PERIYAR UNIVERSITY
PERIYAR PALKALAI NAGAR
SALEM – 636 011

REGULATIONS AND SYLLABUS
M.Sc. Branch – I (B): Mathematics
(For candidates admitted from 2026-27 onwards)
(SEMESTER PATTERN)
(Under Choice Based Credit System)

(For the Department of Mathematics at Periyar University & Periyar University Centre for Post Graduate and Research Studies, Dharmapuri)

CONTENTS

1.1 About the Department

The Department of Mathematics is one of the departments functioning from the inception of Periyar University in the year 1997. The department offers programmes of study and research leading to M.Sc. and Ph.D. degrees and is on a relentless march towards academic excellence. Based on the contributions towards research, the University Grants Commission (UGC) has granted funds under the Special Assistance Programme (SAP), the Department of Science and Technology (DST) has granted Funds for the Improvement of S & T Infrastructure (FIST), and NBHM-DAE has been supporting the library grant to this department.

1.2 About the Programme

This programme is designed with courses included from both pure, and applied mathematics. The curriculum has been designed to meet the current demands of applicable and industrial mathematics with the essence of basic mathematics courses. To make it more aligned with the latest education policy and give diverge opportunities to the students, variety of elective courses, skill-development courses, value-added courses, internship and extension activities have been included.

1.3 Salient Features

(i) In-depth theoretical background and training for pursuing higher studies and research in both pure and applied mathematics.

(i) Create a platform for higher studies and research in mathematical computing and interdisciplinary areas.

(iii) Prepare students to qualify various national and international level competitive examinations.

1.4 Aims and Objectives of the Programme

(i) Sound knowledge in the mathematics discipline that lead to excellence in the art of teaching.

(ii) Nurtures a prospective student into research and makes them industry-ready.

(iii) To assist our students in securing positions or assignments in both national and international institutions.

1.5 Duration of the Programme

The two-year postgraduate programme in Mathematics consists of four semesters under Choice Based Credit System (CBCS).

1.6 Eligibility

Candidates passed the B.Sc. Degree Examination in Mathematics and Mathematics with Computer Applications (CA) of this university or an examination of some other university accepted by the syndicate as equivalent are eligible to apply for the M.Sc. Mathematics programme.

1.7 Curriculum Highlights

The curriculum aims to equip students with a comprehensive theoretical foundation and training in both pure and applied mathematics. In particular, the diverse spectrum of open electives enables a student to develop a career of his/her choice, either in academia or industry. Moreover, a student becomes competent enough to take on challenges in mathematics at the national and international institutions.

It is aimed to structure the curriculum as student-oriented, skill-based, and institution-industry-interaction curriculum with the various courses under ”Outcome-Based Education with Problem-Based, Project-Based, and Industry Aligned Programmes” having revised Bloom's Taxonomy for evaluating students skills based on the following domains:

(i) Cognitive Domain
K1: Remembering; K2: Understanding; K3: Applying;
K4: Analysing; K5: Evaluating; K6: Creating

(ii) Affective Domain

(iii) Psychomotor Domain

1.8 Commencement of this Regulation

These regulations shall take effect from the academic year **2026-27**, that is, for students who are admitted to the first year of the programme during the academic year 2026-27 and thereafter.

Learning Outcomes

Programme Outcomes (POs):
At the time of graduation, students will be able to

PO1 gain knowledge in the fundamental subjects of pure and applied mathematics.

PO2 explain the mathematical concepts with good understanding and clarity.

PO3 conduct research independently with strong mathematics background.

PO4 crack lectureship/fellowship exams like CSIR-NET, GATE, NBHM, SET, TRB etc.

PO5 apply the acquired mathematical techniques to solve the socio-economic and industrial problems.

PO6 obtain a career in the field of education/ research/ industry.

Programme Educational Outcomes (PEOs)

1. **Core Competence in Mathematical Theories and Applications**
   Graduates will acquire an in-depth understanding of advanced mathematical concepts, theories and methods. They will be able to apply these concepts effectively in various fields to solve industrial/real life problems.

2. **Technical Proficiency and Computational Skills**
   Graduates will gain proficiency in using advanced mathematical software, tools, and programming languages that are essential for modelling, simulation, and solving complex mathematical problems in both industry and academic research.

3. **Preparation for Advanced Careers**
   Graduates will be well-prepared to pursue advanced careers in academia, research, industry, or government organizations that require high-level mathematical expertise.

4. **Research and Analytical Skills**
   Graduates will develop strong analytical, critical, and problem solving skills that enable them to conduct independent research in mathematics. They will be proficient in identifying, formulating, and solving complex mathematical problems.

Programme Specific Outcomes (PSOs)

PSO1 Acquire sound knowledge to solve specific theoretical & applied problems in different areas of mathematics & statistics.

PSO2 Understand, formulate, develop mathematical arguments, logically and use quantitative models to address issues arising in social sciences, business and other related context/fields.

PSO3 To prepare the students to demonstrate respectful engagement with other's ideas, behaviors, and beliefs and apply diverse frames of references to take decisions and actions.

3. STRUCTURE OF THE PROGRAMME

S.No	Course Code	Course	Credits	Marks
SEMESTER – I (25)				
1	26UPMAT1C01	Algebra I	5	100
2	26UPMAT1C02	Real Analysis I	5	100
3	26UPMAT1C03	Ordinary Differential Equations	5	100
4	26UPMAT1C04	Number Theory	5	100
5	–	Elective Course I	3	100
6	–	Skill Enhancement Course I	2	–
SEMESTER – II (22)				
5	26UPMAT1C05	Linear Algebra	5	100
8	26UPMAT1C06	Real Analysis II	5	100
9	26UPMAT1C07	Partial Differential Equations	5	100
10	26UPMAT1L01	**Data Analytics with Python**	3	100
11	–	NME I from NPTEL/SWAYAM	2	100
12	26UPPGC1H01	Fundamentals of Human Rights	2	100
SEMESTER – III (24)				
13	26UPMAT1C08	Algebra II	5	100
14	26UPMAT1C09	Measure Theory and Integration	5	100
15	26UPMAT1C10	Topology	5	100
16	–	Elective Course II	3	100
17	–	NME II from other dept.	2	100
18	26UPGEN1V01	Peace Education	2	100
19	26UPMAT1I01	Summer Internship	2	–
SEMESTER – IV (25)				
20	26UPMAT1C11	Functional Analysis	5	100
21	26UPMAT1C12	Complex Analysis	5	100
22	26UPMAT1C13	Methods of Applied Mathematics	5	100
23	26UPMAT1P01	Project	4	100
24	–	Elective Course III	3	100
25	–	Skill Enhancement Course II	2	–
26	–	Extension Activities	1	–
Total			**94+2**	**2200**

3.1 Elective Courses Offered

S.No.	Course Code	Course Title	Credits
1.	26UPMAT1E01	Classical Dynamics	3
2.	26UPMAT1E02	Graph Theory and Applications	3
3.	26UPMAT1E03	Linear Programming	3
4.	26UPMAT1E04	Fuzzy Sets and Their Applications	3
5.	26UPMAT1E05	Discrete Mathematics	3
6.	26UPMAT1E06	Mathematical Foundations for Data Science	3
6.	26UPMAT1E07	Mathematical Modelling	3
8.	26UPMAT1E08	Combinatorial Mathematics	3
9.	26UPMAT1E09	Difference Equations	3
10.	26UPMAT1E10	Machine Learning and Artificial Intelligence	3
11.	26UPMAT1E11	Mathematical Biology	3
12.	26UPMAT1E12	Fractional Calculus	3
13.	26UPMAT1E13	Nonlinear Differential Equations	3
14.	26UPMAT1E14	Stochastic Differential Equations	3
15.	26UPMAT1E15	Control Theory	3
16.	26UPMAT1E16	Differential Geometry	3
17.	26UPMAT1E17	Advanced Partial Differential Equations	3
18.	26UPMAT1E18	Mathematical Finance	3
19.	26UPMAT1E19	Fluid Dynamics	3
20.	26UPMAT1E21	Probability Theory	3
21.	26UPMAT1E22	Numerical Analysis	3

3.2 Computer Laboratory Course

S.No.	Course Code	Course Title	Credits
1.	26UPMAT1L01	Data Analytics with Python	3

3.3 Non Major Elective Courses (NME)

NME courses are divided into two categories:

- **NME-I:** Swayam/ MOOC/ NPTEL online course with 2 credits.
- **NME-II:** Chosen from courses offered by other departments.

3.4 Non Major Elective (NME) Courses for Other Departments

Students from other Departments may choose any one of the following as Non Major Elective Courses.

S.No.	Course Code	Course Title	Credits
1.	26UPMAT1N01	Numerical and Statistical Methods	2
2.	26UPMAT1N02	Mathematics for AI	2

3.5 Skill Enhancement Courses (SEC)

SECs are to be chosen so as to keep in pace with the latest developments in the academic/industrial front and provide flexibility of choice by the stakeholders/institutions.

S.No.	Course Code	Course Title	Credits
1.	26UPMAT1S01	Numerical Linear Algebra using SAGEMATH	2
2.	26UPMAT1S02	Computational Mathematics using MATLAB	2
3.	26UPMAT1S03	Technical Writing using LaTeX	2
4.	26UPMAT1S04	Data Analysis using R Programming	2
5.	26UPMAT1S05	Mathematical Computing using Python	2

The result of examinations conducted shall be **commended (or) highly commended** and the same shall be communicated to the office of the Controller of Examinations.

3.5 Value Added Courses (VAC)

1. Peace education will be offered as compulsory value added course with 2 extra credits in the third semester.

2. One value added course with 2 extra credits shall be offered from the following list:

S.No.	Course Code	Course Title	Credits
1.	26UPMAT1V01	Mathematica (LAB)	2
2.	26UPMAT1V02	MatLab (LAB)	2

3.6 Summer Internship Programme

Every student shall undergo a summer internship programme during summer vacation at the end of the first year for a minimum period of two weeks. The students should get the attendance certificate from the head/mentor of the training institute/industry. Following the training, the student is required to submit a report to the department, detailing the training they have received. The departmental committee shall evaluate and conduct a viva-voce examination during the third semester. The result of such viva-voce shall be **commended (or) highly commended** and the same shall be communicated to the office of the Controller of Examinations for including the same in the third semester mark statement. The internship training will not receive any marks, but completion of the training is mandatory to receive the degree.

6. EXAMINATION

Internal Assessment

Theory Course: For the purpose of uniformity, particularly for interdepartmental transfer of credits, there shall be a uniform pattern of examination to be adopted by all the teachers offering courses. There shall be three tests, one seminar, and one assignments for internal assessment and end-semester examination at the end of each semester.

The distribution of marks for internal assessment and end semester examinations shall be 25 marks and 75 marks, respectively. Further, distribution of internal marks shall be 10 marks for the test, 5 marks for the seminar, 5 marks for the assignment, and 5 marks for attendance, respectively. The best mark out of the first two internal tests (5 marks) and model examination (5 marks) shall be taken as internal test mark (10 marks).

Internal marks corresponding to attendance percentage

65.00 % to 74.99 % = 2

75.00 % to 84.99 % = 3

85.00 % to 94.99 % = 4

95% and above = 5

Computer Laboratory Courses:

The assessment procedure for practical courses is as follows:

Internal Assessment	**Marks**	**External Assessment**	**Marks**
Periodical Assessment	20	Practical	40
Test (Best 2/3)	10	Viva-voce	10
Record	10	Record	10
Total	40	**Total**	60

An external practical examination of 3 hours duration shall be conducted for 60 marks.

7. QUESTION PAPER PATTERN FOR SEMESTER EXAMINATIONS

a) **Question Paper Pattern for Theory Examination**

Intended Learning Skills	Examination Pattern
Memory Recall/Example/ Counter example / Knowledge about about the concepts/ understanding	**Part – A (20 × 1 = 20 Marks)** Answer ALL questions Questions 1 to 20 Each Question carries 1 mark (Four objective type questions from each Unit)
Descriptions / Application (Problems only)	**Part – B (3 × 5 = 15 Marks)** Answer any three questions out of five questions Questions 21 to 25 (One question should be taken from each Unit)
Analysis/ Synthesis/ Evaluation	**Part-C (5 × 8 = 40 Marks)** Answer all the questions Each question carries 8 Marks Question 25(a) or 25(b) to Question 30(a) or 30(b) (Either or type one pair from each unit)

Each question should carry the course outcome and cognitive level. For instance,

1. Question xxxx [CO1 : K2]
2. Question xxxx [CO3 : K1]

(b) **Question paper pattern for Practical Examination**

Time: 3 Hours   Maximum: 100 (Internal: 40 + External: 60) Marks

Passing Minimum : 30 Marks (Aggregate of Practical, Viva-voce and Record) (No passing minimum for records)

The practical examination will consist of two out of three questions, either with or without subsections. The examiner(s) should select each question from the prepared question bank.

8. PASSING MINIMUM

Passing the minimum in the end semester examination shall be 50% out of 75 marks (i.e., 38 marks). There shall be no passing minimum for internal marks.

A candidate who has secured a minimum of 50% marks in all the courses (including practical) prescribed in the programme and earned a minimum of 96 credits will be considered to qualify for the Master's programme.

For the practical paper, a minimum of 30 marks out of 60 marks in the university examination and marks for the record notebook taken together is necessary for getting a pass mark. There is no passing minimum for the record notebook. However, submission of the record notebook is mandatory.

For the project work and viva voce, a candidate should secure 50% of the marks for a pass. The candidate should attend the viva-voce examination to secure a pass in the project.

9. PROJECT AND EDUCATIONAL TOUR

For M.Sc. Mathematics students, individual project is compulsory. To choose their topics/titles for the project, the students may like to visit the libraries at the universities/IITs//IMSc etc. So, the Department of Mathematics may arrange an educational tour either at the end of the III semester or at the beginning of the IV semester for the students to visit the libraries.

1. (a) **Dissertation:** The topic of the project shall be assigned to the candidate at the beginning of the third semester.

2. (b) **No. of copies of Project:** Students should prepare two copies of project and submit the same for the evaluation by Examiners. After evaluation and completion of viva-voce examination, one copy shall be retained by the Department Library and one with the student.

3. **(c) Format for the preparation of the project:**

   (a) Title page

   (b) Bonafide certificate

   (c) Acknowledgement

   (d) Table of contents

Chapter	**Title**	**Page No.**
1.	Introduction	
2.	Review of Literature	
3.	Summary	
4.	Results	
5.	References	

TITLE OF THE DISSERTATION

Dissertation report submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE
IN
MATHEMATICS

Submitted by

NAME

Reg. No:

Under the guidance of

GUIDE NAME

DESIGNATION

logo.jpeg

DEPARTMENT OF MATHEMATICS

PERIYAR UNIVERSITY

SALEM 636 011, TAMIL NADU

MONTH & YEAR

CERTIFICATE

This to certify that the dissertation entitled **"TITLE OF THE DISSERTATION"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Mathematics** to the Periyar University, Salem is a bonafide record of the dissertation work carried out by **NAME (Reg. No.)** under my supervision and guidance in the academic year **YEAR** and that no part of the dissertation has been submitted for the award of any degree, diploma, fellowship or other similar titles to any university.

Date : **Signature of the Guide**

Place :

Signature of the

Head of the Department **External Examiner**

DECLARATION

I, **NAME (Reg. No.)**, hereby declare that the dissertation entitled **"TITLE OF THE DISSERTATION"** submitted to the Periyar University, Salem in partial fulfillment of the requirements for the award of the degree of **Master of Science in Mathematics**, is a bonafide record of the dissertation work done by me during the academic year **YEAR** under the guidance of **GUIDE NAME, Designation**, Department of Mathematics, Periyar University, Salem.

Date : **Signature of the Candidate**

Place :

Course Code	Course Title	L	T	P	C
26UPMAT1C01	**ALGEBRA - I**	**4**	**1**	**0**	**5**

OBJECTIVE: The objectives of this course are to

- recall the fundamental concepts of group theory, including subgroups, cyclic groups, normal subgroups and quotient groups
- develop an understanding of group homomorphisms, automorphisms and permutation groups
- apply counting techniques such as the class equation and Sylow theorems to analyze finite groups
- understand direct products and the structure theorem for finite abelian groups
- strengthen student's ability to construct rigorous proofs and solve abstract algebraic problems

UNIT I:
Subgroups – A Counting Principle.
Chapter 2: Sections 2.4 – 2.5

UNIT II:
Normal Subgroups and Quotient Groups – Homomorphisms.
Chapter 2: Sections 2.6 – 2.7

UNIT III:
Automorphisms – Cayley's Theorem – Permutation Groups.
Chapter 2: Sections 2.8 – 2.10

UNIT IV:
Another Counting Principle – Sylow's Theorem.
Chapter 2: Sections 2.11 – 2.12

UNIT V:
Direct Products – Finite Abelian Groups.
Chapter 2: Sections 2.13 – 2.14

TEXT BOOK:
I.N. Herstein, *Topics in Algebra*, Second Edition, Wiley India Pvt. Ltd., New Delhi, 2009.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. M.Artin, *Algebra*, Prentice Hall of India, 1991.
2. P.B.Bhattacharya, S.K.Jain and S.R.Nagpaul, *Basic Abstract Algebra, (II Edition)*, Cambridge University Press, 1997.(Indian Edition)
3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, John Wiley and Sons, New Delhi, 2011.
4. J.B.Fraleigh, *A First Course in Abstract Algebra*, Addison Wesley, Mass, 1982.
5. J. A. Gallian, *Contemporary Abstract Algebra*, 7th Edition, Brooks/Cole-Cengage Learning, USA, 2010.
6. V.K.Khanna and S.K.Bhambri, *A Course in Abstract Algebra*, Vikas Publishing House Pvt. Ltd, 1993.
7. D.S. Malik, J.N. Mordeson and M.K. Sen, *Fundamental of Abstract Algebra*, McGraw Hill (International Edition), New York, 1997.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Define and analyze subgroups of a given group and apply Lagrange's theorem and related counting principles to finite groups.	K1, K3, K4
CLO 2	Identify normal subgroups, understand quotient groups, and analyze group homomorphisms and their kernels and images.	K1, K2, K4
CLO 3	Describe automorphisms, apply Cayley's theorem to represent groups as permutation groups, and associate cycle notation in permutation groups.	K2, K3, K4
CLO 4	Define conjugate classes, apply the class equation and Sylow theorems to determine the structure and properties of finite groups.	K1, K3, K4
CLO 5	Understand internal and external direct products, relate Sylow subgroups in studying the structure of finite abelian groups and to determine the number of nonisomorphic abelian groups of given order.	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	1	3	3	2	1
CLO2	3	3	3	3	1	3	3	2	1
CLO3	3	3	3	3	1	3	3	2	1
CLO4	3	3	3	3	1	3	3	2	1
CLO5	3	3	3	3	1	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C02	**REAL ANALYSIS - I**	**4**	**1**	**0**	**5**

OBJECTIVE: This course aims to provide the fundamental concepts of derivatives, functions of bounded variation, the Riemann-Stieltjes integral, and the convergence of series and products.

UNIT I: Derivatives

Definition of derivative - Derivatives and continuity - Algebra of derivatives - The chain rule - One-sided derivatives and infinitely derivatives - Functions with nonzero derivative - Zero derivatives and local extrema - Rolle's theorem - The mean-value theorem for derivatives - Taylor's formula with remainder - Derivatives of vector-valued functions - Partial derivatives

Chapters 5: Sections 5.1 - 5.14

UNIT II: Functions of Bounded Variation

Introduction - Properties of monotonic functions - Functions of bounded variation - Total variation - Additive property of total variation - Total variation on [a, x] as a function of x - Functions of bounded variation expressed as the difference of two increasing functions - Continuous functions of bounded variation.

Infinite Series: Absolute and conditional convergence - Dirichlet's test and Abel's test - Rearrangement of series - Riemann's theorem on conditionally convergent series.

Chapters 6 & 8: Sections 6.1-6.8, 8.8, 8.15, 8.17, 8.18

UNIT III: The Riemann-Stieltjes Integral

The definition of the Riemann-Stieltjes (RS) integral – Linear properties – Integration by parts – Change of variable in a RS integral – Step function as integrators – Reduction of a RS integral to a Riemann Integral – Euler's summation formula – Monotonically increasing integrators, Upper and lower integrals – Additive and linearity properties of upper, lower integrals – Riemann's condition - Comparison theorems.

Chapter 7: Sections 7.1-7.14

UNIT IV: The Riemann-Stieltjes Integral

Integrators of bounded variation-Sufficient conditions for the existence of RS integrals-Necessary conditions for the existence of RS integrals- Mean value theorems -integrals as a function of the interval – Second fundamental theorem of integral calculus-Change of variable – Second Mean Value Theorem for Riemann integral – RS integrals depending on a parameter – Differentiation under integral sign – Lebesgue criterion for existence of Riemann integrals.

Chapter 7: Sections 7.15 - 7.24, 7.26

UNIT V: Infinite Series and Infinite Products

Double sequences – Double series – Rearrangement theorem for double series – A sufficient condition for equality of iterated series – Multiplication of series – Cesaro summability – Infinite products. Power series – Multiplication of power series – The Taylor's series generated by a function – Bernstein's theorem – Abel's limit theorem – Tauber's theorem.

Chapters 8 & 9: Sections 8.20-8.26 & Sections 9.14, 9.15, 9.19, 9.20, 9.22, 9.23

TEXT BOOK:

Tom M. Apostol, *Mathematical Analysis,* Second Edition, Addison-Wesley Publishing Company, New York, 1974

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Ajith Kumar and S. Kumeresan, Basic Course in Real Analysis, CRC Press, 2014.
2. S. Arora and B. Lal, Introduction to Real Analysis, Sathya Prakashan, New Delhi, 1991.
3. R.G. Bartle and D.R.Sherbert, Introduction to Real Analysis, Fourth Edition, John Wiley and Sons Inc., 1976.
4. S.C. Malik and S. Arora. Mathematical Analysis, Wiley Eastern Limited, New Delhi, 1991.
5. B.R. Gelbaum and J. Olmsted, Counter Examples in Analysis, Holden day, San Francisco, 1964.
6. A.L. Gupta and N.R. Gupta, Principles of Real Analysis, Pearson Education (Indian print), 2003.
7. W. Rudin, Principles of Mathematical Analysis, 3rd Edition. McGraw Hill Company, New York, 1976.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Recall the concepts of derivatives and partial derivatives	K1, K2
CLO 2	Identify functions of bounded variation and analyze the convergence of the series	K1, K4
CLO 3	Classify Riemann-Stieltjes integrable functions and apply the fundamental theorem of calculus	K2, K3
CLO 4	Explain the rearrangement of terms of a double series	K2, K3
CLO 5	Examine the convergence of a double series and compute the Taylor series and power series for given functions.	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	2	3	3	2	1
CLO2	3	3	3	3	2	3	3	1	1
CLO3	3	3	3	3	2	3	3	1	1
CLO4	3	3	3	3	2	3	3	2	1
CLO5	3	3	3	3	2	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C03	**ORDINARY DIFFERENTIAL EQUATIONS**	**4**	**1**	**0**	**5**

OBJECTIVE: This course aims to develop a strong background in solving differential equations with constant and variable coefficients, including those involving singular points, and to study the existence and uniqueness of solutions to first-order differential equations.

UNIT I: Linear Equations with Constant Coefficients

The second order homogeneous equation – Initial value problems for second order equations – Linear dependence and independence – A formula for Wronskian.

Chapter 2 of [1]: Section 1-5

UNIT II: Linear Equations with Constant Coefficients

The non-homogeneous equation of order two – The homogeneous equation of order n – A special method for solving the non-homogeneous equation. Linear Equations with Variable Coefficients: Reduction of the order of a homogeneous equation – The Legendre Equation.

Chapter 2 of [1]: Section 6,7,11 and Chapter 3 of [1]: Section 5,8

UNIT III: Linear Equations with Regular Singular Points

The Euler equation – Second order equations with regular singular points – The Bessel Equation – The Bessel Equation (continued).

Chapter 4 of [1]: Section 2,3,7,8

UNIT IV: Existence and Uniqueness of Solutions to First Order Equations

Equations with variables separated – Exact equations – The method of successive approximations – The Lipschitz condition – Convergence of the successive approximations

Chapter 5 of [1]: Section 2-6

UNIT V: Boundary Value Problems

Sturm-Liouville problem – Green's functions.

Chapter 7 of [2]: Section 7.2, 7.3

REFERENCES:

1. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall of India, New Delhi, 2011.

2. S. G. Deo, V. Lakshmikantham and V. Raghavendra, Textbook of Ordinary Differential Equations, Tata McGraw-Hill, New Delhi, 1997.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. M.W. Hirsch, S. Smale, R.L. Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos, Third edition, Academic Press, 2013.

2. A. K. Nandakumaran, P.S. Satti and Raju K. George, Ordinary Differential Equations: Principles and Applications, Cambridge University Press, 2017.

3. W.T. Reid. Ordinary Differential Equations, John Wiley and Sons, New York, 1971.

4. B. Rai, D.P.Choudary and H.I. Freedman, A Course in Ordinary Differential Equations, Narosa Publishing House, New Delhi, 2002.

5. M.D. Raisinghania, Advanced Differential Equations, S.Chand & Company Ltd. New Delhi 2001.

6. S.L. Ross, Differential Equation, Fourth Edition, Wiley & Sons, 1984.

7. G.F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw Hill, New Delhi, 1974.

8. G.F. Simmons & S.G. Krantz, Differential Equations: Theory, Technique, and Practice, Tata McGraw Hill, 2012.

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	2	3	3	2	1
CLO2	3	3	3	3	3	3	3	2	1
CLO3	3	3	3	3	3	3	3	2	1
CLO4	2	3	3	3	3	3	3	2	1
CLO5	2	3	3	3	3	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C04	**NUMBER THEORY**	**4**	**1**	**0**	**5**

OBJECTIVE: The aim of this course is to teach the students about the basics of elementary number theory starting with primes, congruences, quadratic residues, primitive roots, arithmetic functions and some Diophantine equations.

UNIT I: Divisibility and Congruences

Divisibility – Primes – Congruences – Solutions of Congruences.

Chapter 1 & 2 : Sections 1.2, 1.3, 2.1, 2.2

UNIT II: Congruences

The Chinese Remainder Theorem – Prime Power Moduli – Prime Modulus – Primitive Roots and Power Residues – Congruences of Degree Two, Prime Modulus.

Chapter 2 : Sections 2.3, 2.6 – 2.9

UNIT III: Quadratic Reciprocity and Quadratic Forms

Quadratic Residues – Quadratic Reciprocity – The Jacobi Symbol – Sums of Two Squares.

Chapter 3 : Sections 3.1 – 3.3, 3.6

UNIT IV: Some Functions of Number Theory

Greatest Integer Function – Arithmetic Functions – The Mobius Inversion Formula.

Chapter 4 : Sections 4.1 – 4.3

UNIT V: Some Diophantine Equations

The Equation ax + by = c – Simultaneous Linear Equations – Pythagorean Triangles.

Chapter 5 : Sections 5.1 – 5.3

TEXT BOOK:

I. Niven, H. S. Zuckerman and H. L. Montgomery, *An Introduction to the Theory of Numbers,* 5th Edition, John Wiley & Sons, Inc., New York, 2004.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. D.M. Burton, *Elementary Number Theory*, Universal Book Stall, New Delhi, 2001.
2. K. Ireland and M. Rosen, *A Classical Introduction to Modern Number Theory*, Springer Verlag, New York, 1972.
3. T.M. Apostol, *Introduction to Analytic Number Theory*, Narosa Publ. House, Chennai, 1980.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Find quotients and remainders from integer division. Apply Euclid's algorithm and backwards substitution.	K1
CLO 2	Understand the definitions of congruences, residue classes and least residues. Add and subtract integers, modulo n, multiply integers and calculate powers, modulo n.	K3
CLO 3	Analyze the Euler's function, applications of Euler's function algebraic structures and its behavior.	K3
CLO 4	Evaluate the quadratic residues, Legendre symbols and solve its problems.	K4
CLO 5	Solve certain types of Diophantine equations.	K3

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	1	1	1	1	2	2	1
CLO2	3	3	1	1	1	1	2	2	1
CLO3	2	2	2	1	2	1	2	2	1
CLO4	2	3	2	1	2	2	2	2	1
CLO5	2	3	2	1	1	2	2	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C05	**LINEAR ALGEBRA**	**4**	**1**	**0**	**5**

OBJECTIVE: The objective of this course is to develop a strong foundation in Linear Algebra, which provides a basis for advanced studies not only in Mathematics but also in other disciplines such as Engineering, Physics, and Computer Science. Particular emphasis is given to the study of canonical forms of linear transformations.

UNIT I:

Vector spaces – Subspaces – Linear Combinations and Systems of Linear Equations – Linear Dependence and Linear Independence – Bases and Dimension.

Chapter 1: Sections 1.2 – 1.6

UNIT II:

Linear Transformations, Null Spaces, and Ranges – The Matrix Representation of a Linear Transformation – Composition of Linear Transformations and Matrix Multiplication – Invertibility and Isomorphisms.

Chapter 2: Sections 2.1 – 2.4

UNIT III:

The Change of Coordinate Matrix – Dual Spaces – Elementary Matrix Operations and Elementary Matrices – The Rank of a Matrix and Matrix Inverses.

Chapter 2: Sections 2.5 – 2.6 & *Chapter 3: Sections 3.1 – 3.2*

UNIT IV:

Eigenvalues and Eigenvectors – Diagonalizability – Invariant Subspaces and the Cayley Hamilton Theorem.

Chapter 5: Sections 5.1 – 5.2, 5.4

UNIT V:

The Jordan Canonical Form I – The Jordan Canonical Form II – The Minimal Polynomial.

Chapter 7: Sections 7.1 – 7.3

TEXT BOOK:

S.H. Friedberg, A.J. Insel and L.E. Spence, *Linear Algebra,* 4th Edition, Prentice-Hall of India Pvt. Ltd., 2009

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. S. Axler, *Linear Algebra Done Right*, Third Edition, Undergraduate Texts in Mathematics, Springer International Publishing, 2015.

2. I.N. Herstein, *Topics in Algebra*, Second Edition, Wiley India Pvt. Ltd., New Delhi, 2009.

3. K. M. Hoffman and R. Kunze, *Linear Algebra*, 2nd Edition, Prentice-Hall of India Pvt. Ltd., New Delhi, 2013.

4. V. Krishnamurthy, V.P. Mainra, and J.L. Arora, *Introduction to Linear Algebra*, East West Press Ltd., 1985.

5. S. Kumaresan, *Linear Algebra: A Geometric Approach*, Prentice-Hall of India Ltd., 2004.

6. G. Strang, *Introduction to Linear Algebra*, 2nd Edition, Prentice Hall of India Pvt. Ltd., 2013.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Define the basic concepts of vector spaces, illustrate concepts such as linear independence, basis and dimension through examples, and solve related problems.	K1, K2, K3
CLO 2	Define linear transformations, determine their null spaces and ranges, compute the matrix of linear transformations, and understand the algebra of linear transformations and isomorphisms.	K1, K2, K3, K4
CLO 3	Understand the concepts of change of basis and dual spaces, apply elementary matrix operations, and determine the rank of a matrix.	K2, K3, K4
CLO 4	Define and compute eigenvalues and eigenvectors, determine diagonalizability, and apply the Cayley–Hamilton Theorem.	K1, K3, K4
CLO 5	Describe and compute the Jordan Canonical Form of linear operators and matrices, and determine minimal polynomials.	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	3	3	3	2	1
CLO2	3	3	3	3	3	3	3	2	1
CLO3	3	3	3	3	3	3	3	2	1
CLO4	3	3	3	3	3	3	3	2	1
CLO5	3	3	3	3	3	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C06	**REAL ANALYSIS - II**	**4**	**1**	**0**	**5**

OBJECTIVE: This course aims to provide a strong foundation in Fourier series and multivariable calculus. It covers the representation of functions using Fourier series, differentiation and integration of functions of several variables, and the study of maxima and minima of multivariable functions with their applications.

UNIT I: Sequences of functions

Pointwise convergence of sequences of functions – Examples of sequences of real – valued functions – Uniform convergence and continuity – Cauchy condition for uniform convergence – Uniform convergence of infinite series of functions – Riemann - Stieltjes integration – Nonuniformly convergent sequences and term-by-term integration – Uniform convergence and differentiation – Sufficient condition for uniform convergence of a series – Mean convergence.

Chapter 9: Sections 9.1-9.6, 9.8-9.11, 9.13

UNIT II: Fourier series and Fourier integrals

Introduction - Orthogonal system of functions – The theorem on best approximation – The Fourier series of a function relative to an orthonormal system – Properties of Fourier Coefficients – The Riesz-Fischer Theorem – The convergence and representation problems for trigonometric series – The Riemann – Lebesgue Lemma – The Dirichlet Integrals – An integral representation for the partial sums of Fourier series – Riemann's localization theorem – Sufficient conditions for convergence of a Fourier series – Cesaro summability of Fourier series – Consequences of Fejes's theorem – The Weierstrass approximation theorem

Chapter 11: Chapter 11: Sections 11.1 to 11.15

UNIT III: Multivariable Differential Calculus

The Directional derivative – Directional derivative and continuity – The total derivative – The total derivative expressed in terms of partial derivatives – An application to complex-valued functions – The matrix of linear function – The Jacobian matrix – Exercises

Chapter 12: Sections 12.1-12.8

UNIT IV: Multivariable Differential Calculus (Cont...)

The chain rule – Matrix form of chain rule – The mean – value theorem for differentiable functions – A sufficient condition for differentiability – A sufficient condition for equality of mixed partial derivatives – Taylor's theorem for functions of Rn to R1 - Exercises

Chapter 12: Sections 12.9-12.14

UNIT V: Implicit Functions and Extremum Problems

Functions with non-zero Jacobian determinants – The inverse function theorem – The Implicit function theorem – Extrema of real valued functions of several variables – Extremum problems with side conditions.

Chapter 13: Sections 13.1-13.7

TEXT BOOK:

Tom M. Apostol, *Mathematical Analysis,* Second Edition, Addison-Wesley Publishing Company, New York, 1974.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. R. Ghorpade and B.V. Limaye, A Course in Multivariable Calculus and Analysis, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 2010.
2. J.H. Hubbard and Busbar Burke Hubbard, Vector Calculus, Linear Algebra and Differential Forms: A Unified Approach, 5th Edition, Matrix Editions Publisher, 2015.
3. L.H. Loomis and S. Sternberg, Advanced Calculus, Revised Edition, Jones and Bartlett Publisher, Inc. Boston, MA 02116, 1990.
4. H. Rogers. Jr, Multivariable Calculus with Vectors, Prentice Hall, New Jersey, 1998.
5. W. Rudin, Principles of Mathematical Analysis, 3rd Edition. McGraw Hill Company, New York, 1976.
6. M. Spivak, Calculus on Manifolds, Addison-Wesley Publishing Company, 1973.
7. J. Stewart, Multivariable Calculus, Cengage Learning Publisher, 2016.
8. J.R.L. Webb, Functions of Several Real Variables, Ellis Horwood, Chichester, 1991.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Examine the uniform convergence of a sequence of functions and employ the properties to limit function with respect to continuity, differentiability and integrability.	K1, K2
CLO 2	Construct a given function in terms of Fourier series	K1, K3
CLO 3	Compute partial derivatives of functions, implicit functions and the function defined by parametric equations.	K2, K3, K4
CLO 4	Prove the n-dimensional analogue of the fundamental theorem of calculus	K1, K2, K5
CLO 5	Evaluate the local extrema of multivariable functions.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	2	3	3	2	1
CLO2	3	3	3	3	2	3	3	1	1
CLO3	3	3	3	3	2	3	3	1	1
CLO4	3	3	3	3	2	3	3	2	1
CLO5	3	3	3	3	2	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C07	**PARTIAL DIFFERENTIAL EQUATIONS**	**4**	**1**	**0**	**5**

OBJECTIVE: The objective of this course is to enable the students to understand the concepts related to the solution of partial differential equations arising in various fields.

UNIT I: Partial differential equations of first order

Formation of partial differential equation - Solution of partial differential equations of first order - The Cauchy's Problem for First-Order - First-order non-linear equations: Cauchy's method of characteristics - Compatible systems of first order equations - Charpit's method: Special types of first order equations.

Chapter 0: Sections - 0.4, 0.5, 0.7, 0.9 - 0.11

UNIT II: Partial differential equations of second order

Classification of second order PDE - Canonical forms - Linear partial differential equations with constant coefficients - Homogeneous linear PDE with constant coefficients.

Chapter 1: Sections - 1.2, 1.3, 1.6, 1.7

UNIT III: Elliptic Differential Equations

Occurrence of the Laplace and Poisson equations - Boundary value problems - Properties of harmonic functions - Separation of variables - Dirichlet and Neumann problems for a rectangle - Interior and Exterior Dirichlet problems for a circle - Interior Neumann problem for a circle - Solution of Laplace equation in cylindrical and spherical coordinates.

Chapter 2: Sections - 2.1, 2.2, 2.4, 2.5 - 2.12

UNIT IV: Parabolic Differential Equations

Occurrence of the diffusion equation - Boundary conditions - Elementary solutions of the diffusion equation - Separation of variables - Solution of diffusion equation in cylindrical coordinates - Solution of diffusion equation in spherical coordinates - Maximum-minimum principle.

Chapter 3: Sections 3.1 - 3.8

UNIT V: Hyperbolic Differential Equations

Occurrence of the Wave Equation - Derivation of one-dimensional wave equation- Solutions of one-dimensional wave equation by canonical reduction - The initial value problem; D'Alembert's solution - Vibrating string: variables separable solution - Forced vibrations - Solution of non-homogenous equations - Duhamel's principle.

Chapter 4: Sections 4.1 - 4.6, 4.12

TEXT BOOK:

K. Sankar Rao, *Introduction to Partial Differential Equations,* Third Edition, Prentice Hall of India, New Delhi, 2004.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. I. N. Sneddon, Elements of Partial Differential Equations, Dover, Singapore, 2006.
2. T. Amarnath, An Elementary Course in Partial Differential Equations, Alpha Science International Ltd., Second Edition, 2003.
3. A. K. Nandakumaran and P.S. Datti, Partial Differential Equations: Classical Theory with a Modern Approach, Cambridge University Press, 2020.
4. M. D. Raisinghania, Advanced Differential Equations, S. Chand & Company Ltd., New Delhi, 2001.
5. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Brikhauser, Boston, 2007.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the fundamental concepts of partial differential equations of first order and second order.	K1, K2
CLO 2	Classify second order PDE and solve standard PDE using separation of variable method.	K2, K3
CLO 3	Learn various methods to solve first linear and non linear partial differential equations	K2, K3
CLO 4	Derive solutions to Laplace equations, heat, and wave equations and investigate their properties	K2, K3
CLO 5	Solve various real life problems by formulating them into partial differential equations.	K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	1	3	3	2	3	3	2	1
CLO2	2	1	3	3	2	3	3	2	1
CLO3	3	2	3	3	2	3	3	2	1
CLO4	1	2	3	3	2	3	3	2	1
CLO5	3	1	3	3	2	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C08	**ALGEBRA - II**	**4**	**1**	**0**	**5**

OBJECTIVE: The objectives of this course are to

- introduce the structure and properties of Euclidean rings and their role in divisibility theory.
- develop an understanding of polynomial rings over fields and commutative rings.
- study field extensions, algebraic elements, and roots of polynomials.
- explore the fundamental ideas of Galois theory and their applications to polynomial equations.
- analyze finite fields and understand the structure of finite division rings through Wedderburn's Theorem.

UNIT I:
Euclidean Rings – A Particular Euclidean Ring.
Chapter 3: Sections 3.7 – 3.8

UNIT II:
Polynomial Rings – Polynomials over the Rational Field – Polynomial Rings over Commutative Rings.
Chapter 3: Sections 3.9 – 3.11

UNIT III:
Extension Fields – Roots of Polynomials.
Chapter 5: Sections 5.1 and 5.3

UNIT IV:
More about Roots – The Elements of Galois Theory.
Chapter 5: Sections 5.5 – 5.6

UNIT V:
Finite Fields – Wedderburn's Theorem on Finite Division Rings.
Chapter 7: Sections 7.1 – 7.2

TEXT BOOK:
I.N. Herstein, *Topics in Algebra*, Second Edition, Wiley India Pvt. Ltd., New Delhi, 2009

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. M.Artin, *Algebra*, Prentice Hall of India, 1991.
2. P.B.Bhattacharya, S.K.Jain and S.R.Nagpaul, *Basic Abstract Algebra, (II Edition)*, Cambridge University Press, 1997.(Indian Edition)
3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, John Wiley and Sons, New Delhi, 2011.
4. J.B.Fraleigh, *A First Course in Abstract Algebra*, Addison Wesley, Mass, 1982.
5. J. A. Gallian, *Contemporary Abstract Algebra*, 7th Edition, Brooks/Cole-Cengage Learning, USA, 2010.
6. V.K.Khanna and S.K.Bhambri, *A Course in Abstract Algebra*, Vikas Publishing House Pvt. Ltd, 1993.
7. D.S. Malik, J.N. Mordeson and M.K. Sen, *Fundamental of Abstract Algebra*, McGraw Hill (International Edition), New York, 1997.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Identify the characteristics of Euclidean rings, describe the structure of the ring of Gaussian integers, and to apply the Euclidean algorithm to determine greatest common divisors and factorization properties.	K1, K2, K3
CLO 2	Define and explain polynomial rings over fields and commutative rings, apply Eisenstein's criterion and determine irreducibility of polynomials.	K1, K2, K3, K4
CLO 3	Describe field extensions, compute degrees of extensions, and identify roots and splitting fields of polynomials.	K1, K2, K3
CLO 4	Predict the existence of multiple roots of irreducible polynomials, determine the fixed field by Galois group, and to understand the concept of fundamental theorem of Galois theory.	K2, K3, K4
CLO 5	Determine all possible finite fields with their properties, apply the nature of finite fields to prove the existence of certain equations and explain the significance of Wedderburn's Theorem.	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	1	3	3	2	1
CLO2	3	3	3	3	1	3	3	2	1
CLO3	3	3	3	3	1	3	3	2	1
CLO4	3	3	3	3	1	3	3	2	1
CLO5	3	3	3	3	1	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C09	**MEASURE THEORY AND INTEGRATION**	**4**	**1**	**0**	**5**

OBJECTIVE: The objectives of this course are

- To gain understanding of the abstract measure theory and main properties of the Lebesgue integral.
- To make the students acquire basic knowledge of measure theory needed to understand probability theory, statistics and functional analysis.
- To get ability to differentiate and integrate the Lebesgue integral.

UNIT I: Lebesgue Measure
Introduction – Outer measure – Measurable sets and Lebesgue measure – Measurable functions – Littlewood's three principles
Chapter 3: Sections 1 - 3, 5 & 6

UNIT II: Lebesgue integral
The Riemann integral – Lebesgue integral of bounded functions over a set of finite measure – The integral of a nonnegative function – The general Lebesgue integral
Chapter 4: Sections 1 - 4

UNIT III: Differentiation and Integration
Differentiation of monotone functions – Functions of bounded variation – Differentiation of an integral – Absolute continuity
Chapter 5: Sections 1 - 4

UNIT IV: General Measure and Integration
Measure spaces – Measurable functions – Integration – General convergence theorems – Signed Measure – The Radon- Nikodym theorem
Chapter 11: Sections 1 - 6

UNIT V: Measure and Outer Measure
Outer measure and measurability – The Extension theorem – Product measures.
Chapter 12: Sections 1, 2, 4

TEXT BOOK:
H.L. Royden, *Real Analysis,* Third Edition, Macmillan Publishing Company, New York, 1988

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. S. Axler, Measure, Integration & Real Analysis, Springer, 2019.
2. Robert G. Bartle, The Elements of Integration and Lebesgue Measure, 2nd Edition, Wiley-Blackwell, 1995.
3. G. de Barra, Measure Theory and Integration, 2nd Edition, Horwood, Publishing, 2003.
4. S. Kumaresan and Dharmatti Sheetal, A Course In Lebesgue Measure & Integration, Techno World, 2026.
5. W.Rudin, Real and Complex Analysis, 3rd Edition, Tata McGraw-Hill Education, New Delhi, 2013.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Know the meaning of outer and inner measures with their basic properties and know the meaning with examples of algebras, sigma-algebras, measurable sets, measurable space and measure space.	K1, K2
CLO 2	Understand the concept of Lebesgue integration both on the general measure space and the real line and know the basic theory of integration and convergence, with the application in evaluating integrals.	K2, K3
CLO 3	Develop the concepts of Differentiation of monotone functions, Functions of bounded variation, Differentiation of an integral, Absolute continuity	K4, K6
CLO 4	Study the Radon-Nikodym theorem and its applications. Understand the concepts of Convergence in Measure and Lebesgue Integrability	K4, K3
CLO 5	Demonstrate understanding of the statements of the main results on integration on product spaces and an ability to apply these in examples.	K2, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	2	3	3	2	1	3	3	2
CLO2	3	2	2	3	2	1	3	2	2
CLO3	3	2	2	3	2	1	3	2	2
CLO4	3	3	2	1	2	1	3	2	2
CLO5	3	3	2	1	1	1	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C10	**TOPOLOGY**	**4**	**1**	**0**	**5**

OBJECTIVE: The objective of this course is to study topological spaces, continuous functions, connectedness, compactness, countability and separation axioms.

UNIT I:
Topological Spaces – Basis for a Topology – The Order Topology – The Product Topology on $X \times Y$ – The Subspace Topology – Closed Sets and Limit Points.
Chapter 2: Sections 12 – 17

UNIT II:
Continuous Functions – The Product Topology – The Metric topology.
Chapter 2: Sections 18 – 21

UNIT III:
Connected Spaces – Connected Subspaces of the Real Line – Components and Local Connectedness.
Chapter 3: Sections 23 – 25

UNIT IV:
Compact Spaces – Compact Subspaces of the Real Line – Limit Point Compactness – Local Compactness.
Chapter 3: Sections 26 – 29

UNIT V:
The Countability Axioms – The Separation Axioms – Normal spaces – The Urysohn Lemma – The Tietz Extension Theorem.
Chapter 4: Sections 30 – 33, 35

TEXT BOOK:
James R. Munkres, *Topology,* Second Edition, Prentice Hall of India, New Delhi, 2011

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. J. Dugundji, *Topology*, Prentice Hall of India, New Delhi, 1975.
2. S. Kumaresan and V. Aithal, *Topology*, First Edition, Techno World, 2023.
3. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill Book Co., 1963.
4. L. Steen and J. Subhash, *Counter Examples in Topology*, Holt, Rinehart and Winston, New York, 1970.

5. S. Willard, *General Topology*, Addison - Wesley, Mass., 1970.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Define what a topological space is, understand the concepts like open sets, closed sets, limit points, and classify different topologies.	K1, K2, K3
CLO 2	List equivalent definitions for continuous functions, explain the ways of constructing new continuous functions and to examine the metrizability of various topological spaces.	K1, K2, K4
CLO 3	Define connected spaces, examine the connectedness and understand the concepts of path connectedness and local connectedness.	K1, K2, K4
CLO 4	Define compact spaces, examine the compactness, construct new compact spaces from existing ones, analyze compact subspaces of the real line and relate different versions of compactness.	K1, K3, K4
CLO 5	Explain and analyze the countability and separation axioms, and apply Urysohn Lemma to prove the Tietz extension theorem	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	1	3	3	2	1
CLO2	3	3	3	3	1	3	3	2	1
CLO3	3	3	3	3	1	3	3	2	1
CLO4	3	3	3	3	1	3	3	2	1
CLO5	3	3	3	3	1	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C11	**FUNCTIONAL ANALYSIS**	**4**	**1**	**0**	**5**

OBJECTIVE: The objective of this course is to provide students with a strong foundation in functional analysis, focusing on spaces, operators and fundamental theorems and to develop student's skills and confidence in mathematical analysis and proof techniques.

UNIT I: Banach Spaces

The definition and some examples – Continuous linear transformations – The Hahn-Banach theorem – The natural imbedding of N in N^{**} – The open mapping theorem – The conjugate of an operator.

Chapter 9: Sections 46-51

UNIT II: Hilbert Spaces

The definition and some simple properties – Orthogonal complements – Ortho normal sets – The conjugate space H^{*}

Chapter 10: Sections 52-55

UNIT III: Hilbert Spaces (Contd...)

The adjoint of an operator – Self-adjoint operators – Normal and unitary operators – Projections

Chapter 10: Sections 56-59

UNIT IV: Finite-Dimensional Spectral Theory

Matrices – Determinants and the spectrum of an operator – The spectral theorem.

Chapter 11: Sections 60-62

UNIT V: General Preliminaries on Banach Algebras

The definition and some examples – Regular and singular elements – Topological divisors of zero – The spectrum – The formula for the spectral radius – Radical and semi simplicity.

Chapter 12: Sections 64-69

TEXT BOOK:

G.F. Simmons, *Introduction to Topology and Modern Analysis,* McGraw Hill Education (India) Private Limited, New Delhi, 1983

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. C. Goffman and G. Pedrick, First course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.
2. S. Kesavan, Functional Analysis, Springer, Singapore, 2023.
3. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
4. S. Kumaresan and D. Sukumar, Functional Analysis: A First Course, Narosa Publishing House, 2020.
5. B.V. Limaye, Functional Analysis, New Age International, 1996.
6. . W. Rudin, Functional Analysis, McGraw Hill Education (India) Private Limited, New Delhi, 1973.
7. M. Thamban Nair, Functional Analysis, A First course, Prentice Hall of India, New Delhi, 2002.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the Banach spaces and Transformations on Banach Spaces	K2, K3, K4
CLO 2	Prove Hahn Banach theorem and open mapping theorem.	K3, K4, K5
CLO 3	Describe operators and fundamental theorems	K3, K4, K5
CLO 4	Validate orthogonal and orthonormal sets	K3, K4
CLO 5	Analyze and establish the regular and singular elements and obtain a formula for spectral radius	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	1	3	3	3	3	3	2	1
CLO2	2	1	3	3	3	3	3	2	1
CLO3	3	2	3	3	3	3	3	2	1
CLO4	1	2	3	1	3	3	3	2	1
CLO5	3	1	3	1	3	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C12	**COMPLEX ANALYSIS**	**4**	**1**	**0**	**5**

OBJECTIVE: The objectives of this course are:

- To know the algebraic and topological properties of complex numbers.
- To provide understanding of the analytic functions of a complex variable and their role in modern mathematics.
- To demonstrate ability to think knowledge of integration in complex analysis.

UNIT I: Complex Functions

The spherical representation of complex numbers – Introduction to the concept of analytic functions – Limits and Continuity – Lucas's theorem – Elementary theory of power series – Abel's limit theorem – The Exponential and Trigonometric functions.

Chapter 1: Section 2.4; Chapter 2: Sections 1–3

UNIT II: Analytic Functions as Mappings

Conformality – Arcs and closed curves – Conformal Mapping – Linear transformations – The cross ratio – Symmetry – Oriented circle – Families of circles – Elementary conformal mappings.

Chapter 3: Sections 2–4

UNIT III: Complex Integration

Fundamental theorems – The line integral – Cauchy theorem for a rectangle – Cauchy's integral formula – Higher order derivative – Local properties of analytic functions – Taylor's theorem – Zeroes and poles – Local mapping – Maximum principle – Schwartz lemma.

Chapter 4: Sections 1–3

UNIT IV: Complex Integration

The general form of Cauchy's theorem – Chains and cycles – Homology – General statement of Cauchy's theorem – Calculus of residues – Argument principle – Evaluation of definite integrals.

Chapter 4: Sections 4–5

UNIT V: Harmonic Functions and Power Series

Harmonic functions – Definition and basic properties – Mean value property – Poisson formula – Schwartz theorem – Power series expansions – Weierstrass theorem – Taylor's and Laurent's series.

Chapter 4: Section 6; Chapter 5: Section 1

TEXT BOOK:

Lars V. Ahlfors, *Complex Analysis,* 3rd Edition, McGraw Hill Education, New York, 1979

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. J.B. Conway, *Functions of One Complex Variable*, 2nd Edition, Springer-Verlag, New York, 1978.
2. S. Lang, *Complex Analysis*, 4th Edition, Springer-Verlag, New York, 1999.
3. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Alpha Science International, 2005.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Analyze analytic functions of complex variable using limits, continuity and power series expansion.	K1, K2, K3
CLO 2	Construct conformal mappings between many kinds of domain.	K1, K2, K3
CLO 3	Find parameterizations of curves, and compute line integrals directly. Use Cauchy's integral theorem or formula to compute line integrals.	K1, K2, K3, K4
CLO 4	Find the number of zeros and poles within a given curve using the argument principle or Rouche's theorem and determine residues. Use the residue theorem to compute several kinds of real integrals.	K1, K2, K3, K4
CLO 5	Analyze harmonic functions, Poisson formula and series expansions including Taylor and Laurent series for analytic functions.	K2, K3, K4,K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	3	3	2	3	2	1
CLO2	2	2	3	3	2	1	3	2	1
CLO3	3	3	3	3	1	2	3	2	1
CLO4	3	3	3	3	1	2	3	2	1
CLO5	3	3	2	3	2	2	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1C13	**METHODS OF APPLIED MATHEMATICS**	**4**	**1**	**0**	**5**

OBJECTIVE: This course treats the foundations of calculus of variations and give examples on some applications within physics and engineering science.

UNIT I: Calculus of Variations

Maxima and Minima – The simplest case – Examples – Natural and transition boundary conditions – The variational notation – The more general case – Constraints and Lagrange multipliers – Variable end points – Sturm–Liouville problems.

Chapter 5: Sections 2.1–2.9

UNIT II: Applications of Calculus of Variations

Hamilton's principle – Lagrange's equation – Generalized dynamical entities – Constraints in dynamical systems – Small vibrations about equilibrium – Normal coordinates – Variational problems for deformable bodies – Rayleigh–Ritz method.

Chapter 5: Sections 2.10–2.14, 2.16, 2.19

UNIT III: Integral Equations

Integral equations – Relations between differential and integral equations – The Green's function – Fredholm equations with separable kernels – Examples.

Chapter 5: Sections 3.1–3.3, 3.6, 3.7

UNIT IV: Integral Equations

Hilbert–Schmidt theory – Iterative method for solving equations of the second kind – The Neumann series – Fredholm theory – Singular integral equations.

Chapter 5: Sections 3.8–3.12

UNIT V: Special Devices

Special devices – Iterative approximation to characteristic functions – Approximation of Fredholm equations by sets of algebraic equations.

Chapter 5: Sections 3.13–3.15

TEXT BOOK:

F.B. Hildebrand, *Methods of Applied Mathematics,* Prentice-Hall of India Pvt. Ltd., New Delhi, 1968

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. A.S. Gupta, *Calculus of Variations with Application*, Prentice-Hall of India, New Delhi, 2005.
2. L. Elsgolts, *Differential Equations and Calculus of Variations*, University Press of the Pacific, 2003.
3. I.M. Gelfand and S.V. Fomin, *Calculus of Variations*, Prentice Hall, New Jersey, 1963.
4. R.P. Kanwal, *Linear Integral Equation: Theory and Techniques*, 2nd Edition, Birkhäuser, 1996.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Describe the fundamentals of calculus of variations and its uses in physics and mathematics. Using simplest case with Examples and Natural , transition boundary conditions.	K1, K2
CLO 2	Describe the Rayleih-Ritz approach, variational problems, Lagrange's equation, and Hamilton's principle.	K2, K3 ,K4
CLO 3	Explain Green's function, Fredholm equations with separable kernels, the relationships between differential and integral equations, and solve the case.	K2, K3, K4
CLO 4	Handle the Neumann Series, the Hilbert-Schmidt theory, the Fredholm theory, and the iterative approach to solving second-kind problems.	K2, K3, K4
CLO 5	Solve the Fredholm equations using the theory, procedures, and strategies and some special devices.	K4,K5,K6

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	2	1	2	3	2	1	3
CLO2	1	2	2	1	2	2	2	1	2
CLO3	1	1	2	3	2	3	1	1	3
CLO4	1	2	1	2	3	3	1	2	2
CLO5	1	1	2	3	2	2	1	1	2

Course Code	Course Title	L	T	P	C
26UPMAT1E01	**CLASSICAL DYNAMICS**	**4**	**1**	**0**	**5**

OBJECTIVE: The objective of this course is to understand the Lagrangian and Hamiltonian equations for dynamical systems.

UNIT I: Mechanical Systems

The Mechanical system – Generalized coordinates – Constraints – Virtual work – Energy and Momentum.

Chapter 1: Sections 1.1 – 1.5

UNIT II: Lagrange's Equations

Derivation of Lagrange's Equations – Examples – Integrals of the motion.

Chapter 2: Sections 2.1 – 2.3

UNIT III: Hamilton's Equations

Hamilton's Principle – Hamilton's Equations – Other variational principles.

Chapter 4: Sections 4.1 – 4.3

UNIT IV: Hamilton–Jacobi Theory

Hamilton Principle Function – Hamilton-Jacobi Equation – Separability.

Chapter 5: Sections 5.1 – 5.3

UNIT V: Canonical Transformation

Differential forms and Generating Functions – Special Transformations – Lagrange and Poisson Brackets.

Chapter 6: Sections 6.1 – 6.3

TEXT BOOK:

D.T. Greenwood, *Classical Dynamics,* Prentice Hall of India, New Delhi, 1985

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. H. Goldstein, *Classical Mechanics* , 2nd Edition, Narosa Publishing House, New Delhi.
2. R.D. Gregory, *Classical Mechanics*, Cambridge University Press, 2006.
3. J.L. Synge and B.A. Griffith, *Principles of Mechanics*, 3rd Edition, McGraw Hill Book Co., New York, 1970.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Define mechanical systems using generalized coordinates, virtual work, energy, and momentum.	K1, K2
CLO 2	Explain the derivation of Lagrange's equations and interpret the concept of integrals of motion.	K1, K2, K3
CLO 3	Classify Hamilton's equations and other variational principles.	K2, K3
CLO 4	Formulate Hamilton's equation of motion and apply the Hamilton-Jacobi theory to solve integral equations.	K2, K3, K4
CLO 5	Analyze generating functions in canonical transformations and evaluate special transformations, Lagrange, and Poisson brackets.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	2	3	3	3	1	2	3
CLO2	1	1	2	1	3	3	1	1	2
CLO3	1	1	2	3	3	3	1	1	2
CLO4	1	2	2	3	3	3	1	1	2
CLO5	1	2	2	3	3	3	1	1	2

Course Code	Course Title	L	T	P	C
26UPMAT1E02	**GRAPH THEORY AND APPLICATIONS**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective of the course is to introduce students with the fundamental concepts in graph theory, with a sense to know some of the new developments and its modern applications. They will be able to use these concepts/techniques in subsequent courses in the design and analysis of algorithms, software engineering and computer systems.

UNIT I: Graphs and Digraphs

Basic concepts – subgraphs – degrees of vertices – paths and connectedness – automorphism of a simple graphs – line graphs – operations on graphs – applications to social psychology – basic concepts in digraphs – tournaments.

Chapter 1: Sections 1.1 – 1.8, 1.11 & Chapter 2: Sections 2.1 – 2.3

UNIT II: Connectivity and trees

Vertex cuts and edge cuts – connectivity and edge connectivity – Cyclical edge connectivity of a graph – Definition, Characterization and simple properties of trees – centers and centroids – counting the Number of spanning trees – Cayley's formula – Applications: Connector Problem – Kruskal's Algorithm.

Chapter 3: Sections 3.1 – 3.3, 3.5 & Chapter 4: Sections 4.1 – 4.5, 4.7.1 and 4.7.2

UNIT III: Independent sets, Matchings and Cycles

Independents sets and coverings (both vertex & edge) – matchings and factors – matchings in bipartite graphs – Eularian graphs and Hamiltonian graphs – Introduction – Eulerian Graphs – Hamiltonian Graphs – 2-Factorable Graphs.

Chapter 5: Sections 5.1 – 5.5 & Chapter 6: Sections 6.1 – 6.3, 6.6

UNIT IV: Graph colorings

Vertex colorings – applications of graph coloring – critical graphs – Brooks Theorem – other coloring parameters – b-colorings; Edge colorings – the time table problem – Vizings theorem – Kirkman's Schoolgirl Problem – chromatic polynomials.

Chapter 7: Sections 7.1 – 7.3, 7.6, 7.8, 7.9

UNIT V: Planar Graphs

Planar and non planar graphs – Euler formula and its consequences – K_5 and $K_{3,3}$ are non planar graphs – dual of a plane graph – The four color theorem and the Heawood five color theorem – Hamiltonian plane graphs – Tait coloring.

Chapter 8: Sections 8.1 – 8.6, 8.8, 8.9

TEXT BOOK:

R. Balakrishnan and K. Ranganathan, *A Textbook of Graph Theory,* Second Edition, Springer, New York, 2012

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. J. Clark and D.A. Holton, *A First look at Graph Theory*, Allied Publishers, New Delhi, 1995.
2. R.J. Wilson and J.J. Watkins, *Graphs: An Introductory Approach*, John Wiley and Sons, New York, 1989.
3. S.A. Choudum, *A First Course in Graph Theory*, MacMillan India Ltd. 1987.
4. J.A. Bondy and U.S.R. Murty, *Graph Theory and Applications*, Macmillan, London, 1976.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the basic concepts of graphs, subgraphs, paths and connectivity, operations on graphs and digraphs and be able to present a graph as a model to solve many real life problems.	K1, K2, K3
CLO 2	Understand the concepts of vertex cuts and edge cuts, connectivity, cyclical edge connectivity of a graph, properties of trees, centers and centroids, and be able to find a counting the number of spanning trees. Demonstrate Cayley's formula and solve the Connector Problem and Kruskal's Algorithm.	K1, K2, K3
CLO 3	Understand the concepts of independent sets and coverings, matching and factors, matching in bipartite graphs, Eulerian and Hamiltonian graphs, which make the model for optimal communication systems, and solve 2-factorable graphs.	K2, K3, K4
CLO 4	Demonstrate the Brooks Theorem, Vizings theorem, Kirkman's Schoolgirl Problem and chromatic polynomials.	K3, K4
CLO 5	Understand the basic concepts of planar and non-planar graphs, Euler formula and its consequences, dual of a plane graph, The four color theorem and the Heawood five color theorem, Hamiltonian plane graphs and Tait coloring.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO 1	1	2	2	3	3	3	2	1	2
CLO 2	1	2	2	3	2	3	1	2	2
CLO 3	1	2	3	3	2	2	2	1	3
CLO 4	1	3	2	3	2	2	1	2	3
CLO 5	2	2	2	3	3	3	2	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1E03	**LINEAR PROGRAMMING**	**3**	**1**	**0**	**3**

OBJECTIVE: The objectives of this course is

- the understanding mathematical structure and properties of the fundamental problem (e.g., linear, non-linear and integer programming, dynamic programming).
- the use of Mathematical Problem algorithms for problem solving but also the design of their variants for special problem cases.
- the formulation and solving of problems arising from the practical, real-life settings.

UNIT I: Integer Linear Programming
Types of integer linear programming problems – Enumeration and cutting plane solution concept – Gomary's all integer cutting plane method – Gomary's mixed integer cutting plane method – Branch and Bound method – applications of Zero-one integer programming.
Chapter 7: Sections 7.1 – 7.7

UNIT II: Classical Optimization Methods
Unconstrained optimization – Constrained multi-variable optimization with equality constraints – Constrained multi-variable optimization with inequality constraints.
Chapter 23: Sections 23.1 – 23.4

UNIT III: Theory of Simplex Method
Canonical and standard form of LP problem – Slack and surplus variables – Reduction of any feasible solution to basic feasible solution – Alternative optimal solution – Unbounded solution – Optimality conditions – some complications and their resolution– Degeneracy and its resolution.
Chapter 25: Sections 25.1–25.4, 25.6–25.9

UNIT IV: Revised Simplex Method
Standard forms for revised simplex method – Computational procedure for standard form I – Comparison of simplex method and revised simplex method.
Chapter 26: Sections 26.1–26.4

UNIT V: Goal Programming
Difference between LP and GP approach –Concept of Goal Programming – Goal programming Model formulation – Graphical Solution Method of Goal Programming – Modified Simplex method of Goal Programming – Alternative Simplex method of Goal Programming.
Chapter 8: Sections 8.1–8.7

TEXT BOOK:

J.K. Sharma, *Operations Research: Theory and Applications,* Sixth Edition, Macmillan India Ltd., 2016

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Hamdy A. Taha, *Operations Research*, 7th edition, Prentice-Hall of India Private Limited, New Delhi, 1997.

2. F.S. Hillier and J. Lieberman, *Introduction to Operation Research* , 7th edition, Tata-McGraw Hill company, New Delhi, 2001.

3. Beightler. C, D. Phillips, B. Wilde, *Foundations of Optimization* , 2nd edition, Prentice Hall Pvt Ltd., New York, 1979.

4. S.S. Rao , *Optimization Theory and Applications*, Wiley Eastern Ltd., NewDelhi, 1990

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Formulate the linear programming problems approach to solve LPP.	K1, K2, K3
CLO 2	Use single variable, multivariable, and nonlinear programming techniques to solve a variety of constrained and unconstrained problems.	K1, K2, K3
CLO 3	Use the simplex approach and the standard and canonical form of the LP-slack and excess variables to solve the optimization issue. reduction, using examples, of every feasible solution to a simple feasible solution.	K1, K2, K3
CLO 4	Apply the teaching of Revised simplex method to solve LPP.	K2, K3, K4
CLO 5	Apply modified simplex method to goal programming problems.	K3, K4,K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	3	2	1	2	2	1	2
CLO2	2	1	2	2	2	3	1	1	2
CLO3	1	2	2	3	2	3	1	1	1
CLO4	1	2	3	2	3	2	1	2	3
CLO5	1	2	3	2	2	3	1	1	2

Course Code	Course Title	L	T	P	C
26UPMAT1E04	**FUZZY SETS AND THEIR APPLICATIONS**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective of this course is to introduce the basic ideas of Fuzzy Sets; Fuzzy sets versus crisp sets, operation on Fuzzy sets, Fuzzy arithmetic and methods of contracting fuzzy sets.

UNIT I: Fuzzy sets

Fuzzy sets – Basic types – basic concepts – Characteristics – Significance of the paradigm shift - Additional properties of α-cuts.

Chapter 1 & 2: Sections 1.3 – 1.5, 2.1

UNIT II: Fuzzy sets versus crisp sets

Representation of Fuzzy sets – Extension principle of Fuzzy sets – Operation on Fuzzy Sets – Types of operation – Fuzzy complements.

Chapter 2 & 3: Sections 2.2, 2.3, 3.1, 3.2

UNIT III: Operations on Fuzzy sets

Fuzzy intersection – t-norms, Fuzzy unions – t conorms – Combinations of operations – Aggregation operations.

Chapter 3: Sections 3.3 – 3.6

UNIT IV: Fuzzy Arithmetic

Fuzzy numbers – Linguistic variables – Arithmetic operation on intervals – Lattice of Fuzzy numbers.

Chapter 4: Sections 4.1 – 4.5

UNIT V: Constructing Fuzzy Sets

Methods of construction: an overview – direct methods with one expert – direct method with multiple experts – indirect method with multiple experts and one expert- Construction from sample data.

Chapter 10: Sections 10.2 – 10.7

TEXT BOOK:

G. J. Klir and Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications,* Prentice Hall of India Ltd, New Delhi, 2005.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. H.J. Zimmermann, Fuzzy Set Theory and its Applications, Allied Publishers, Chennai,

1996.

2. A. Kaufman, Introduction to the Theory of Fuzzy Subsets, Academic Press, New York, 1975.
3. V. Novak, Fuzzy Sets and Their Applications, Adam Hilger, Bristol, 1969.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Distinguish between the crisp set and fuzzy set concepts.	K1, K2
CLO 2	Draw a parallelism between crisp set operations and fuzzy set operations through the use of characteristic and membership functions, respectively.	K1, K2, K3
CLO 3	Define fuzzy sets using linguistic word and represent these sets by membership functions.	K1, K2, K3
CLO 4	Know how to perform mapping of fuzzy sets by a function and also use α-level sets in such instances.	K2, K3, K4
CLO 5	Become aware of the use of fuzzy inference systems in the design of intelligent or humanistic systems.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	1	-	2	3	1	1	2
CLO2	2	2	2	-	3	3	2	2	2
CLO3	1	2	1	-	3	3	1	1	3
CLO4	2	2	2	-	3	3	2	2	3
CLO5	2	1	1	-	3	3	2	2	3

Course Code	Course Title	L	T	P	C
26UPMAT1E05	**DISCRETE MATHEMATICS**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective of this course is to understand the basic ideas of logic, proof methods and strategy, the growth of functions, counting techniques, pigeonhole principle, recurrence relations, solving recurrences using generating functions, Boolean functions, apply Boolean algebra to circuits and getting networks, use finite-state machines to model computer operations.

UNIT I: The Foundation of Logic

Logic – Propositional equivalence – Predicates and quantifiers – Proof Methods and Strategy – The growth of functions.

Chapter 1 & 3 – Sections 1.1–1.3 & 1.8, 3.2

UNIT II: Counting

Basics of counting – The pigeonhole principle – Permutations and combinations – Generalized permutations and combinations – Generating permutations and combinations.

Chapter 5: Sections 5.1–5.6

UNIT III: Advanced Counting Techniques

Recurrence relation – Solving recurrence relations – Generating functions.

Chapter 6: Sections 6.1, 6.2, 6.4

UNIT IV: Boolean Algebra

Boolean functions – Representing Boolean functions – Logic Gates – Minimization of circuits.

Chapter 10: Sections 10.1–10.4

UNIT V: Modeling Computations

Finite-state machines with output – Finite-state machines with no output – Turing machines.

Chapter 12: Sections 12.2, 12.3, 12.5

TEXT BOOK:

Kenneth H. Rosen, *Discrete Mathematics and its Applications,* Seventh Edition, WCB/McGraw Hill Publications, New Delhi, 2011.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Edward A. Bender and S. Gill Williamson, *A Short Course in Discrete Mathematics*, Dover Publications, 2006.
2. M.O. Albertson and J.P. Hutchinson, *Discrete Mathematics with Algorithms*, John Wiley & Sons, 2008.
3. Rajendra Akerkar and Rupali Akarkar, *Discrete Mathematics*, Pearson Education Pvt. Ltd, Singapore, 2004.
4. J.P. Trembley and R. Manohar, *Discrete Mathematical Structures*, Tata McGraw Hill, New Delhi, 1997.
5. Martin Aigner, *A Course in Enumeration*, Springer-Verlag, Heidelberg, 2007.
6. J.H. Van Lint and R.M. Wilson, *A Course in Combinatorics*, 2nd Edition, Cambridge University Press, Cambridge, 2001.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Express a logic sentence in terms of predicates, quantifiers and logical connectives.	K1, K2
CLO 2	Apply the rules of inference and methods of proof including direct and indirect proof forms, proof by contradiction and mathematical induction.	K2, K3
CLO 3	Solve discrete mathematics problems that involve permutations and combinations of set, fundamental enumeration principles.	K2, K3, K4
CLO 4	Evaluate Boolean functions and simplify Boolean expressions using the properties of Boolean algebra.	K3, K4, K5
CLO 5	Simplify Boolean function using circuits with different type of gates.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	2	2	2	3	1	2	2
CLO2	1	1	2	2	3	3	1	1	2
CLO3	1	1	1	2	2	2	1	1	2
CLO4	1	2	2	2	3	3	2	2	2
CLO5	2	2	2	2	3	3	2	2	3

Course Code	Course Title	L	T	P	C
26UPMAT1E06	MATHEMATICAL FOUNDATIONS FOR DATA SCIENCE	3	1	0	3

OBJECTIVE: This course aims to provide the fundamental mathematical concepts required for getting into the field of data science and machine learning.

UNIT I: Data Science Fundamentals

Identifying and framing a data science problem in different fields – Data - Types, Pre- processing; Different types of Analytics – Introduction to Machine Learning, Artificial Intelligence.

UNIT II: Linear Algebra

Vectors and Matrices, Vector Spaces, Linear Transformations, Matrix Operations, Eigenvalues and Eigenvectors, Iterative methods for computing eigenvalues, Gram- Schmidt Process, Singular Value Decomposition (SVD), LU decomposition, QR Decomposition and the Moore Penrose inverse.

UNIT III: Numerical Linear Algebra

Matrix Norms and Condition Numbers: Definition and properties of matrix norms. Condition number and its significance, Ill-conditioning and numerical stability. Matrix Factorizations: Least squares approximation, Solving over determined and underdetermined systems.

UNIT IV: Optimization Methods in ML

Introduction to Optimization Problems, Classification of Optimization Problem, Definition of Global and Local optima, Optimality conditions; Convex Programming Problems; Analytical Optimization Techniques: Lagrange's Multipliers Methods, Karaush-Kuhn- Tucker (KKT) Method; Numerical Optimization Techniques: Steepest Descent Method, Conjugate Gradient Method, Newton's Method, Quasi-Newton Methods; Penalty Function Methods.

UNIT V: Statistical Methods for Data Science

Data Visualization, Descriptive Statistics, Sampling & Monte Carlo Methods, Statistical Inference (Both Likelihood based and Bayesian), Linear and Logistic Regression, Dimension Reduction Techniques, Support Vector Machines, Linear Discriminant Analysis, Unsupervised learning. Case studies in different domains (healthcare, finance, etc.)

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. C. Shah, A Hands-on Introduction to Data Science. Cambridge University Press, 2020.
2. M. P. Deisenroth, A. A. Faisal, and C. S. Ong. Mathematics for Machine Learning, Cambridge University Press, 2020.
3. Gilbert Strang, Linear Algebra and its Applications, Cengage India Private Limited, Fourth Edition, 2005.
4. L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, 1997.
5. B. N. Datta, Numerical Linear Algebra and Applications, Second Edition,SIAM, 2010.
6. S. S Rao, Engineering Optimization Theory and Practice, New Age, 4th Edn., 2023.
7. S. Sra, S. Nowozin and S.J. Wright, Optimization for Machine Learning, MIT Press, 2011.
8. Kalyanmoy Deb, Optimization for Engineering Design, PHI, 2nd Edn., 2021.
9. S. Sra, S. Nowozin and S.J. Wright, Optimization for Machine Learning, MIT Press, 2011.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the basic mathematical concepts in data science, related to linear algebra, probability, and calculus	K1, K2, K3
CLO 2	Employ techniques and methods related to these concepts in a variety of data science applications.	K1, K2, K3
CLO 3	Apply logical thinking to understand and solve problems	K1, K2, K3
CLO 4	Demonstrate skills in writing mathematics	K1, K2, K3
CLO 5	Adopt a rigorous and mathematical approach to solving problems in machine learning and data science.	K1, K2, K3

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	2	1	2	3	2	2	1
CLO2	2	2	2	1	2	3	2	2	2
CLO3	3	3	2	1	2	3	2	2	2
CLO4	2	2	2	1	2	3	2	2	1
CLO5	3	3	2	1	2	3	2	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1E07	MATHEMATICAL MODELLING	3	1	0	3

OBJECTIVE: This course aims to

- Provide rigorous instruction in fundamental mathematical concepts and skills presented in the context of real-world applications.
- Gain a working knowledge of core techniques behind mathematical modelling and develop a basic ability to quantify certain phenomena associated with the physical sciences.
- Represent real-world systems in a mathematical framework.

UNIT I: Mathematical Modelling through Ordinary Differential Equations of First Order
Linear Growth and Decay Models – Non-Linear Growth and Decay Models – Compartment Models – Dynamics Problems – Simple problems.
Chapter 2: Sections 2.1 – 2.6

UNIT II: Mathematical Modelling through Systems of Ordinary Differential Equations of First Order
Population Dynamics – Epidemics – Compartment Models – Economics – Medicine, Arms Race, Battles and International Trade – Simple problems.
Chapter 3: Sections 3.1 – 3.6

UNIT III: Mathematical Modelling through Ordinary Differential Equations of Second Order
Planetary Motions – Circular Motion and Motion of Satellites – Mathematical Modelling through Linear Differential Equations of Second Order – Miscellaneous Mathematical Models – Simple problems.
Chapter 4: Sections 4.1 – 4.4

UNIT IV: Mathematical Modelling through Difference Equations
Simple Models – Basic Theory of Linear Difference Equations with Constant Coefficients – Economics and Finance – Population Dynamics and Genetics – Probability Theory – Simple problems.
Chapter 5: Sections 5.1 – 5.6

UNIT V: Mathematical Modelling through Graphs
Situations that can be modelled through Graphs – Mathematical Modelling in Terms of Directed Graphs, Signed Graphs, Weighted Digraphs – Simple problems.
Chapter 7: Sections 7.1 – 7.4

TEXT BOOK:

J.N. Kapur, *Mathematical Modelling,* Wiley Eastern Limited, New Delhi, 4th Reprint, May 1994

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. M. Braun, C.S. Coleman and D.A. Drew, *Differential Equation Models*, 1994.
2. A.C. Fowler, *Mathematical Models in Applied Sciences*, Cambridge University Press, 1997.
3. Walter J. Meyer, *Concepts of Mathematical Modeling*.
4. Edward A. Bender, *Introduction to Mathematical Modelling*, Dover Publications, 1st Edition, 2000.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Create mathematical models of empirical or theoretical phenomena in domains such as the physical, natural, or social sciences.	K1, K2, K3
CLO 2	Draw inferences from models using mathematical techniques including problem solving, quantitative reasoning, and exploration using multiple representations such as equations, tables, and graphs.	K2, K3, K4
CLO 3	Design difference equation based mathematical model and resolve the problem of field population, pollution, Econometrics, and cooling system etc.	K2, K3, K4
CLO 4	Apply the difference equation based mathematical model to resolve the problems related to Epidemic model, compartment model, inflection model etc.	K2, K3, K4
CLO 5	Establish the connection of applicability of mathematical models to resolve the real problems arise in the fields of science and engineering.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	2	1	2	2	1	1	2
CLO2	1	1	2	1	1	3	1	1	2
CLO3	2	2	2	1	2	3	1	2	3
CLO4	2	2	2	1	2	2	1	1	2
CLO5	1	1	3	1	2	3	1	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1E08	COMBINATORIAL MATHEMATICS	3	1	0	3

OBJECTIVE: Combinatorial mathematics is the study of the arrangements of objects, according to prescribed rules, to count the number of possible arrangements or patterns, to determine whether a pattern of a specified kind exists and to find methods of constructing arrangements of a given type. The objective of this course is to acquaint the students with the concepts of permutations and combinatorics, generating functions, recurrence relations, the principle of inclusion and exclusion and Polya's theory of counting.

UNIT I: Permutations and Combinatorics
The rules of sum and product – Permutations – Combinations – Distributions of distinct objects – Distribution of nondistinct objects.
Chapter 1: Sections 1.1 – 1.7

UNIT II: Generating Functions
Generating functions for combinations – Enumerators for permutations – Distributions of distinct objects into nondistinct cells – Partitions of integers – The Ferrers graph – Elementary relations.
Chapter 2: Sections 2.1 – 2.7

UNIT III: Recurrence Relations
Linear recurrence relations with constant coefficients – Solution by the technique of generating functions – A special class of nonlinear difference equations – Recurrence relations with two indices.
Chapter 3: Sections 3.1 – 3.5

UNIT IV: The Principle of Inclusion and Exclusion
The Principle of inclusion and exclusion – The general formula – Derangements – Permutations with restrictions on relative positions – The rook polynomials – Permutations with forbidden positions.
Chapter 4: Sections 4.1 – 4.7

UNIT V: Polya's Theory of Counting
Sets, relations and groups – Equivalence classes under a permutation group – Equivalence classes of functions – Polya's fundamental theorem.
Chapter 5: Sections 5.1 – 5.7

TEXT BOOK:
C.L. Liu, *Introduction to Combinatorial Mathematics,* McGraw Hill Book Company, New York,

1968.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Murray Edelberg and C.L. Liu, *Solutions to Problems in Introduction to Combinatorial Mathematics*, McGraw-Hill Book & Co., New York, 1968.
2. R.P. Stanley, *Enumerative Combinatorics*, Volume I, 2nd Edition, Cambridge Studies in Advanced Mathematics (Book 49), Cambridge University Press, 1997.
3. P.J. Cameron, *Combinatorics: Topics, Techniques, Algorithms*, Cambridge University Press, Cambridge, 1998.
4. Miklos Bona, *A Walk through Combinatorics*, World Scientific Publishing Company, 2002.
5. M. Aigner, *A Course in Enumeration*, Springer-Verlag, Heidelberg, 2007.
6. J.H. Van Lint and R.M. Wilson, *A Course in Combinatorics*, 2nd Edition, Cambridge University Press, Cambridge, 2001.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Use formulas for counting basic combinatorial outcomes to construct solutions to complete combinatorial enumeration problems: permutation with and without repetitions; combination with and without repetitions.	K1, K2
CLO 2	Apply counting strategies to solve discrete probability problems.	K1, K2, K3
CLO 3	Use specialized techniques to solve combinatorial enumeration problems like generating functions, recurrence relations, Inclusion-exclusion principle.	K2, K3, K4
CLO 4	Understand the concepts of permutations with restrictions on relative positions and the rook polynomials.	K3, K4, K5
CLO 5	Enumerate configuration using Polya's theory.	K1, K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	1	3	2	1	1	1	2
CLO2	1	1	2	3	2	2	1	2	2
CLO3	2	2	2	3	2	2	2	2	2
CLO4	1	2	2	3	3	2	1	2	2
CLO5	2	1	1	1	2	2	1	1	2

Course Code	Course Title	L	T	P	C
26UPMAT1E09	**DIFFERENCE EQUATIONS**	**3**	**1**	**0**	**3**

OBJECTIVE: The objectives of this course are to

- introduce the difference calculus
- study linear difference equations and to know how to solve them
- know the stability theory for homogeneous linear system of difference equations
- study the asymptotic behavior of solutions of homogeneous linear difference equations

UNIT I:
The Difference Operator – Summation – Generating Functions and Approximate Summation.
Chapter 2: Sections 2.1 – 2.3

UNIT II:
First Order Equations – General Results for Linear Equations – Solving Linear Equations.
Chapter 3: Sections 3.1 – 3.3

UNIT III:
Equations with Variable Coefficients – The z - transform.
Chapter 3: Sections 3.5, 3.7

UNIT IV:
Initial Value Problems for Linear Systems – Stability of Linear Systems.
Chapter 4: Sections 4.1 – 4.2

UNIT V:
Introduction – Asymptotic Analysis of Sums – Linear Equations.
Chapter 5: Sections 5.1 – 5.3

TEXT BOOK:
W.G. Kelley and A.C. Peterson, *Difference Equations,* Second Edition, Academic Press, New York, 2001

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. R.P. Agarwal, *Difference Equations and Inequalities*, 2nd Edition, Marcel Dekker, New York, 2000.
2. S.N. Elaydi, *An Introduction to Difference Equations*, 3rd Edition, Springer, India, 2008.
3. R. E. Mickens, *Difference Equations*, 3rd Edition, CRC Press, 2015.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Define a difference, summation operators, understand their properties, and apply generating functions to solve problems in discrete calculus.	K1, K2, K3
CLO 2	Identify and solve first-order and higher-order linear difference equations with constant coefficients, and explain Annihilator method.	K1, K2, K3
CLO 3	Define z-transforms, explain reduction of order method, and to solve linear difference equations with variable coefficients and Volterra summation equations	K1, K2, K3
CLO 4	Identify the eigen values, eigen vectors, spectral radius, solve initial value problems and determine the stability of linear discrete systems	K1, K3, K4
CLO 5	Define basic concepts and tools of asymptotic analysis, apply asymptotic methods to study the qualitative and long-term behavior of solutions to difference equations, and analyze the asymptotic behavior of solutions to linear difference equations by the theorems of Poincare and Perron	K1, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	1	3	2	2	3	1
CLO2	3	3	3	1	3	2	2	3	1
CLO3	3	3	3	1	3	2	2	3	1
CLO4	3	3	3	1	3	2	2	3	1
CLO5	3	3	3	1	3	2	2	3	1

Course Code	Course Title	L	T	P	C
26UPMAT1E10	MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE	3	1	0	3

OBJECTIVE: This course is aimed at building the foundation of computational thinking with applications to Artificial Intelligence and Machine learning (AI & ML). Besides, how to build a neural network and how to train, evaluate and optimize it with TensorFlow will also be covered in this course.

UNIT I: Programming Foundation

Digital storage of data in computers, memory and data representation, Overflow and Underflow, Round-off errors, the performance of a computer, Caches, Debugging and Profiling, Basic optimization techniques for serial code.

UNIT II: Introduction to Python

Object and Data Structure Basics, Python Statements, Methods and Functions,Object- oriented-programming(OOP): Inheritance, Encapsulation, Abstraction, Polymorphism. OOP concepts in Python.

UNIT III: Python tools for Data Science

Pandas, NumPy, Matplotlib, Scikit-Learn, Just-in-Time (JIT) compilers, Numba.

UNIT IV: Computational Thinking

Arrays, Matrix-Vector, Matrix multiplication, Solving dense and sparse systems.

UNIT V: Deep Learning with Tensor Flow

Tensors, Install TensorFlow, TensorFlow basics, Simple statistics and plotting, Loading and exploring data, learning with TensorFlow and Keras, Mini-project.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. John Hennessy David Patterson. Computer Architecture. A Quantitative Approach. 7th Edition, Morgan Kauffman, 2017.
2. Shaw, Zed A. Learn python 3 the hard way: A very simple introduction to the terrifyingly beautiful world of computers and code.Addison-Wesley Professional, 2017.

3. Aurélien Géron, Hands-O Machine Learning with Scikit-Learn, Keras, and Tensor Flow, 2nd Edition, O'Reilly Media, Inc. 2019.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Develop the soft skills required for data science career.	K1, K2
CLO 2	To learn basics of data structure and object-oriented programming (OOP)s	K1, K2, K3
CLO 3	To learn basics of python tools	K1, K2, K3
CLO 4	Understanding computational thinking	K1, K2, K3
CLO 5	Application of tensors flow to deep learning	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	2	-	2	3	1	1	2
CLO2	1	1	1	-	2	3	1	1	2
CLO3	1	1	1	-	2	2	1	1	2
CLO4	1	1	1	-	2	3	1	1	3
CLO5	2	2	2	-	2	3	2	2	3

Course Code	Course Title	L	T	P	C
26UPMAT1E11	**MATHEMATICAL BIOLOGY**	**3**	**1**	**0**	**3**

OBJECTIVE: Biology is undergoing a quantitative revolution, generating vast quantities of data that are analysed using bioinformatics techniques and modelled using mathematics to give insight into the underlying biological processes. This module aims to give a flavour of how mathematical modelling can be used in different areas of biology.

UNIT I: Continuous Population Models for Single Species

Continuous growth Models – Insect Outbreak Model: Spruce Budworm – Delay Models – Linear Analysis of Delay Population Models: Periodic Solutions – Harvesting a Single Natural Population –Population Model with Age Distribution.

Chapter 1 : Sections 1.1–1.4, 1.6, 1.7

UNIT II: Models for Interacting Populations

Predator - Prey Models: Lotka - Volterra systems – Realistic Predator-Prey Models – Analysis of a Predator-Prey Model with Limit Cycle Periodic Behavior: Parameter Domains of Stability – Competition Models: Competitive Exclusion Principle – Mutualism or Symbiosis.

Chapter 3 : Sections 3.1, 3.3 –3.6

UNIT III: Dynamics of Infectious Diseases

Simple Epidemic Models and Practical Applications – Modelling Venereal Diseases – Multi - Group Model of Gonorrhea and Its control – Age - Dependent Epidemic Model and Threshold Criterion –Simple Drug Use Epidemic Model and Threshold Analysis

Chapter 10 : Sections 10.2 – 10.4, 10.9 – 10.10

UNIT IV: Reaction Kinetics

Enzyme Kinetics: Basic Enzyme Reaction – Transient Time Estimates and Non dimensionalisation– Michaelis-Menten Quasi -Steady State Analysis – Cooperative Phenomena – Autocatalysis, Activation and Inhibition.

Chapter 6 : Sections 6.1–6.3, 6.5 , 6.6

UNIT V: Reaction Diffusion, Chemotaxis, and Nonlocal Mechanisms

Simple Random Walk and Derivation of the Diffusion Equation – Reaction Diffusion Equations –Models for Animal Dispersal – Chemotaxis.

Chapter 11: Sections 11.1 – 11.4

TEXT BOOK:

J.D. Murray, *Mathematical Biology I: An Introduction,* 3rd Edition, Springer, Berlin, 2001.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. N. Britton, *Essential Mathematical Biology*, Springer Science & Business Media, 2012.
2. L.A. Segel and L. Edelstein-Keshet, *A Primer in Mathematical Models in Biology*, SIAM, Vol. 129, 2013.
3. A.D. Bazykin, *Nonlinear Dynamics of Interacting Populations*, World Scientific, 1998.
4. J.N. Kapur, *Mathematical Models in Biology and Medicine*, Affiliated East-West, New Delhi, 1985.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Identify the concepts of Continuous time models, Growth models, Logistic model, Delay models.	K1, K2
CLO 2	Understand the concepts of Lotka-Volterra Prey-Predator equations and modelling the predator functional response Competition.	K2, K3
CLO 3	Develop the epidemic and SIS diseases, SIR Epidemics, SIR Endemics and its behavior.	K2, K3, K4
CLO 4	Analyze the Transitions between states at the molecular and populations level and Law of mass action.	K2, K3, K4
CLO 5	Apply the concepts of Simple models for polymer growth dynamics.	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	2	2	2	-	3	2	3	2	1
CLO2	2	1	3	-	3	2	3	1	1
CLO3	2	1	2	-	3	2	3	2	1
CLO4	2	2	2	-	3	2	3	2	1
CLO5	2	2	2	-	3	2	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1E12	**FRACTIONAL CALCULUS**	**3**	**1**	**0**	**3**

OBJECTIVE: This course aims to provide an introductory level and elementary concepts of fractional calculus and fractional differential equations along with applications for the beginners of mathematics students.

UNIT I: Fractional Calculus

Preliminaries – Riemann-Liouville Fractional Integrals and Derivatives – Caputo Fractional Derivatives – Examples

Chapter 2: Sections 2.1 - 2.4

UNIT II: Fractional Differential Equations

Motivation – Equation with Constant Coefficient – Equation with Matrix Coefficient – Nonlinear Equations – Nonlinear Damped Equations – Examples

Chapter 3: Sections 3.1 – 3.6

UNIT III: Applications

Observability – Controllability of Linear Systems – Controllability of Nonlinear Systems – Stability – Nonlinear Equations - Examples

Chapter 4: Sections 4.1 - 4.6

UNIT IV: Fractional Partial Differential Equations

Motivation – Fractional Partial Integral and Derivative – Linear Fractional Equations – Nonlinear Fractional Equations – Fractional Equations with Kernel – Examples

UNIT V: Fractional Integrals and Derivatives

Definitions of Fractional Integrals – Definitions of Fractional Derivatives – Examples

TEXT BOOK:

K. Balachandran, *An Introduction to Fractional Differential Equations,* Industrial and Applied Mathematics, Springer, 2023.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. A. A. Kilbas, H.M. Srivastava, J.J.Trujillo, Theory and Applications of Fractional Differential Equations, Mathematical Studies 204, Elsevier, 2006.
2. K.S.Miller and B. Ross, An Introduction to the Fractional Calculus and Fractional Differential Equations, John Wiley & Sons, 1993.

3. I. Podlubny, Fractional Differential Equations, Vol. 198, Mathematics in Science and Engineering Series, Academic Press, 1999.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the fundamentals of fractional calculus	K1, K2, K3
CLO 2	Understand the fundamentals of fractional differential equations	K3, K4, K5
CLO 3	Apply the concepts to controllability, observability and stability of dynamical systems	K2, K3, K4
CLO 4	Learn the concept of fractional partial differentia equations	K2, K3, K4
CLO 5	Understand the concepts of fractional integrals and derivatives	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	2	-	3	3	1	2	3
CLO2	1	2	2	-	2	3	1	2	2
CLO3	1	2	2	-	3	3	1	2	3
CLO4	1	2	3	-	3	3	1	3	3
CLO5	1	2	2	-	3	3	1	2	3

Course Code	Course Title	L	T	P	C
26UPMAT1E13	**NONLINEAR DIFFERENTIAL EQUATIONS**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective of this course is

1. to discuss nonlinear ordinary differential equations for their different behavior of the solutions.
2. to study periodic solutions and averaging methods, perturbation methods and stability.
3. to analyze some applications of nonlinear ordinary differential equations studied in the present work to some concrete problem of the other areas of mathematics.

UNIT I: Plane autonomous systems and linearization

The general phase plane – Some population models – Linear approximation at equilibrium points – Linear systems in matrix form.

Chapter 2: Sections 2.1 – 2.5

UNIT II: Periodic Solutions and Averaging Methods

An energy balance method for limit cycles – Amplitude and frequency estimates – Slowly varying amplitudes; Nearly periodic solutions – Periodic solutions: Harmonic balance – Equivalent linear equation by harmonic balance – Accuracy of a period estimate.

Chapter 4: Sections 4.1 – 4.5

UNIT III: Perturbation Methods

Outline of the direct method – Forced oscillations far from resonance– Forced oscillations near resonance with weak excitation – Amplitude equation for undamped pendulum – Amplitude perturbation for the pendulum equation – Lindstedt's method – Forced oscillation of a self – excited equation – The Perturbation method and Fourier series.

Chapter 5: Sections 5.1 – 5.5, 5.8 – 5.11

UNIT IV: Stability

Poincare stability – Paths and solution curves for general systems - Stability of time solutions: Liapunov stability - Liapunov stability of plane autonomous linear systems.

Chapter 8: Sections 8.1 – 8.4

UNIT V: Stability

Structure of the solutions of n-dimensional linear systems - Structure of n-dimensional inhomogeneous linear systems - Stability and boundedness for linear systems - Stability of linear systems with constant coefficients.

Chapter 8: Section 8.5 – 8.8

TEXT BOOK:

D.W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations,* Fourth Edition, Oxford University Press, New York, 2007

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. G.F. Simmons, *Differential Equations*, Tata McGraw-Hill, New Delhi, 1995.
2. D.A. Sanchez, *Ordinary Differential Equations and Stability Theory*, Dover, New York, 1979.
3. J.K. Aggarwal, *Notes on Nonlinear Systems*, Van Nostrand, 1972.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Identify the concepts of population model with phase plane.	K1, K2, K3
CLO 2	Derive the limit cycle via energy balance method.	K3, K4, K5
CLO 3	Use perturbation method and Fourier series to solve Forced oscillations and Amplitude equation for undamped pendulum.	K2, K3, K4
CLO 4	Understand the stability through Liapunov function and Poincare stability.	K2, K3, K4
CLO 5	Apply stability theory to n-dimensional linear systems. .	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	2	2	1	3	2	2	3	2	1
CLO2	2	2	2	1	2	2	3	2	1
CLO3	2	2	1	1	1	2	3	1	1
CLO4	2	2	3	1	2	2	3	2	1
CLO5	2	2	2	1	1	2	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1E14	STOCHASTIC DIFFERENTIAL EQUATIONS	3	1	0	3

OBJECTIVE: Stochastic differential equations have been used extensively in many areas of application, including finance and social science as well as in physics, chemistry. This course develops the theory of Itôs calculus and stochastic differential equations.

UNIT I: A Crash Course in Probability Theory

Basic definitions - Expected value, variance - Independence - Some probabilistic methods – Law of Large Numbers - Central Limit Theorem - Conditional expectation - Martingales

Chapter 2

UNIT II: Brownian Motion and White Noise

Motivation - Definition, elementary properties - Construction of Brownian motion - Sample path properties - Markov property

Chapter 3

UNIT III: Stochastic Integrals

Preliminaries - Itô's integral - Itô's chain and product rules - Itô's integral in higher dimensions

Chapter 4

UNIT IV: Stochastic Differential Equations

Definitions, examples - Existence and uniqueness of solutions - Properties of solutions - Linear stochastic differential equations

Chapter 5

UNIT V: Applications

Stopping times - Applications to PDE, Feynman-Kac formula - Optimal stopping - Options pricing - The Stratonovich integral

Chapter 6

TEXT BOOK:

Lawrence C. Evans, *An Introduction to Stochastic Differential Equations,* American Mathematical Society, 2013.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. L. Arnold, Stochastic Differential Equations: Theory and Applications, Dover Publications, 2011.
2. A. Friedman, Stochastic Differential Equations and Applications, Dover Publications, 2006.

3. D. Henderson and P. Plaschko, Stochastic Differential Equations in Science and Engineering, World Scientific, 2006.

4. B. Oksendal, Stochastic Differential Equations: An Introduction with Applications, 6th Edition, Springer - Verlag, Heidelberg, 2003.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	understand the building blocks of basic and modern control systems	K1, K2
CLO 2	obtain solution to stochastic differential equations	K1, K2, K3
CLO 3	learn about general existence and uniqueness results for stochastic differential equations	K2, K3, K4
CLO 4	Apply Itô Lemma to find SDEs arising in real-world applications	K2, K3, K4
CLO 5	take a research career in the area of stochastic differential equations	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	3	-	3	3	1	2	3
CLO2	1	1	3	-	2	2	1	2	2
CLO3	2	2	3	-	2	3	2	2	3
CLO4	1	2	3	-	2	3	1	2	3
CLO5	2	2	3	-	2	3	2	2	3

Course Code	Course Title	L	T	P	C
26UPMAT1E15	CONTROL THEORY	3	1	0	3

OBJECTIVE: This is an introductory course in mathematical systems theory. The subject provides the mathematical foundation of modern control theory. The aim of the course is to acquire a systematic understanding of linear dynamical systems. The acquirement of such knowledge is useful in preparation for work on system analysis and design problems that appear in many engineering fields.

UNIT I: Observability
Linear Systems – Nonlinear Systems.
Chapter 2: Sections 2.1 - 2.3

UNIT II: Controllability
Linear systems – Nonlinear systems.
Chapter 3: Sections 3.1, 3.2

UNIT III: :Stability
Stability – Perturbed linear systems – Nonlinear systems.
Chapter 4: 4.1 - 4.3, 4.5

UNIT IV: Stabilizability
Stabilization via linear feedback control – The controllable subspace – Stabilization with restricted feedback.
Chapter 5: 5.1 - 5.4

UNIT V: Optimal Control
Linear time varying systems – Linear time invariant systems – Nonlinear Systems.
Chapter 6: Sections 6.1 - 6.3

TEXT BOOK:
K.Balachandran and J.P.Dauer, *Elements of Control Theory,* 2nd Edition (revised), Alpha Science International Ltd, 2011.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. R. Conti, Linear Differential Equations and Control, Academic Press, London, 1976.
2. R.F. Curtain and A.J.Pritchard, Functional Analysis and Modern Applied Mathematics, Academic Press, New York, 1977.
3. J. Klamka, Controllability of Dynamical Systems, Kluwer Academic Publisher, Dordrecht, 1991.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	understand the building blocks of basic and modern control systems	K1, K2, K3
CLO 2	get an understanding of the basic ingredients of linear systems theory	K1, K2, K3
CLO 3	select appropriate methodologies for the analysis or design of feedback and open-loop control systems	K2, K3, K4
CLO 4	learn some basic notions and results in control theory, which are very useful for applied mathematicians	K1, K2, K3
CLO 5	take a research career in the area of differential equations and control theory	K4, K5, K6

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	3	-	2	2	1	1	2
CLO2	1	2	3	-	2	2	1	2	2
CLO3	1	1	3	-	2	3	1	1	2
CLO4	1	1	3	-	2	2	1	1	2
CLO5	2	2	3	-	2	2	2	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1E16	**DIFFERENTIAL GEOMETRY**	**4**	**1**	**0**	**5**

OBJECTIVE: The objective of this course is to introduce space curves and their intrinsic properties of a surface and geodesics. Further the non-intrinsic properties of surface and the differential geometry of surfaces are explored.

UNIT I: Space curves

Definition of a space curve – Arc length – tangent, normal and binormal – Curvature and torsion of the curve given as the intersection of two surfaces – Contact between curves and surfaces- Tangent surface, involutes and evolutes – Intrinsic equations, Fundamental existence theorem for space curves – Helices.

Chapter I: Sections 1 – 9

UNIT II: Intrinsic properties of a surface

Definition of a surface – Curves on a surface – Surface of revolution – Helicoids – Metric- Direction coefficients – Families of curves- Isometric correspondence – Intrinsic properties.

Chapter II: Sections 1 – 9

UNIT III: Geodesics

Geodesics – Canonical geodesic equations – Normal property of geodesics – Existence Theorems – Geodesic parallels.

Chapter II: 10 – 14

UNIT IV: Geodesics

Geodesics curvature – Gauss- Bonnet Theorem – Gaussian curvature – Surface of constant curvature.

Chapter II: 14 – 18

UNIT V: Non Intrinsic properties of a surface

The second fundamental form – Principle curvature – Lines of curvature – Developables – Developables associated with space curves – Developables associated with curves on surface – Minimal surfaces – Ruled surfaces.

Chapter III: 1 – 8

TEXT BOOK:

T.J. Willmore, *An Introduction to Differential Geometry,* Oxford University Press (Indian Print), 17th Impression, New Delhi, 2002

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. D.T. Struik, *Lectures on Classical Differential Geometry*, Addison-Wesley, Mass., 1950.
2. S. Kobayashi and K. Nomizu, *Foundations of Differential Geometry*, Interscience Publishers, 1963.
3. Wilhelm Klingenberg, *A Course in Differential Geometry*, Graduate Texts in Mathematics, Springer-Verlag, 1978.
4. J.A. Thorpe, *Elementary Topics in Differential Geometry*, Undergraduate Texts in Mathematics, Springer-Verlag, 1979.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Explain space curves, Curves between surfaces, metrics on a surface, fundamental form of a surface and Geodesics.	K2, K3, K4
CLO 2	Evaluate these concepts with related examples.	K2, K3, K4
CLO 3	Compose problems on geodesics.	K3, K4, K5
CLO 4	Recognize applicability of developable.	K3, K4, K5
CLO 5	Construct and analyze the problems on curvature and minimal surfaces.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	2	1	1	2	3	2	1
CLO2	3	3	2	1	2	2	3	2	1
CLO3	3	2	2	1	2	2	3	2	1
CLO4	2	2	3	1	2	2	3	2	1
CLO5	3	2	3	1	2	2	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1E17	**ADVANCED PARTIAL DIFFERENTIAL EQUATIONS**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective is to

- develop an understanding of the theory and methods of solution for partial differential equations.
- provide an introduction to the study and solution methods for partial differential equations of first and second order.
- make the students to understand the characteristics of heat, wave, and Laplace's equations.
- provide the students a better understanding to the diffusion and wave equations and their applications.

UNIT I: Laplace Equation
Partial Differential Equations – Classifications – Examples – Fundamental solution – Mean-value formulas – Properties of harmonic functions – Green's functions – Energy methods.
Chapter 1 & 2: Sections 1.1, 1.2, 2.2

UNIT II: Heat Equation
Fundamental solution – Mean-value formula – Properties of solutions – Energy methods.
Chapter 2: Section 2.3

UNIT III: Wave Equation
Solution by spherical means – Nonhomogeneous problem – Energy methods.
Chapter 2: Section 2.4

UNIT IV: Other ways to represent solutions
Separation of variables – Similarity solutions.
Chapter 4: Sections 4.1, 4.2

UNIT V: Other ways to represent solutions
Transform methods – Converting nonlinear into linear PDE.
Chapter 4: Sections 4.3, 4.4

TEXT BOOK:

L. C. EVANS, *Partial Differential Equations,* American Mathematical Society, Indian Edition, 2009.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. D. Colton, Partial Differential Equations: An Introduction, Dover Publishers, New York, 1988.

2. F. John, Partial Differential Equations, Applied Mathematical Science (Vol. 1), Springer, 1982.

3. M. Renardy and R.C.Rogers, An Introduction to Partial Differential Equations, Springer, 2004.

4. R. McOwen, Partial Differential Equations: Methods and Applications, 2nd Edition, Pearson Education, 2005.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Obtain the fundamental solutions of Laplace's, Heat and Wave equations	K1, K2, K3
CLO 2	Derive the mean-value formula of Laplace's, Heat and Wave equations	K2, K3, K4
CLO 3	Enhance their mathematical understanding in representing solutions of partial differential equations.	K2, K3, K4
CLO 4	Understand the fundamental theory to take a research career in the area of partial differential equations	K2, K3, K4
CLO 5	Apply different methods to obtain solutions	K2, K3, K4

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	2	2	2	2	1	2	2
CLO2	1	2	2	2	3	3	1	2	3
CLO3	1	2	2	2	2	3	1	1	3
CLO4	1	1	2	2	3	3	1	2	3
CLO5	1	2	2	2	2	3	1	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1E18	**MATHEMATICAL FINANCE**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective of this course is to introduce some basic definitions from finance and investigate the problem of pricing financial instruments and to build some more sophisticated market models that track the evolution stock prices over a succession of time periods.

UNIT I: Financial markets, Binomial trees, Portfolios and Arbitrage

Markets and Math – Stocks – Derivatives – Pricing futures contracts – Bond markets – Interest rate futures – Game theory method – Replicating portfolios – Probabilistic approach – Risk – Arbitrage

Chapters 1 & 2: Sections 1.1 - 1.5, 2.2-2.6

UNIT II: Stock Models and Option Pricing Models

Stock model – Tree model – Pricing an American and Exoticoption – Adjusting to real world data – Hedging the N-period – Discrete and continuous model – Black-Scholes formula andits derivation – Trees and Continuous models.

Chapter 3: Sections 3.1, 3.3, 3.4, 3.5

UNIT III: Black-Scholes Model and Hedging

Black-Scholes formula – Derivation – Solving the Black-Scholes Equations – Options on futures – Deltahedging – Methods for hedging – Implied volatility – Parameters Δ, Γ and Θ.

Chapters 5, 6 & 7: Sections 5.4 - 5.5, 6.5, 6.6, 7.1, 7.2, 7.3

UNIT IV: Interest Rate Options

Interest rates and forward rates – Zero-coupon bonds – Swaps – Pricing and hedging a swap – Interest rate models.

Chapter 8: Sections 8.1-8.5

UNIT V: Pricing Bonds

Bond price dynamics – Bond price formula – Spot rate – The HJM miracle – Tree models for bond prices – A BinomialVasicek model.

Chapters 8 & 9: Sections 8.6-8.9 & Sections 9.1, 9.2

TEXT BOOK:

Joseph Stampfli, Victor Goodman, *The Mathematics of Finance: Modeling and Hedging,* American Mathematical Society, First Indian Edition, 2013.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. S. Basu, John. C. Hull, Options, Futures and Other Derivatives, Eleventh Edition, Pearson Education, New Delhi, 2022.

2. Mark S. Joshi, The Concepts and Practice of Mathematical Finance, Cambridge University Press, 2008.

3. Sheldon M. Ross, An Elementary Introduction to Mathematical Finance, Cambridge University Press, London, 2011.

4. Ernst Eberlein, Jan Kallsen, Mathematical Finance, Springer Nature,Switzerland, 2019.

5. Steven Roman, Introduction to the Mathematics of Finance from Risk Management to Options Pricing, Springer International Edition, India, 2010.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the basic concepts of financial mathematics and financial derivative instruments.	K2, K3, K4
CLO 2	fundamental understanding of ho-Arbitrage pricing concept.	K2, K3, K4
CLO 3	Apply basic probability theory to option pricing in discrete time in the context of simple financial models.	K3, K4, K5
CLO 4	calculate basic quantities in financial mathematics and apply these concepts in financial markets and real- life situations.	K3, K4, K5
CLO 5	Study and random walks and use continuous martingale theory to simplify a number of calculations for Brownian motion.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	3	-	2	2	1	2	2
CLO2	1	1	3	-	2	2	1	1	2
CLO3	1	1	3	-	2	2	1	1	2
CLO4	1	1	3	-	2	2	1	1	3
CLO5	1	2	3	-	2	2	1	2	3

Course Code	Course Title	L	T	P	C
26UPMAT1E19	FLUID DYNAMICS	3	1	0	3

OBJECTIVE: The objective of this course is

- To give fundamental knowledge of fluid, its properties and behavior under various conditions of internal and external flows.
- To understand basic laws and equations used for analysis of static and dynamic fluids.
- To develop an appreciation for the properties of Newtonian fluids.
- To understand the dynamics of fluid flows and the governing non-dimensional parameters

UNIT I: Inviscid Theory

Introductory Notions, velocity: Streamlines and paths of the particles-stream tubes and filaments – fluid body – Density – Pressure – Bernoulli's theorem. Differentiation with respect to time – Equation of continuity – Boundary conditions: kinematical and physical – Rate of change of linear momentum – The equation of motion of an inviscid fluid.

Chapter I & III (TB1): Sections 1.0 - 1.4, 3.10 - 3.31, 3.40, 3.41

UNIT II: Inviscid Theory (contd…)

Euler's momentum theorem – conservative forces – Lagrangian form of the equation of motion – Steady motion – The energy equation – Rate of change of circulation – Vortex motion – Permanence of vorticity.

Chapter III (TB1): Sections 3.42 - 3.45, 3.50 - 3.53

UNIT III: Two Dimensional Motions

Two dimensional functions: Stream function – Velocity potential – Complex potential – Indirect approach – Inverse function. Basic singularities: Source – Doublet – Vortex – Mixed flow – Method of images: Circle theorem – Flow past circular cylinder with circulation. The aerofoil: Blasius's theorem – Lift force.

Chapter 3 (TB2): Sections 3.2, 3.3, 3.5 - 3.5.1, 3.5.2, 3.7.4, 3.7.5

Chapter 8 (TB3): Sections 8.3 - a,b, 8.4 - a

UNIT IV: Viscous Theory

The equations of motion for viscous flow: The stress tensor – The Navier-Stokes equations – Vorticity and circulation in a viscous fluid. Flow between parallel flat plates: Couette flow, Plane Poiseuille flow. Steady flow in pipes: Hagen-Poiseuille flow.

Chapter 5 (TB2): Sections 5.2.1- 5.2.3

UNIT V: Boundary Layer Theory

Boundary layer concept- Boundary layer equations in two dimensional flow- Boundary layer along a flat plate: Blasius solution – Shearing stress and boundary layer thickness – Momentum integral theorem for the boundary layer: The von Karman integral relation – von Karman integral relation by momentum law.

Chapter 9 (TB3): Sections 9.1, 9.2, 9.3 - a,b, 9.5 - a,b

TEXT BOOKS:

1. L.M. Milne Thomson, Theoretical Hydrodynamics, Dover, 1996.
2. N. Curle and H.J. Davies, Modern Fluid Dynamics Vol-I, D Van Nostrand Company Ltd., London, 1968.
3. S.W. Yuan, Foundations of Fluid Mechanics, Prentice Hall of India, New Delhi, 1988.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. R.K. Bansal, An Introduction to Fluid Dynamics, Firewall Media, 2005.
2. G.K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 2000.
3. F. Chorlton, Text Book of Fluid Dynamics, CBS Publications, Delhi, 1985.
4. D.E. Rutherford, Fluid Dynamics, Oliver and Boyd, 1959.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Apply laws of discrete mechanics to continuous systems	K3, K4
CLO 2	Apply basic principles of multi-variable calculus, differential equations and complex variables to fluid dynamic problems (OOP)s	K3, K4
CLO 3	Analyze fluid flow problems with the application of the momentum and energy	K4
CLO 4	Understand modeling approximations in finding exact solutions	K2
CLO 5	Derive boundary layer equations by logical reasoning	K3

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	-	3	3	3	3	2
CLO2	3	3	3	-	2	3	3	3	3
CLO3	2	3	3	-	3	2	3	3	3
CLO4	3	2	3	-	3	3	2	3	3
CLO5	2	3	3	-	2	2	3	3	3

Course Code	Course Title	L	T	P	C
26UPMAT1E21	**PROBABILITY THEORY**	**3**	**1**	**0**	**3**

OBJECTIVE: The objective of this course is to introduce axiomatic approach to probability theory and to study some statistical characteristics, discrete and continuous distribution functions and their properties, characteristic function and basic limit theorems of probability.

UNIT I: Random Events and Random Variables

Random events - Probability axioms - Combinatorial formulae - conditional probability - Bayes Theorem - Independent events - Random Variables - Distribution Function - Joint Distribution - Marginal Distribution - Conditional Distribution - Independent random variables - Functions of random variables.

Chapter 1 & 2: Sections 1.1 - 1.7, 2.1 - 2.9

UNIT II: Parameters of the Distribution

Expectation - Moments-The Chebyshev Inequality - Absolute moments - Order parameters - Moments of random vectors - Regression of the first and second types.

Chapter 3: Sections 3.1 - 3.8

UNIT III: Characteristic Functions

Properties of characteristic functions - Characteristic functions and moments - semi-invariants - characteristic function of the sum of the independent random variables - Determination of distribution function by the Characteristic function - Characteristic function of multidimensional random vectors - Probability generating functions.

Chapter 4: Sections 4.1 - 4.7

UNIT IV: Some Probability Distributions

One point, two point, Binomial - Polya - Hypergeometric - Poisson (discrete) distributions - Uniform - normal gamma - Beta - Cauchy and Laplace (continuous) distributions.

Chapter 5: Sections 5.1 - 5.10

UNIT V: Limit Theorems

Stochastic convergence - Bernoulli law of large numbers - Convergence of sequence of distribution functions - Levy-Cramer Theorems - de Moivre-Laplace Theorem - Poisson, Chebyshev, Khintchine Weak law of large numbers - Lindeberg Theorem - Lapunov Theroem - Borel-Cantelli Lemma - Kolmogorov Inequality and Kolmogorov Strong Law of large numbers.

Chapter 6: Sections 6.1 - 6.4, 6.6 - 6.9, 6.11 and 6.12

TEXT BOOK:

M. Fisz, *Probability Theory and Mathematical Statistics,* John Wiley and Sons, New York, 1963.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. R.B. Ash, Real Analysis and Probability, Academic Press, New York, 1972
2. K.L. Chung, A course in Probability, Academic Press, New York, 1974.
3. R. Durrett, Probability: Theory and Examples, (2nd Edition) Duxbury Press, New York, 1996
4. V.K. Rohatgi, An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi, 1988(3rd Print).
5. S.I. Resnick, A Probability Path, Birhauser, Berlin,1999.
6. B.R.Bhat, Modern Probability Theory (3rd Edition), New Age International (P)Ltd, New Delhi, 1999.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Calculate the expectation and moments of random variables.	K1, K2, K3
CLO 2	Identify the applications of various moment inequalities.	K2, K3, K4
CLO 3	Obtain the expressions for the characteristic function of a random variable and verify its properties.	K2, K3, K4
CLO 4	Classify the probability distributions as discrete or continuous case.	K2, K3, K4
CLO 5	Apply the various laws of large numbers to sequence of random variables.	K3, K4, K5

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	1	3	3	3	3	3	2	1
CLO2	2	1	3	3	3	3	3	2	1
CLO3	3	2	3	3	3	3	3	2	1
CLO4	1	2	3	3	3	3	3	2	1
CLO5	3	1	3	3	3	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1E22	NUMERICAL ANALYSIS	3	1	0	3

OBJECTIVES: The objectives of this course are

- to make the students familiarize with the ways of solving complicated mathematical problems numerically.
- To provide numerical methods for solving the non-linear equations, interpolation, differentiation, integration, ordinary and partial differential equations.
- Describing and understanding error analysis in numerical methods.

UNIT I: Solutions of Equations in One Variable
Newton's Method and its Extensions – Error Analysis for Iterative Methods – interpolation and Polynomial Approximation – Interpolation and the Lagrange Polynomial – Cubic Spline Interpolation.
Chapters 2 & 3: Sections 2.3, 2.4, 3.1, 3.5 (Algorithms are not included)

UNIT II: Numerical Differentiation and Integration
Numerical Differentiation – Elements of Numerical Integration – Romberg Integration.
Chapter 4: Sections 4.1, 4.3, 4.5 (Algorithms are not included)

UNIT III: Initial Value Problems for Ordinary Differential Equations
Elementary Theory of Initial Value Problems – Euler's Method – Taylor Method – Runge-Kutta Methods.
Chapter 5: Sections 5.1-5.4 (Algorithms are not included)

UNIT IV: Initial Value Problems for Ordinary Differential Equations (Continued)
Multistep Methods – Higher-Order Equations and Systems of Differential Equations – Stability.
Chapter 5: Sections 5.6, 5.9, 5.10 (Algorithms are not included)

UNIT V: Numerical Solutions to Partial Differential Equations
Elliptic Partial Differential Equations – Parabolic Partial Differential Equations – Hyperbolic Partial Differential Equations.
Chapter 12: Sections 12.1-12.3 (Algorithms are not included)

TEXT BOOK:
R. L. Burden and J.D. Faires, *Numerical Analysis,* 9th Edition, Thomson Learning. Inc., Stanford, Connecticut, 2011.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Sixth Edition, Addison-Wesley, Reading, 1998.

2. M.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International, 2003.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Apply numerical methods to obtain approximate solutions to mathematical problems.	K1, K2
CLO 2	Understand how to approximate the functions using interpolating polynomials	K2, K3 ,K4
CLO 3	Perform error analysis for various methods	K2, K3, K4
CLO 4	Learn numerical solution of ordinary and partial differential equations with an understanding of convergence, stability and consistency.	K2, K3, K4
CLO 5	Analyze and evaluate the accuracy of common numerical methods	K4,K5,K6

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	3	3	3	1	3	3	2	2	3
CLO2	2	2	2	3	2	3	2	2	2
CLO3	2	3	3	3	3	3	3	2	3
CLO4	3	3	3	2	2	3	2	3	3
CLO5	2	2	3	1	3	3	1	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1L01	DATA ANALYTICS WITH PYTHON	0	0	4	3

OBJECTIVE: The objective of this course is to provide students with a clear and practical understanding of data analytics using Python and Power BI. The course focuses on data handling, data preparation, basic database concepts, data modeling, and interactive data visualization, enabling students to analyze and present data effectively for decision-making.

Module I: Python Programming for Data Analytics

Objective: Develop a strong foundation in Python programming and essential libraries for data analysis.

- Introduction to Data Analytics and Python
- Installing Anaconda and Jupyter Notebook
- Python syntax, variables, data types, and operators
- Input/output operations
- Control structures (if, for, while)
- Looping statements: for and while - break, continue, and pass
- Functions and modules
- Strings, lists, tuples, dictionaries, and sets
- Introduction to NumPy: arrays, indexing, slicing, broadcasting, Matrix and array/vectorized operations using NumPy
- Basic data processing tasks

Module II: Data Analysis using Pandas

Objective: Learn to import, clean, transform, and explore datasets using Pandas.

- Introduction to Pandas
- Series and DataFrame
- Importing data from CSV, Excel, and databases
- Data inspection and summarization
- Data quality issues in real-world datasets
- Data cleaning: Data type correction and formatting, handling missing values, incorrect, duplicates, and inconsistent data
- Data transformation and feature engineering (Date and time handling - Renaming and restructuring columns - Merging and joining datasets - Reshaping data using pivot and melt - Preparing datasets for analytics and visualization)

- Filtering, sorting, and indexing
- Grouping, aggregation, and pivot tables
- Exploratory Data Analysis (EDA)

Module III: Data Visualization and Statistical Analysis

Objective: Visualize data effectively and perform statistical analysis to derive meaningful insights.

- Visualization using Matplotlib (line, bar, scatter, histogram, box, and pie charts)
- Interactive Visualization with Plotly
- Statistical analysis using SciPy and Statsmodels
- Descriptive statistics (Mean, Median, Mode, Variance, Standard Deviation)
- Probability: Random variables, probability distributions
- Correlation and covariance
- Sampling methods
- Confidence intervals
- Hypothesis testing (t-test, Chi-square test, ANOVA)

Module IV: Predictive Analytics Using Machine Learning

Objective: Build predictive models and evaluate their performance using Python.

- Introduction to Machine Learning - Supervised and Unsupervised learning
- Data preprocessing using Scikit-learn.
- Training and testing datasets
- Linear regression, Logistic regression
- Decision tree classification.
- Classification using K-Nearest Neighbors (KNN).
- Clustering using K-Means.
- Model evaluation and performance metrics: Accuracy, Precision, Recall, F1-score, ROC curve, Confusion matrix
- Introduction to model deployment concepts

Module V: Real-World Data Analytics Projects

Objective: Apply data analytics techniques to solve practical business and research problems.

- End-to-end analytics workflow
- Problem formulation
- Data acquisition
- Data preprocessing
- Exploratory Data Analysis (EDA)
- Statistical interpretation
- Predictive modeling
- Report generation
- Dashboard development
- Presentation of findings

Miniproject from anyone the following:

- Sales Analytics Dashboard
- Healthcare Data Analytics
- HR Analytics
- Banking Analytics
- Retail Analytics
- Education Analytics
- Financial Data Analysis
- Customer Segmentation and Market Basket Analysis

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Wes McKinney, Python for Data Analysis, O'Reilly Media.
2. Cole Nussbaumer Knaflic, Storytelling with Data

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Apply Python programming concepts for data handling and analysis	K2, K3
CLO 2	Import, clean, transform, and manage structured datasets using NumPy and Pandas.	K2, K3
CLO 3	Perform exploratory data analysis and create effective visualizations using Matplotlib and Plotly.	K3, K4
CLO 4	Develop, evaluate, and interpret basic machine learning models for predictive analytics using scikit-learn.	K3, K4
CLO 5	Execute end-to-end data analytics projects and communicate insights through professional reports and dashboards.	K5, K6

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	3	-	3	3	3	2	1
CLO2	1	2	3	-	3	3	3	2	1
CLO3	1	2	3	-	3	3	3	2	1
CLO4	1	2	3	-	3	3	3	2	1
CLO5	1	2	3	-	3	3	3	2	1

Course Code	Course Title	L	T	P	C
26UPMAT1S01	**NUMERICAL LINEAR ALGEBRA USING SAGEMATH**	**0**	**0**	**2**	**2**

OBJECTIVE: The aim of this course is to apply the concepts and solve problems in linear algebra through a hands-on training with SAGEMATH.

Module I: Vector Spaces and Matrices

- Performing various vector space operations.
- Performing various matrix manipulations.

Module II: Systems of Linear Equations and Vector Spaces

- Solving a system of linear equations.
- Verifying whether the given vectors are linearly independent and finding the dimension and basis of a given vector space.

Module III: Linear Transformations

- Performing addition, scalar multiplication, and composition of linear transformations.
- Constructing the linear transformation corresponding to a given matrix and finding the matrix representation of a given linear transformation.

Module IV: Eigenvalues and Diagonalization

- Computing the eigenvalues and eigenvectors of a given matrix.
- Verifying whether a given matrix is diagonalizable.

Module V: Integrated Laboratory Applications

- Solving comprehensive problems involving vector spaces, linear transformations, eigenvalues, and diagonalization.
- Mini project: Developing MATLAB programs for selected topics in linear algebra and interpreting the results.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Robert A. Beezer, A First Course in Linear Algebra, Independent, 2015.
2. P. Zimmermann et. al., Computational Mathematics with SageMath, Society for Industrial and Applied Mathematics (SIAM), 2018.

Course Code	Course Title	L	T	P	C
26UPMAT1S02	COMPUTATIONAL MATHEMATICS WITH MATLAB	0	0	2	2

OBJECTIVE: The objective of this course is to introduce students to numerical methods and techniques for solving mathematical problems that arise in various scientific and engineering disciplines. Emphasis is placed on both theoretical understanding and practical implementation using MATLAB.

Module I: MATLAB Programming Fundamentals

- Introduction to MATLAB environment
- Creating and manipulating arrays
- Matrix and vector operations
- Built-in mathematical functions
- Scripts and user-defined function files

Module II: Numerical Methods for Algebraic and Linear Systems

- Root-finding methods: Bisection, Newton–Raphson, and Secant methods
- Convergence and convergence rates
- Gaussian elimination
- LU decomposition
- Iterative methods: Jacobi and Gauss–Seidel
- Matrix factorizations and MATLAB implementation

Module III: Numerical Approximation Techniques

- Polynomial interpolation and curve fitting
- Numerical differentiation using finite differences
- Numerical integration
- Trapezoidal rule
- Simpson's rule

- Romberg integration
- MATLAB implementation of interpolation and integration methods

Module IV: Numerical Solution of Ordinary Differential Equations

- Euler's method
- Runge–Kutta methods
- Multistep methods
- Predictor–Corrector methods
- MATLAB implementation for solving initial value problems

Module V: Numerical Solution of Partial Differential Equations

- Classification of partial differential equations
- Finite difference methods
- Explicit and implicit schemes
- Numerical solution of one-dimensional and two-dimensional PDEs
- MATLAB implementation of finite difference methods

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. Amos Gilat, MATLAB: An Introduction with Applications, 4th Edition, Wiley, 2016
2. John H. Mathews and Kurtis D. Fink, Numerical Methods using MATLAB, 3rd Edition, Prentice Hall,
3. R. Pratap, *Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers*, Oxford University Press, 2009.
4. R.S. Esfandiari, *Numerical Methods for Engineers and Scientists Using MATLAB*, CRC Press, 2017.
5. A. Gupta, *Numerical Methods Using MATLAB*, Apress, 2015.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the basic starting of MATLAB and Windows, mathematical operations.	K1, K2, K3
CLO 2	Apply numerical methods to non -linear equations and linear systems with MATLAB.	K2, K3, K4
CLO 3	Perform curve fitting, numerical differentiation and integration in MATLAB.	K1, K2, K3
CLO 4	Use MATLAB to solve ordinary differential equations numerically.	K2, K3, K4
CLO 5	Apply finite difference methods to partial differential equations using MATLAB.	K2, K3, K4

Course Code	Course Title	L	T	P	C
26UPMAT1S03	TECHNICAL WRITING USING LATEX	0	0	2	2

OBJECTIVE: This course aims introduce the fundamentals of technical and scientific document preparation using LaTeX.

Module I: Introduction to LaTeX and Document Preparation

1. Introduction to Technical Writing
2. Installation of LaTeX Distribution and Editors (TeX Live/MiKTeX, TeXstudio, Overleaf)
3. Basic Structure of a LaTeX Document
4. Document Classes and Packages
5. Text Formatting, Lists, Sections, Fonts, and Special Characters
6. Compilation Process and Error Handling

Module II: Mathematical Typesetting and Graphics

8. Mathematical Symbols and Equations
9. Multi-line Equations and Equation Numbering
10. Matrices, Cases, Theorems, Lemmas, and Proof Environments
11. Tables and Figures
12. Drawing with TikZ and PGFPlots (Introduction)
13. Inserting Images and Controlling Float Placement

Module III: References, Bibliography, and Cross-Referencing

15. Labels, References, and Hyperlinks
16. Citations using BibTeX and BibLaTeX
17. Bibliography Styles
18. Footnotes, Endnotes, and Index Creation
19. Acronyms and Glossaries
20. Managing Large Documents with Multiple Files

Module IV: Scientific and Technical Document Preparation

22. Preparing Research Papers in Standard Journal Formats
23. Thesis and Dissertation Preparation
24. Title Page, Abstract, Keywords, Table of Contents
25. List of Figures, Tables, and Appendices
26. Page Layout, Headers, Footers, and Page Numbering
27. Journal Templates (IEEE, Springer, Elsevier, etc.)

Module V: Advanced LaTeX Applications and Best Practices

29. Creating Presentations using Beamer
30. Posters and Conference Proceedings
31. Custom Commands, Macros, and Style Files
32. Advanced Table and Figure Formatting
33. Collaborative Writing with Overleaf and Version Control
34. Best Practices in Technical Writing and Final Project Preparation

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. B. N. Basu, Technical Writing, PHI Learning Pvt. Ltd., 2007.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the fundamentals of technical and scientific document preparation using LaTeX.	K1, K2
CLO 2	Create well-structured academic documents, including research papers, dissertations, theses, and technical reports, using appropriate LaTeX document classes.	K2, K3
CLO 3	Format mathematical equations, theorems, proofs, algorithms, tables, figures, and bibliographic references according to academic standards.	K3, K4
CLO 4	Apply advanced LaTeX features such as cross-referencing, citations, indexing, hyperlinks, and bibliography management using BibTeX/Biber.	K3, K4
CLO 5	Design professional-quality documents, presentations, and posters using suitable LaTeX packages and templates.	K4

Course Code	Course Title	L	T	P	C
26UPMAT1S04	DATA ANALYSIS USING R PROGRAMMING	0	0	2	2

OBJECTIVE: The objective of this course is to equip students with the knowledge and practical skills required to perform data analysis using the R programming language. The course introduces students to data acquisition, cleaning, transformation, visualization, and statistical analysis, and provides hands-on experience in applying machine learning techniques and advanced analytical tools to real-world datasets.

Module I: Introduction to R and Data Handling

1. Install R and RStudio and explore the R programming environment.
2. Import and export datasets in CSV and Excel formats.
3. Create and manipulate vectors, matrices, lists, and data frames.
4. Explore dataset structure and summary statistics.
5. Select, filter, and sort data.
6. Rename variables and create new variables.
7. Handle missing values and duplicate records.
8. Perform data type conversion (numeric, character, factor, logical).
9. Manipulate date, time, and string variables.
10. Merge and join multiple datasets.

Module II: Data Manipulation and Exploratory Data Analysis

11. Compute descriptive statistics and summary measures.
12. Calculate measures of central tendency and dispersion.
13. Generate frequency tables and contingency tables.
14. Identify outliers using boxplots.
15. Create histograms and density plots.
16. Construct scatter plots and pair plots.
17. Generate correlation matrices and correlation plots.

18. Perform grouped data analysis using aggregation functions.
19. Transform and reshape datasets.
20. Produce publication-quality graphics using `ggplot2`.

Module III: Statistical Data Analysis and Regression

21. Perform one-sample, paired, and independent t-tests.
22. Conduct chi-square tests of independence.
23. Perform one-way and two-way ANOVA.
24. Compute correlation and covariance matrices.
25. Develop simple linear regression models.
26. Develop multiple linear regression models.
27. Perform logistic regression.
28. Validate regression models using residual diagnostics.
29. Perform Principal Component Analysis (PCA).
30. Perform Cluster Analysis using K-Means and Hierarchical Clustering.

Module IV: Data Visualization and Time Series Analysis

31. Create bar charts, pie charts, and line graphs.
32. Create grouped boxplots and violin plots.
33. Generate heatmaps.
34. Create interactive visualizations using `Plotly`.
35. Import and visualize time-series data.
36. Perform moving average smoothing.
37. Decompose time-series into trend and seasonal components.
38. Forecast future observations using ARIMA models.
39. Evaluate forecasting accuracy.
40. Prepare analytical reports using R Markdown.

Module V: Machine Learning Using R

41. Split datasets into training and testing sets.
42. Normalize and preprocess datasets.
43. Build Decision Tree classifiers.
44. Develop Random Forest models.
45. Implement K-Nearest Neighbour (KNN) classification.
46. Build Support Vector Machine (SVM) models.
47. Apply Na ve Bayes classification.
48. Evaluate models using confusion matrices and ROC curves.
49. Perform cross-validation and compare predictive models.
50. Mini Project: Perform end-to-end data analysis and predictive modeling on a real-world dataset, including data preprocessing, visualization, model development, evaluation, and presentation of results.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the fundamentals of R programming and data structures for data analysis.	K1, K2
CLO 2	Apply data preprocessing, transformation, and visualization techniques using R packages.	K2, K3
CLO 3	Perform descriptive and inferential statistical analyses on real-world datasets.	K2, K3
CLO 4	Develop predictive models using machine learning and time-series analysis techniques in R.	K3, K4
CLO 5	Create interactive visualizations, dashboards, and analytical reports to communicate data-driven insights effectively.	K3, K4

Course Code	Course Title	L	T	P	C
26UPMAT1S05	**MATHEMATICAL COMPUTING USING PYTHON**	**0**	**0**	**2**	**2**

OBJECTIVE: To develop proficiency in Python programming for solving mathematical, scientific, and real-world computational problems.

Module I: Python Programming Fundamentals

1. Basic arithmetic operations and input/output.
2. Conditional statements and loops.
3. Factorial, Prime number, Armstrong number, and palindrome programs.
4. Fibonacci series and factorial using recursion.
5. String manipulation and pattern generation.
6. Lists, tuples, dictionaries, and sets.
7. Functions and lambda expressions.
8. Exception handling.
9. File handling (Text and CSV files).
10. Modules and packages.

Module II: Object-Oriented Programming and Data Processing

1. Classes and objects.
2. Inheritance, polymorphism, and encapsulation.
3. Operator overloading.
4. Matrix operations using NumPy.
5. Solving systems of linear equations.
6. Computing eigenvalues and eigenvectors.
7. Reading and manipulating datasets using Pandas.
8. Statistical analysis of datasets.
9. Data visualization using Matplotlib.
10. Advanced plotting techniques.

Module III: Numerical Computing and Scientific Programming

1. Numerical integration using the Trapezoidal and Simpson's rules.
2. Newton–Raphson method for solving nonlinear equations.
3. Newton's forward and backward interpolation
4. Lagrange's interpolation.
5. Numerical differentiation.
6. Solving ordinary differential equations using `solve_ivp`.
7. Solving boundary value problems.
8. Numerical optimization using SciPy.
9. Symbolic computation using SymPy.

Module IV: Advanced Python Applications

1. Finite difference solution of the heat equation.
2. Finite difference solution of the wave equation.
3. GUI programming using Tkinter.
4. Database programming using SQLite.
5. Reading and writing Excel files.
6. Interactive data visualization using Plotly.
7. Image processing using OpenCV.

Module V: Machine Learning and Mini Projects

1. Data preprocessing using Scikit-learn.
2. Linear regression.
3. Classification using K-Nearest Neighbors (KNN).
4. Decision tree classification.
5. Clustering using K-Means.
6. Model evaluation and performance metrics.

7. Numerical solver for differential equations.

8. Mini project integrating Python, scientific computing, and data analysis.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. W. J. Chun, Core Python Programming, Prentice Hall, 2006.

2. A. B. Dowley, Think Python: How to Think Like a Computer Scientist, 2nd Edition, Shroff/O'Reilly, 2016.

3. J. Kiusalaas, Numerical Methods in Engineering with Python 3, Cambridge University Press, 2014.

4. W. McKinney, Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython, O'Reilly, 2nd Edition, 2018.

5. J.VanderPlas, Python Data Science Hand Book: Essential Tools for working with Data, O'Reilly, 2017.

6. N. Safina Devi and C.Devamanoharan, Algorithmic Problem Solving and Python – A Beginner's Guide, Francidev Publications, 2023.

Course Code	Course Title	L	T	P	C
26UPGEN1V01	PEACE EDUCATION	2	0	0	2

OBJECTIVE: To develop learners' knowledge, values, attitudes, and skills that promote peace, mutual respect, non-violence, and responsible citizenship in a diverse society.

UNIT I: Introduction to Peace Education and HWPL

Aims and objectives of Peace Education - Development of peace work of HWPL - Making groups for assignments - Rapport building.

UNIT II: Finding peace and Me

Diversity - Harmony - Original State of All Creation - Connectivity - Value-Role - Duty - Interpersonal Relationship - Greed - Love - Order.

UNIT III: Peace Values

Gratitude - Consideration - Sacrifice - Understanding - Forgiveness - Respect for Parents, Teachers and Peace - Scripture - Cultural Sphere.

UNIT IV: Peace Citizen

Heritage - World Peace - Great Legacy; a case of peace - Law - Law-abiding Spirit - Treaty - DPCW - NGO; HWPL - Peace citizen - Courage - Peace-loving Heart - Messenger of Peace.

UNIT V: Peace Messenger

Peace Messenger - Peace experience - Will for Peace.

Tasks and Assignments:

1. Writing an Essay on World Peace and Gratitude.
2. Engaging in debates on topics related to Peace.
3. Group Project for practicing Peace Values.
4. Group Project to promote the importance of Peace.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. https://www.un.org/en/
2. https://www.youtube.com/watch?v=18LhBZc6Sn4
3. https://www.hwpl.kr/language/en/home-hwpl-_en/
4. Heavenly Culture of World Peace Restoration of Light, 2022.

5. Road to Peace Oh IK-soo, 1996.
6. Youth Group counseling.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the importance of Peace	K2
CLO 2	Explain how to recover the state of Peace	K2
CLO 3	Internalize and Practice the Values of Peace	K3
CLO 4	Understand sustainable Peace and the role of oneself	K2
CLO 5	Become the peace messenger who spreads the culture of peace	K3

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CLO1	3	1	1	2	1	1
CLO2	2	3	3	1	1	1
CLO3	1	2	1	-	3	3
CLO4	3	3	3	3	3	2
CLO5	3	3	3	3	1	2

Course Code	Course Title	L	T	P	C
26UPMAT1N01	**NUMERICAL AND STATISTICAL METHODS**	**2**	**0**	**0**	**2**

OBJECTIVE: The objective of this course is to provide the mathematical foundation for numerical methods and statistics.

UNIT I: Algebraic and Transcendental Equations

Bisection Method − Iteration Method − The Method of False Position − Newton − Raphson − Method

Chapter 3 (TB1): Sections 3.1 to 3.4

UNIT II: System of Linear Equation

Gauss Elimination, Gauss Jordon elimination − Triangularization method −Iterative Methods, Jacobi, Gauss−Seidal iteration.

Chapter 4 (TB1): Sections 4.1 to 4.4, 4.8, 4.9

UNIT III: Interpolation

Interpolation for equal intervals − Newton forward and backward formula − Central Difference Interpolation formula − Gauss forward and backward formula −Stirling's formula − Bessel's Formula − Numerical differentiation: Maximum and minimum values of a tabulated function. Numerical Integration: Trapezoidal Rule − Simpson's Rule.

Chapters 6, 7 & 9 (TB1): Sections 6.1 to 6.3, 7.2 to 7.6, 9.6 to 9.16

UNIT IV: Basic Distribution

Binominal distribution − Poisson distribution − Normal distribution − Properties and Applications.

Chapter 7 & 8 (TB2): Sections 7.2, 7.3, 8.2

UNIT V: Correlation and Regression

Fitting of the curve of the form $ax + b$, $ax^2 + bx + c$, ab^x and $a^x b$ − Correlation Coefficient − Rank correlation coefficient of determination − Linear regression − Method of least squares − Multiple and partial correlation (3-variable only).

Chapter 9 & 10 (TB2): Sections 10.3 to 10.7, 10.11, 9.1

TEXTBOOK:

1. P. Kandasamy, K. Thilagavathy and K. Gunavathi, Numerical Methods, 3rd Edition, S. Chand, 2006.

2. 2. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand &

Sons, 1994.

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. S. Kalavathy, *"Numerical Methods", Vijay Nicole, Chennai, 2004.*
2. S.S. Sastry, *"Introductory Methods of Numerical Analysis", Prentice Hall of India, Pvt Ltd., 1995.*

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Apply numerical methods to obtain approximate solutions to algebraic equations.	K1, K2
CLO 2	Understand how to solve system of linear equation	K1, K2, K3
CLO 3	Application of numerical integration and differentation.	K1, K2, K3
CLO 4	Basic concepts of distribution	K1, K2, K3
CLO 5	Computation of correlation and regression	K1, K2, K3

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	1	1	2	2	2	1	1	2
CLO2	1	1	1	2	2	3	1	1	3
CLO3	1	1	1	2	2	2	1	1	2
CLO4	1	1	1	2	2	3	1	1	2
CLO5	1	1	1	2	2	2	1	1	2

Course Code	Course Title	L	T	P	C
26UPMAT1N02	**MATHEMATICS FOR AI**	**2**	**0**	**0**	**2**

OBJECTIVE: This course aims to provide the fundamental mathematical concepts required for getting into the field of artificial intelligence.

UNIT I: Linear Algebra for AI

Scalars, vectors, matrices and tensors, Matrix operations and special matrices, Systems of linear equations and Gaussian elimination

UNIT II: Linear Algebra for AI

Matrix Operations, Eigenvalues and Eigenvectors – Iterative methods for computing eigenvalues – Gram-Schmidt Process – Singular Value Decomposition – LU decomposition, QR Decomposition – Moore Penrose inverse – Principal Component Analysis

UNIT III: Calculus for Machine Learning

Functions of one and several variables – Limits and continuity – Partial derivatives and gradients – Jacobian and Hessian matrices – Chain rule and multivariable differentiation.

UNIT IV: Probability and Statistics for AI

Probability axioms and conditional probability – Bayes' theorem – Random variables and probability distributions – Expectation, variance and covariance – Common distributions (Bernoulli, Binomial, Poisson, Gaussian) – Joint and marginal distributions – Correlation, Regression and Covariance.

UNIT IV: Optimization Methods in Machine Learning

Introduction to Optimization Problems, Classification of Optimization Problem, Definition of Global and Local optima, Optimality conditions; Convex Programming Problems; Analytical Optimization Techniques: Lagrange's Multipliers Methods, Karaush-Kuhn- Tucker (KKT) Method

BOOKS FOR SUPPLEMENTARY READING AND REFERENCES:

1. C. Shah, A Hands-on Introduction to Data Science. Cambridge University Press, 2020.
2. M. P. Deisenroth, A. A. Faisal, and C. S. Ong. Mathematics for Machine Learning, Cambridge University Press, 2020.
3. Gilbert Strang, Linear Algebra and its Applications, Cengage India Private Limited, Fourth Edition, 2005.
4. B. N. Datta, Numerical Linear Algebra and Applications, Second Edition,SIAM, 2010.

5. S. S Rao, Engineering Optimization Theory and Practice, New Age, 4th Edn., 2023.
6. S. Sra, S. Nowozin and S.J. Wright, Optimization for Machine Learning, MIT Press, 2011.
7. Kalyanmoy Deb, Optimization for Engineering Design, PHI, 2nd Edn., 2021.
8. S. Sra, S. Nowozin and S.J. Wright, Optimization for Machine Learning, MIT Press, 2011.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Understand the basic mathematical concepts in data science, related to linear algebra, probability, and calculus	K1, K2, K3
CLO 2	Employ techniques and methods related to these concepts in a variety of data science applications.	K1, K2, K3
CLO 3	Apply logical thinking to understand and solve problems	K1, K2, K3
CLO 4	Demonstrate skills in writing mathematics	K1, K2, K3
CLO 5	Adopt a rigorous and mathematical approach to solving problems in machine learning and data science.	K1, K2, K3

MAPPING WITH PROGRAMME OUTCOMES:

CLO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PSO 1	PSO 2	PSO 3
CLO1	1	2	2	1	2	3	2	2	1
CLO2	2	2	2	1	2	3	2	2	2
CLO3	3	3	2	1	2	3	2	2	2
CLO4	2	2	2	1	2	3	2	2	1
CLO5	3	3	2	1	2	3	2	2	2

Course Code	Course Title	L	T	P	C
26UPMAT1V01	**MATHEMATICA (LAB)**	**0**	**0**	**2**	**2**

OBJECTIVE: Numerical calculation, Compile notes, equations, sample calculations, graphics, references, and hyperlinks in a single document. Visualize data or functions with 2D/3D graphics and charts. Analyze real-world data with ready-to-use data sets. Mathematical functions - Algebraic manipulation - Numerical calculations of differential and integral Calculus.

UNIT I:

Running Mathematica – Numerical calculations – Building up calculations – Using the Mathematica system – Algebraic calculations – Symbolic mathematics – Numerical mathematics.

Chapter 1: Sections 1.0 – 1.6

UNIT II:

Graphics and Sound – Files and External Operations

Chapter 1: Sections 1.9 – 1.11

UNIT III:

Textual Input and Output – The Structure of Graphics and Sound

Chapter 6: Sections 2.9 – 2.10

UNIT IV:

Numbers – Mathematical functions – Algebraic manipulation – Manipulating equations - Calculus.

Chapter 3: Sections 3.1 – 3.5

UNIT V:

Series, limits and residues - Linear algebra.

Chapter 3: Section 3.6 – 3.7

TEXT BOOK:

S. Wolfram, *The Mathematica Book,* Fourth Edition, Cambridge University Press, Cambridge, 1999.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Start with Running mathematical- Basic Mathematical calculation with symbolic	K1, K2, K3
CLO 2	Understanding the graphics & sound in 2D and 3D	K2, K3, K4
CLO 3	Learning the output and input formation in mathematica.	K2, K3, K4
CLO 4	Evaluate the mathematical functions and calculus in mathematica.	K2, K3, K4
CLO 5	Applications to mathematical calculation like a series, limits, residue at Linear Algebra.	K2, K3, K4

Course Code	Course Title	L	T	P	C
26UPMAT1V02	**MATLAB (LAB)**	**0**	**0**	**2**	**2**

OBJECTIVE: This course provides basic fundamentals on MATLAB, primarily for numerical computing. To learn the characteristics of script files, functions and function files, two-dimensional plots and three-dimensional plots. To enhance the programming skills with the help of MATLAB and its features which allow learning and applying specialized technologies.

UNIT I:
Starting with Matlab – Creating arrays – Mathematical operations with arrays.
Chapters 1, 2 & 3

UNIT II:
Script files – Functions and function files.
Chapters 4 & 6

UNIT III:
Two-dimensional plots – Three-dimensional plots.
Chapters 5 & 9

UNIT IV:
Programming in MATLAB. (Keywords to be included)
Chapter 7

UNIT V:
Polynomials, Curve fitting and interpolation – Applications in numerical analysis.
Chapters 8 & 9

TEXT BOOK:
A. Gilat, *MATLAB - An Introduction with Application,* John Wiley & Sons, Singapore, 2004

List of practical programs will be issued by course teacher.

COURSE LEARNING OUTCOMES: After the successful completion of the course, students will be able to

CLO	Statements	Knowledge Level
CLO 1	Learning the basic windows in MATLAB and mathematical operations with arrays	K1, K2, K3
CLO 2	Creating scripts e functions file in MATLAB	K2, K3, K4
CLO 3	Understanding the various type of 2D & 3D plots and animations	K2, K3, K4
CLO 4	Study the various type of loops in MATLAB	K2, K3, K4, K5
CLO 5	Applications to numerical analysis like solving algebraic equations, curve fitting and interpolation	K3, K4, K5