. Market Share Pie Chart:
    - Represent the market share of five companies (A, B, C, D, E) as a pie chart. Use percentages and include labels for each slice.
24. Histogram of Exam Scores:
    - Generate random exam scores for 100 students between 0 and 100 and plot a histogram. Divide the scores into bins of size 10.

Suggested Readings:

1. M. Sundarrajan, Mani Deepak Choudhry, S. Jeevanandham, Akshya Jothi, Python Programming: Beginners Guide, 2024.
2. Dave Brueck. Stephen Tanner, Python 2.1 Bible, Hungry Minds, Inc, New York, 2001.
3. Abhijit Kar Gupta, Scientific Computing in Python, Techno World Computational Playsics, Mark Newman, Amazon Digital, 2022.
4. Ch Satyanarayana, M Radhika Mani and B N Jagadesh, *Programming, University Press, 2018.*
5. J.Elkner, C. Meyer, A Downey, Learning with Python- how to think like a computer scientist, Dreamtech Press, 2015.

ELECTIVE COURSES

Semester – 4

Elective 1A: Linear Programming **Credits 04**

Elective 1A: Linear Programming
Course contents:

Unit 1
Introduction to linear programming problem. Theory of simplex method, graphical solution, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method. Big-M method and their comparison.

Unit 2
Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.
Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Unit 3
Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure,linearprogramming solutionof games.
Marking scheme on question paper:

UNIT	Marks	QUESTION PATTERN	
		Mark of each question	Number of Question to be attempted
UNIT-I (Simplex Algorithm)	25	2 5 10	5 1 1
UNIT-II (Duality & Special LPP)	21	2 5 10	3 1 1
UNIT-III (Game Theory)	14	2 5	2 2

Reference Books

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.

3. Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006
4. G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Understand and apply** fundamental concepts of probability, including random variables, probability distributions, expectation, and moment-generating functions in real-world scenarios.
b) **Analyze joint distributions**, conditional expectations, and bivariate normal distributions, and apply regression and correlation techniques for statistical modeling.
c) **Apply key statistical theorems** such as Chebyshev's inequality, the Law of Large Numbers, and the Central Limit Theorem to analyze large data sets and Markov processes.
d) **Formulate and solve** linear programming problems using the graphical and simplex methods, and understand concepts of convexity, optimality, and artificial variables.
e) **Utilize duality theory** to interpret primal-dual relationships, solve transportation and assignment problems using optimization techniques, and apply Hungarian and Vogel's methods.
f) **Apply game theory principles** to solve two-person zero-sum games, analyze mixed strategies, and use linear programming techniques for game solutions.

Elective 1B: Partial Differential Equations & Applications
Course contents:

Unit 1
Partial differential equations – Basic concepts and definitions. Mathematical problems. First- order equations: classification, construction and geometrical interpretation. Method of characteristics for obtaining general solution of quasi linear equations. Canonical forms of first-order linear equations. Method of separation of variables for solving first order partial differential equations.

Unit 2
Derivation of heat equation, wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.

Unit 3
The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial boundary value problems. Semi-infinite string with a fixed end, semi-infinite string with a free end. Equations with non-homogeneous boundary conditions. Non-homogeneous wave equation. Method of separation of variables, solving the vibrating string problem. Solving the heat conduction problem
Marking scheme on question paper:

UNIT	Marks	QUESTION PATTERN	
		Mark of each question	Number of Question to be attempted
UNIT-I (1st order PDE)	13	2 5	4 1
UNIT-II (2nd order PDE)	12	2 10	1 1
UNIT-III (Applications of PDE)	15	5 10	1 1
UNIT-IV (Particle Dynamics)	20	2 5	5 2

Reference Books

1. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.
2. S.L. Ross, Differential equations, 3rd Ed., John Wiley and Sons, India, 2004.
3. Martha L Abell, James P Braselton, Differential equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
4. Sneddon, I. N., Elements of Partial Differential Equations, McGraw Hill.
5. Miller, F. H., Partial Differential Equations, John Wiley and Sons.
6. Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press.

Course Outcomes (COs):

After completing this course, students will be able to:

a) **Understand and classify** partial differential equations (PDEs), apply the method of characteristics for solving first-order quasi-linear PDEs, and utilize separation of variables for first-order PDEs.
b) **Derive and analyze** fundamental second-order PDEs, including the heat equation, wave equation, and Laplace equation, and classify them as hyperbolic, parabolic, or elliptic.
c) **Solve initial and boundary value problems** using the Cauchy problem, Cauchy-Kowalewskaya theorem, and separation of variables, and analyze wave and heat conduction problems.
d) **Apply concepts of central force and constrained motion** to model and solve problems in physics, including varying mass systems, ballistics, planetary motion, and Kepler's second law.

These outcomes ensure students gain a strong foundation in PDEs, their physical applications, and mathematical modeling techniques.

Elective 1C: Group Theory-1

Course contents:

Unit 1

Symmetries of a square, dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups.

Unit 2

Subgroups and examples of subgroups, centralizer, normalizer, centre of a group, product of two subgroups.

Unit 3

Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.

Unit 4

The external direct product of a finite number of groups **(definition and examples only)**, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups **(only statement)**.

Unit 5

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

Marking scheme on question paper:

UNIT	Marks	QUESTION PATTERN	
		Mark of each question	Number of Question to be attempted
UNIT-I	9	2 5	2 1
UNIT-II	14	2 5	2 2
UNIT-III	14	2 10	2 1
UNIT-IV	9	2 5	2 1
UNIT-V	14	2 10	2 1

Suggested Readings:

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
4. Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.
5. I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
6. 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 and analyze** the symmetries of geometric objects, dihedral groups, permutation groups, and quaternion groups, along with their fundamental properties.
b) **Identify and explore** subgroups, including centralizers, normalizers, centers, and the product of subgroups, to understand group structures.
c) **Classify and apply** properties of cyclic groups, permutation groups, alternating groups, and cosets, and utilize Lagrange's theorem with its consequences, including Fermat's Little theorem.
d) **Demonstrate knowledge** of external direct products, normal subgroups, factor groups, and fundamental results such as Cauchy's theorem for finite abelian groups.
e) **Apply group homomorphisms and isomorphisms**, verify Cayley's theorem, and utilize the first, second, and third isomorphism theorems to analyze group structures.

These outcomes help students build a strong foundation in group theory, essential for higher mathematics and applications in various fields.