ఆంధ్రప్రదేశ్ కేంద్రీయ విశ్వవిద్యాలయం आंध्रप्रदेश केंद्रीय विश्वविद्यालय

CENTRAL UNIVERSITY OF ANDHRA PRADESH

Jnana Seema, Ananthapuramu, India - 515701

DEPARTMENT OF MATHEMATICS AND COMPUTING
SCHOOL OF INTERDISCIPLINARY AND APPLIED SCIENCES

Masters Programme
(as per the National Credit Framework 2023)

Vidya Dadati Vinayam
(Education Gives Humility)

M.Sc. Mathematics and Computing

Programme Structure
(Effect from Academic Year 2026 - 27)

M.Sc. Mathematics and Computing

Department of Mathematics and Computing

School of Interdisciplinary and Applied Sciences

CONTENTS

M.Sc. Mathematics and Computing
Department of Mathematics and Computing
School of Interdisciplinary and Applied Sciences

1. Introduction to the Programme

The Department of Mathematics was established in the Academic Year 2021-22. In view of present industry and technology requirements/demands, the Department name has changed into **Department of Mathematics and Computing** from the Academic Year 2025-26 onwards. The Department of Mathematics and Computing offers a two-year M.Sc. programme in **Mathematics and Computing**, which is an advanced version of the traditional M.Sc. Mathematics programme. This updated curriculum reflects the growing importance and intersection of mathematics and computer science in various fields including Science, Artificial Intelligence (AI), Machine Learning (ML), and Data Science (DS). This programme consists of core mathematics courses, which are helpful to the students to clear the national and international level competitive exams, as well as Ph.D. entrance tests in pure and applied mathematics. This programme also covers foundational level courses like Python and 'R' software for programming, Introduction to AI and ML for understanding the practical and techniques in AI, ML and DS. The department also has well equipped labs to support the students to enhance programming skills through latest computational softwares. Furthermore, the department also recommends the latest courses in mathematics, statistics, computer science, and related fields through MOOC courses each semester. The department also encourages/motivates the students towards the latest research on Mathematics, Computer Science, and other disciplines of applied sciences through master's dissertation projects.

2. Programme Vision

It aims to bridge the gap between theoretical mathematical concepts and their practical applications in computing, equipping students to tackle complex real-world problems in various fields. Product graduates who are adept at leveraging mathematical principles and computational tools to address complex challenges, innovate, and make meaningful contributions to academia, industry, and society.

3. Programme Educational Objectives (PEOs)

The Programme Educational Objectives describe the expected accomplishments of graduates within a few years after completing the programme.

PEO1: To provide strong foundational knowledge in pure and applied mathematics, along with computational techniques, enabling graduates to solve complex real-world problems.

PEO2: To develop analytical, logical, and problem-solving skills required for careers in academia, research, industry, and interdisciplinary domains such as data science, AI, and scientific computing.

PEO3: To equip students with modern computational tools (Python, R, MATLAB, optimization techniques) for modeling, simulation, and data-driven decision-making.

PEO4: To foster research aptitude and innovation through exposure to advanced topics such as functional analysis, numerical methods, machine learning, and optimization.

PEO5: To prepare graduates for lifelong learning, higher studies (Ph.D.), and professional growth with ethical and societal responsibility.

4. Programme Outcomes (POs)

Upon successful completion of the programme, graduates will be able to:

PO1: Mathematical Knowledge
Apply advanced knowledge of core areas such as Real Analysis, Abstract Algebra, Linear Algebra, Topology, and Functional Analysis to solve theoretical and applied problems.

PO2: Problem Analysis
Identify, formulate, and analyze complex mathematical, computational, and interdisciplinary problems using logical reasoning and analytical skills.

PO3: Computational Skills
Develop and implement algorithms using programming languages such as Python, R, and MATLAB for solving mathematical and real-world problems.

PO4: Modeling and Simulation
Construct and analyze mathematical models using differential equations, numerical methods, and optimization techniques to study physical and engineering systems.

PO5: Statistical and Data Analysis
Apply probability, statistics, and statistical inference techniques to analyze data and support decision-making in scientific and industrial applications.

PO6: Machine Learning and AI Competence
Understand and apply foundational concepts of Artificial Intelligence and Machine Learning, including neural networks and data-driven techniques.

PO7: Research and Innovation
Demonstrate the ability to conduct independent research, including problem identification, literature review, methodology design, and dissertation work.

PO8: Modern Tool Usage
Utilize modern computational tools, software, and platforms (such as Python, R, MATLAB, and MOOCs) effectively for mathematical computation and analysis.

PO9: Interdisciplinary Approach
Integrate mathematical and computational techniques with domains such as computer science, physics, economics, and engineering.

PO10: Communication Skills
Communicate mathematical concepts, computational results, and research findings effectively through presentations, reports, and seminars.

PO11: Professional Ethics and Lifelong Learning
Demonstrate ethical responsibility, professional integrity, and a commitment to continuous learning through MOOCs and emerging technologies.

PO12: Project Management and Teamwork
Exhibit the ability to work independently and collaboratively, manage projects efficiently, and meet deadlines, especially during internships and dissertation work.

5. Programme-Specific Outcomes (PSOs):

PSO1 Advanced Mathematical Modeling: Develop and analyze mathematical models using real analysis, functional analysis, differential equations, and optimization techniques.

PSO2 Scientific Computing and Programming: Design and implement algorithms using Python, R, and MATLAB for numerical analysis, data science, and scientific computing applications.

PSO3 Data Science and AI Applications: Apply probability, statistics, machine learning, and linear programming techniques to solve problems in artificial intelligence, data analytics, and industry applications.

5. Pedagogy of the Programme

The pedagogy of an M.Sc program in Mathematics and computing typically combines traditional lectures with interactive seminars, workshops, practical sessions, Student-centric learning, Group discussions, Guest lectures, Independent Studies and Interactive sessions, Project based learning, Research orientation, Seminars & workshops on current topics, Tutorial & assignments, Class test / Open book test. Overall, it emphasizes active learning, problem-solving, collaboration, and research, equipping students with the knowledge, skills, and mindset required for success in academia, industry, and beyond.

6. Programme Structure

- The Master of Science in Mathematics and Computing is a two-year postgraduate programme divided into four semesters, comprising a total of 92 credits.
- The curriculum integrates Core Courses, Discipline-Specific Electives, Multidisciplinary Courses, MOOCs, Skill-based Courses, Laboratory Components, and Dissertation Work, ensuring a balanced and comprehensive learning experience that combines theoretical depth with computational and practical skills.
- **Semester-wise Structure:**
    - **Semester I:** Consists of four core courses, namely Real Analysis, Abstract Algebra, and Ordinary Differential Equations, along with a programming course in Python with laboratory component. This semester consists of one Discipline-Specific Elective (DSE) course (Number Theory/Linear Algebra and Matrix Methods) and one MOOC (IDE-I). This semester builds a strong mathematical and computational foundation essential for advanced coursework in subsequent semesters.
    - **Semester II:** Includes core courses such as Topology, Partial Differential Equations, Mathematical Foundations for Computer Science, along with Probability and Statistics with R Programming (with lab component). It also offers a Discipline-Specific Elective (Calculus of Variations and Integral Equations/ Statistical Inference), one MOOC (IDE-II), and a skill-based course on Introduction to AI and ML with lab component. This semester emphasizes both theoretical advancement and data-driven computational skills.
    - **Semester III:** Focuses on advanced and applied topics including Functional Analysis, Fluid dynamics, Numerical Analysis and Scientific Computing (with MATLAB lab), Complex Analysis and one computing related course i.e. Data Structures. It also includes a Discipline-Specific Elective (Database Management System / Machine Learning Foundations and Techniques) to build a foundations for AI/ML and Data Science and one MOOC (IDE-III). This semester also contains one Common Compulsory Course (Building Mathematical Ability and Financial Literacy) and research internship. This semester strengthens research orientation and interdisciplinary applications.
    - **Semester IV:** Comprises advanced core courses such as Advanced Numerical Analysis and Scientific Computing and Operation Research, along with a major Dissertation/Project Work. This semester is dedicated to independent research, enabling students to apply mathematical and computational techniques to real-world problems.

M.Sc. Mathematics and Computing

Department of Mathematics and Computing

School of Interdisciplinary and Applied Sciences

Semester and Course wise Credits Distribution

Semester	Core Course Crdits				DSE Credits		IDE Credits		CCC Credits				SIP Credits		Dissertation Credits		Total Credits
	Code	T	L/P	Total	Code	Total	Code	Total	Code	T	L/P	Total	Code	Total	Code	Total	
1	MAT101	4	0	4	MAT111	**3**	MAT112 MOOC	3	-		-	-	-	-	-	-	**22**
	MAT102	4	0	4													
	MAT103	4	0	4													
	MAT104	2	2	4													
	Total	**14**	**2**	**16**	-	**3**	-	**3**	-	-	-	-	-	-	-	-	
II	MAT201	2	2	4	MAT211	3	MAT212 MOOC	3	CCC213	2	2	4	-	-	-	-	**23**
	MAT202	3	0	3													
	MAT203	3	0	3													
	MAT204	3	0	3													
	Total	**11**	**2**	**13**		**3**	-	**3**	-	**2**	**2**	**4**	-		-	-	
III	MAT301	4	0	4	MAT311	3	MAT312 MOOC	3	CCC313	**2**	-	**2**	MAT314	**2**	-	-	**28**
	MAT302	2	2	4													
	MAT303	2	2	4													
	MAT304	3	0	3													
	MAT305	3	0	3													
	Total	**14**	**4**	**18**		**3**	-	**3**	-	**2**	-	**2**	-	**2**	-	-	
IV	MAT401	4	0	4	-	-	-	-	-	-	-	-	-	-	MAT411	**12**	**19**
	MAT402	3	0	3													
	Total	**7**	**0**	**7**	-	-	-	-	-	-	-	-	-	-	-	**12**	
Total Courses	**15**	-	-	-	**3**	-	**3**	-	**2**	-	-	-	-	-	**1**	-	**24**
Total Credits	-	46	8	**54**	-	**9**	-	**9**	-	4	2	**6**	-	**2**	-	**12**	**92**
Percentage	-	-	-	**58.69**	-	**9.78**	-	**9.78**	-	-	-	**6.52**	-	**2.17**	-	**13.04**	**100**

Note: T: Theory **L/P:** Lab/Practicals **DSE:** Discipline Specific Elective
IDE: Inter-disciplinary Electives **CCC:** Common Compulsory Course **SIP:** Summer Internship Project

Programme Structure

Semester I						
Sl. No.	Course Code	Title of the Course	Credit Points	Credit Distribution		
				L*	T*	P*
1	MAT101	Real Analysis	4	3	1	0
2	MAT102	Abstract Algebra	4	3	1	0
3	MAT103	Ordinary Differential Equations	4	3	1	0
4	MAT104	Computer Programming in Python	4	2	0	0
		Lab: Computer Programming in Python		0	0	2
6	**Elective-I: Any one of the following**		3	2	1	0
	MAT111	A. Number Theory				
		B. Linear Algebra and Matrix Methods				
7	MAT112	***IDE-I:** MOOCs	3	3	0	0
Total			**22**	**14**	**4**	**2**

Semester II						
Sl. No.	Course Code	Title of the Course	Credit Points	Credit Distribution		
				L*	T*	P*
1	MAT201	Probability and Statistics with R Programming	4	2	0	0
		Lab: Probability and Statistics with R Programming		0	0	2
2	MAT202	Topology	3	2	1	0
3	MAT203	Partial Differential Equations	3	2	1	0
4	MAT204	Mathematical Foundations for Computer Science	3	2	1	0
5	**Elective-II: Any one of the following**		3	2	1	0
	MAT211	A. Calculus of Variations and Integral Equations				
		B. Statistical Inference				
6	MAT212	***IDE-II:** MOOCs	3	3	0	0
7	CCC213	**CCC:** Introduction to AI and ML	4	2	0	0
		Lab: Introduction to AI and ML		0	0	2
Total			**23**	**15**	**4**	**4**

Semester III						
Sl. No.	**Course Code**	**Title of the Course**	**Credit Points**	**Credit Distribution**		
				L*	**T***	**P***
1	MAT301	Fluid Dynamics	4	3	1	0
2	MAT302	Numerical Analysis and Scientific Computing with MATLAB	4	2	0	0
		Lab: Numerical Analysis and Scientific Computing with MATLAB		0	0	2
3	MAT303	Data Structures	4	2	0	0
		Lab: Data Structures		0	0	2
4	MAT304	Functional Analysis	3	2	1	0
5	MAT305	Complex Analysis	3	2	1	0
6	**Elective-III: Any one of the following**		3	2	1	0
	MAT311	A. Database Management System				
		B. Machine Learning Foundations and Techniques				
7	MAT312	***IDE-III:** MOOCs	3	3	0	0
8	CCC313	Building Mathematical Ability and Financial Literacy	2	2	0	0
9	MAT314	Internship	2	0	0	2
Total			**28**	**18**	**4**	**6**

Semester IV						
Sl. No.	**Course Code**	**Title of the Course**	**Credit Points**	**Credit Distribution**		
				L*	**T***	**P***
1	MAT401	Advanced Numerical Analysis and Scientific Computing	4	3	1	0
2	MAT402	Operations Research	3	2	1	0
3	MAT411	Dissertation	12	0	0	12
Total			**19**	**5**	**2**	**12**
Grand Total			**92**	**52**	**14**	**24**

Note: L: Lectures; **T:** Tutorials; **P:** Practical's

Semester-wise Credit Distribution

Semester	Total Credits	Cumulative credit at the end of the semester
1	22	22
II	23	45
III	28	73
IV	19	92

I. Credit Requirement

- The minimum number of credits required to be earned by a student for the award of the degree is **95**.
- Students may earn credits in excess of 95 by opting for additional courses; however, the upper limit shall not exceed **96 credits**.

II. Assessment Pattern

- **Theory Courses**:
  - **Internal (40%)** – Formative evaluation comprising two best out of three tests (each test carrying a maximum of 15 marks, totalling 30 marks), along with seminar/assignments/attendance (10 marks).
  - **External (60%)** – Summative evaluation through the semester-end examination.

III. Laboratory Components:

- **Internal (60%)** – Continuous assessment through lab work and internal examination.
- **External (40%)** – Summative evaluation through the semester-end practical examination.

IV. End-Semester Examination:

- Maximum Marks: **60**
- Duration: **3 Hours**

Important Information to Students

i. Eligibility: A Bachelor's degree in Economics with at least 50% marks in aggregate and at least 50% marks in Economics with Mathematics/Statistics; Or Bachelor's degree with at least 60% marks in aggregate any of the allied subjects viz. Commerce, Statistics, Mathematics, Engineering or any of the Social Sciences subjects with Mathematics/Statistics.

ii. The minimum duration for completion of the programme is four semesters (two academic years) and the maximum duration is eight semesters (four academic years) or as per amendments made by the regulatory bodies from time to time.

iii. A student should attend at least 75% of the classes, seminars, practicals in each course of study.

iv. All theory courses in the programme carry a Continuous Internal Assessment (CIA) component to a maximum of 40 marks and Semester End Examination (SEE) for a maximum of 60 marks. The minimum pass marks for a course is 50%.

v. All lab components carry a Continuous Internal Assessment (CIA) component to a maximum of 60 marks and Semester End Practical Examination (SEE) for maximum of 40 marks. The minimum pass marks for a course in 40%.

vi. A student should pass separately in both CIA and the SEE, i.e., a student should secure 16 (50%) out of 40 marks for theory and 24 (50%) out of 60 marks in the lab components in CIA. A student should secure 24 (50%) out of 60 marks for theory and 16 (50%) out of 40 marks for lab components in the SEE.

vii. There are 3 CIA tests for each course per semester from which the best 2 performances are considered for the purpose of calculating the marks in CIA. A record of the continuous assessment is maintained by the academic unit. A record of the continuous assessment is maintained by the academic unit.

viii. Each CIA contains 15 marks, out of the best 2 tests scores are considered for 30 marks. Remaining 10 marks awarded for assignments, class presentations and class participation and punctuality of the student.

ix. A student failing to secure the minimum pass marks in the CIA is not allowed to take the semester end examination of that course. S/he has to redo the course by attending special classes for that course and get the pass percentage in the internal tests to become eligible to take the end semester examination.

x. Semester-end examination shall consist of objective type questions, descriptive type questions, short answer questions and case studies or any other recommended by the Board of Studies (BoS).

xi. Students failing a course due to lack of attendance should redo the course.

xii. Re-evaluation is applicable only for SEE papers and shall not be entertained for other components such as lab/practical /thesis/ dissertation/ internship etc.

xiii. An on-campus elective course is offered only if 10 or 50% of the students registered, whichever is higher.

SEMESTER WISE DETAILED SYLLAB

SEMESTER-I

Course Code : **MAT101** Course Type : **Core** No. of Credits : **4.0** No. of Hours : **60**	**Course Title** **Real Analysis**

Course Objectives:

The main objectives of this course are to:

- Develop a rigorous understanding of metric spaces, sequences, and continuity in abstract settings.
- Equip students with analytical techniques for studying convergence, compactness, and connectedness.
- Introduce multivariable analysis and sequences/series of functions for advanced mathematical modeling.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Provide a strong foundation in set theory, relations, and cardinality concepts.
- **CO2:** Develop understanding of metric spaces, completeness, and topological properties.
- **CO3:** Analyze continuity, compactness, and connectedness in abstract spaces.
- **CO4:** Introduce multivariable differentiation and optimization techniques.
- **CO5:** Study sequences and series of functions with emphasis on uniform convergence.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	1	1	1	–	–	-	-	-	-	-
CO2 Explain & interpret	3	3	1	2	1	-	–	-	-	-	-	-
CO3 Apply Models	3	3	2	3	2	1	–	-	-	-	-	1
CO4 Analyse & evaluate	3	3	1	2	2	-	2	-	-	-	-	1
CO5 Research & create	3	3	2	2	2	1	3	-	-	-	1	2

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I **[10 Hours]**

Set theory: Review of sets, binary relation, equivalence and partial order relation, total order, maximal element, upper bound, Zorn's lemma; finite sets, countable and uncountable sets and their properties.

Unit-II	[14 Hours]

Metric Spaces: Definition of metric space, open ball, closed ball, limit point of set, definition of norm, metric induced norm, sequences in metric spaces, complete metric spaces, Cantor's intersection theorem, dense of a set, first and second category of sets, Baire category theorem.

Unit-III	[14 Hours]

Functions on metric spaces: Limit and Continuity of a function on metric spaces, uniform continuity, homeomorphism, functions of bounded variation. **Connectedness:** Definition of connected set, interval, Intermediate value theorem. **Compactness:** Definition and properties of compact set, totally bounded set, Bolzano Weierstrass theorem, Heine - Borel theorem. **Reimann-Steiltjes Integrals**: Definition and properties of Reimann-Steiltjes Integrals.

Unit-IV	[10 Hours]

Multivariable analysis: Limit, continuity, differentiability of functions of several variable, implicit function theorems, Taylor series, Maxima-Minima.

Unit-V	[12 Hours]

Sequences and series of functions: Sequence of functions, pointwise convergence, series of functions, uniform convergence, uniformly bounded sequence, uniformly Cauchy sequence, uniform convergence and differentiation, uniform convergence and integration, Weierstrass M-test, Dini's theorem.

Suggested Readings:

Rudin, W. "*Principles of Mathematical Analysis*" (latest ed.). New York, NY: McGraw-Hill.
Apostol, T. M. "*Mathematical Analysis*" (latest ed.). Narora Publishing House.
Lang, S. "*Undergraduate analysis"* (latest ed). Springer.
Tao, T. "*Analysis II*" (latest ed.). Texts and Readings in Mathematics. Hindustan Book Agency.

References:

Simmons, G. F. *"Introduction to topology and modern analysis"* (latest ed.). McGraw-Hill.
Pugh, C. C. "*Real mathematical analysis"* (latest ed.). Springer.
Fitzpatrick, P. M. "*Advanced Calculus*" (latest ed.). Belmont, CA: Thomson Brooks/Cole.
Shifrin, T. "*Multivariable mathematics: Linear algebra, multivariable calculus, and manifolds*" (latest ed.). Wiley.
Tao, T. "*Analysis I*" (latest ed.). Texts and Readings in Mathematics. Hindustan Book Agency.

Course Code : **MAT102** Course Type : **Core** No. of Credits : **4.0** No. of Hours : **60**	**Course Title** **Abstract Algebra**

Course Objectives:

The main objectives of this course are to:

- To develop a deep understanding of group homomorphisms, automorphisms, isomorphisms, and fundamental theorems, including Cayley's theorem.
- To study rings, ideals, domains, and polynomial rings, focusing on unique factorization, irreducibility criteria, and algebraic properties.
- To apply splitting fields, normal extensions, and the fundamental theorem of Galois theory in solving algebraic equations and understanding field automorphisms.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Demonstrate the use of group homomorphisms, automorphisms, and isomorphisms, and apply Cayley's theorem to represent groups.
- **CO2:** Analyze group actions, class equations, and apply Sylow theorems to study finite groups and their structure.
- **CO3:** Identify and classify rings, integral domains, fields, and ideals, including prime and maximal ideals, and construct quotient rings.
- **CO4:** Solve problems using unique factorization domains, principal ideal domains, Euclidean domains, and apply Eisenstein's criterion for irreducibility of polynomials.
- **CO5:** Apply splitting fields, normal extensions, and the fundamental theorem of Galois theory to analyze automorphism groups, fixed fields, and algebraic equations.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	**3**	**2**	**2**	**2**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**1**
CO2 **Explain & interpret**	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**2**
CO3 **Apply Models**	**3**	**3**	**2**	**2**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**2**
CO4 **Analyse & evaluate**	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**2**
CO5 **Research & create**	**3**	**3**	**2**	**3**	**-**	**-**	**-**	**-**	**2**	**-**	**-**	**2**

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I **[12 Hours]**

Group Homomorphisms: homomoprhisms, automorphisms, isomorphisms, fundamental theorems of group homomoprhisms, Cayley's theorem.

Unit-II **[12 Hours]**

Group actions: Group actions, class equations, Sylow theorems, direct products, fundamental theorem of finite abelian groups.

Unit-III **[12 Hours]**

Rings and Ideals: Rings- Integral domains, fields, ideals, prime and maximal ideals, quotient rings.

Unit-IV **[12 Hours]**

Factorization and Polynomial Domains: Unique factorization domain, principal ideal domain, Euclidean domain, polynomial rings and irreducibility criteria.

Unit-V **[12 Hours]**

Galois Theory: Splitting fields, normal extensions, Galois theory, automorphic groups and fixed fields, fundamental theorem of Galois theory.

Suggested Readings:

Wallace, D. A. R. (1998). "*Groups, Rings and Fields*." Springer (SUMS).
Artin, M. (2010). "*Algebra*". PHI.
Gallian, G. A. (2013). "*Contemporary Abstract Algebra*". Narosa Publisher.

References:

Bhattacharya, P. B., Jain, S. K., & Nagpaul, S. R. (2003). "*Basic Abstract Algebra*." Cambridge University Press.
Singh, S., & Zameeruddin, Q. (1994). "Modern Algebra." Vikas Publishing House.
Jacobson, N. (2009). "*Basic Algebra*-I" (2nd ed). Dover Publications.
Holt, D. F., Eick, B., & O'Brien, E. A. (2005). "*Handbook of Computational Group Theory." Chapman & Hall/CRC Press.*

Course Code : **MAT103** Course Type : **Core** No. of Credits : **4** No. of Hours : **60**	**Course Title** **Ordinary Differential Equations**

Course Objectives:

- To develop a rigorous understanding of ordinary differential equations and advanced analytical techniques at the postgraduate level.
- To study special functions, Sturm–Liouville theory, stability, oscillation, and boundary value problems with applications in mathematical sciences.
- To enhance problem-solving and research skills required for CSIR-NET, GATE, and other competitive examinations.

Course Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Analyze and solve ordinary differential equations using advanced analytical methods and existence–uniqueness theorems.
- **CO2:** Solve higher-order linear differential equations, systems of differential equations, and series solutions including Legendre and Bessel equations.
- **CO3:** Apply Sturm–Liouville theory and orthogonal expansions in solving mathematical and physical problems.
- **CO4:** Formulate and analyze mathematical models arising in physics, engineering, biology, and economics using ordinary differential equations.
- **CO5:** Investigate oscillation theory, stability, asymptotic behavior, and boundary value problems using Lyapunov methods and Green's functions

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	3	3	2	2	1	–	–	–	-	-	–	2
CO2 **Explain & interpret**	3	3	3	2	2	-	2	–	-	-	1	2
CO3 **Apply Models**	3	3	2	3	2	-	–	–	-	-	–	2
CO4 **Analyse & evaluate**	3	3	3	3	2	-	2	-	-	-	2	3
CO5 **Research & create**	3	3	3	3	2	-	–	–	-	2	-	3

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I: **[15 Hours]**

First and Higher Order Differential Equations: Existence and uniqueness of first order Initial Value Problems (IVPs), Picard's and Peano's theorems and their consequences, Gronwall's inequality, second and higher-order linear differential equations, Wronskian, Euler-Cauchy equations, method of variation of parameters.

Unit-II: [9 Hours]

Power series Solutions: Singular points, regular singular points, Frobenius methods, Legendre polynomials, Bessel functions and properties, orthogonality properties.

Unit-III: [12 Hours]

Sturm–Liouville Theory: Sturm–Liouville problems, self-adjoint equations, eigen values and eigen functions, orthogonal expansions, Fourier-Legendre and Fourier-Bessel series, Applications in mathematical physics.

Unit-IV: [12 Hours]

Systems of Differential Equations: Algebraic properties of solutions of linear systems, fundamental matrix solutions, Matrix exponential, existence and uniqueness theorems, singular solutions of first order ODE's, stability, asymptotic behavior, Lyapunov stability.

Unit-V: [12 Hours]

Oscillation, Boundary Value Problems: Oscillation theory, Sturm comparison theorems, Boundary Value Problems for Second Order Equations-Green's functions.

Suggested Readings:

Boyce, W. E., & DiPrima, R. C. (2012). "*Elementary Differential Equations and Boundary Value Problems*" (10th ed.). Hoboken, NJ: Wiley.
Tenenbaum, M., & Pollard, H. (1985). "*Ordinary Differential Equations*". Mineola, NY: Dover Publications.
G.F. Simmons (1974), *Differential Equations*, TMH Edition, New Delhi.
E.A. Coddington (1999), *An Introduction to Ordinary Differential Equations*, PHI Learning.

References:

Ince, E.L. (1956). "*Ordinary Differential Equations*." Dover Publications.
Simmons, G. F. (2007). "*Differential Equations with Applications and Historical Notes*". New York, NY: McGraw-Hill Education.
Bender, C.M., & Orszag, S.A. (1999). "*Advanced Mathematical Methods for Scientists and Engineers*". New York, NY: Springer.

Course Code : **MAT104** Course Type : **Core** No. of Credits : **4.0** No. of Hours : **30T+60L**	**Course Title** **Computer Programming in Python**

Course Objectives:

- To provide advanced knowledge of Python programming concepts, data structures, and problem-solving techniques.
- To develop programming skills using control structures, functions, recursion, and string processing in Python.
- To introduce scientific computing and data analysis using Python libraries such as NumPy, Pandas, and Matplotlib

Course Outcomes (COs):

After completing the course, students will be able to:

- CO1: Apply advanced Python programming concepts to solve computational problems.
- CO2: Design programs using control statements, functions, recursion, and data structures.
- CO3: Perform efficient string processing and data manipulation tasks.
- CO4: Use Python libraries such as NumPy, Pandas, and Matplotlib for scientific computing and visualization.
- CO5: Develop modular and analytical Python applications for real-world scenarios.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	**3**	**2**	**2**	**1**	**2**	**–**	**–**	**–**	**-**	**-**	**–**	**-**
CO2 **Explain & interpret**	**2**	**3**	**3**	**1**	**2**	**-**	**–**	**–**	**-**	**-**	**–**	**–**
CO3 **Apply Models**	**2**	**2**	**2**	**2**	**3**	**-**	**–**	**–**	**-**	**-**	**–**	**–**
CO4 **Analyse & evaluate**	**2**	**2**	**2**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**–**	**–**
CO5 **Research & create**	**3**	**3**	**3**	**2**	**3**	**-**	**–**	**–**	**-**	**-**	**-**	**–**

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I: **[18 Hours]**

Python Fundamentals: Python environment, variables, data types, numeric types (int, float, complex), operators, type conversion, and advanced input-output operations.

Unit-II: **[16 Hours]**

Control Structures: Boolean expressions, conditional statements (if, elif, else), loops (for, while), loop control statements, comprehensions, and iterative problem solving.

Unit-III: **[16 Hours]**

String Processing: String operations, indexing, slicing, formatting, Unicode and raw strings, built-in string methods, and regular expressions.

Unit-IV:	[20 Hours]

Data Structures: Lists, tuples, dictionaries, sets, indexing, slicing, matrix representation, built-in functions, and functional programming concepts.

Unit-V:	[20 Hours]

Functions and Scientific Computing: Functions, recursion, parameter passing, modules, packages, and introduction to NumPy, Pandas, Matplotlib, and data analysis applications.

Suggested Readings:

Mitchell, W., Solin, P., Novak, M., et al. (2012). "*Introduction to Python Programming*". NC Lab Public Computing.
Fredslund, J. (2007). "*Introduction to Python Programming*."

References:

Lusth, J. C. (2011). "*An Introduction to Python*". The University of Alabama.

Kuhlman, D. (2008). "*Introduction to Python*."

Course Code : **MAT111** Course Type : **Elective I** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Number Theory**

Course Objectives:

The main objectives of this course are to:

- To prepare students typically revolves around understanding the fundamental properties and structures of integers and their relationships.
- Students often explore topics such as prime numbers, divisibility, congruences, Diophantine equations, and theorems like Fermat's Little Theorem and the Chinese Remainder Theorem.
- Mastering the principles and techniques of solving Diophantine equations, including Brahmagupta's equation (Pell's equation), Fermat's method of descent, and in-depth analysis of the Mordell equation, enabling students to tackle complex mathematical problems with confidence and precision.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Studying number theory equips you with a deep understanding of the properties and relationships of integers.
- **CO2:** Key outcomes include enhanced problem-solving skills, a grasp of advanced mathematical concepts, and the ability to analyze complex systems.
- **CO3**: It also lays the groundwork for further exploration in mathematics and related disciplines.
- **CO4:** Apply the concepts continued fractions and rational approximations.
- **CO5:** Apply the concepts equivalence and reduction.

Course Outline:

Unit-I	**[12 Hours]**

Infinitude of primes, discussion of the prime number theorem, infinitude of primes in specific arithmetic progressions, Dirichlet's theorem (without proof), arithmetic functions, mobius inversion formula.

Unit-II	**[13 Hours]**

Euler's phi function, congruences theorems of Fermat and Euler, Wilson's theorem, linear congruences, quadratic residues, law of quadratic reciprocity.

Unit-III	**[7 Hours]**

Binary quadratics forms, equivalence, reduction, Fermat's two square theorem, Lagrange's four-square theorem, Ramanuja Roger identities.

Unit-IV	**[5 Hours]**

Continued fractions, rational approximations, Liouville's theorem, discussion of Roth's theorem, transcendental numbers, transcendence of "e" and "pi".

Unit-V: **[8 Hours]**

Brahmagupta's equation (also known as Pell's equation), Fermat's method of descent, discussion of the Mordell equation.

Suggested Readings:

Adams, W. W., & Goldstein, L. J. (1972). "*Introduction to the Theory of Numbers*" (3rd ed). Wiley Eastern.

Baker, A. (1984). "*A Concise Introduction to the Theory of Numbers*." Cambridge University Press.

References:

Niven, I., & Zuckerman, H. S. (1980). "*An Introduction to the Theory of Numbers*" (4th ed). Wiley.

Course Code : **MAT111** Course Type : **Elective I** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Linear Algebra and Matrix Methods**

Course Objectives:

The main objectives of this course are to:

- Develop a strong foundation in linear transformations, eigenvalues, and canonical forms.
- Equip students with techniques of matrix analysis, orthogonality, and numerical stability.
- Apply matrix decompositions and linear algebra methods in real-world computational problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to:

- **CO1:** Recall and explain concepts of vector spaces, linear transformations, and matrix operations.
- **CO2:** Interpret properties of eigenvalues, orthogonality, matrix subspaces, and special matrices.
- **CO3:** Apply matrix methods such as least squares, QR decomposition, and SVD to solve practical problems.
- **CO4:** Analyze numerical stability, matrix norms, condition numbers, and sensitivity of linear systems.
- **CO5:** Develop advanced solutions using matrix decompositions and explore applications in data science and research.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	1	1	1	–	–	1	1	-	-	-
CO2 Explain & interpret	3	3	1	2	1	-	-	1	1	1	-	-
CO3 Apply Models	3	3	3	3	2	1	–	2	2	1	-	1
CO4 Analyse & evaluate	3	3	2	2	2	-	2	1	1	1	-	1
CO5 Research & create	2	3	2	2	3	1	3	2	2	2	1	2

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I **[10 Hours]**

Linear and Affine Transformations: Review of vector spaces, bases, and dimensions; linear transformation, Rank-nullity theorem, isomorphism, matrix of linear transformation, transpose of transformation, linear functional, affine transformations, differences between linear and affine transformations. **Characterization of Linear Operators:** Eigen values and Eigen vectors, diagonalizability of linear operator, minimal polynomial, and Jordan Canonical form and it's properties.

Unit-II **[10 Hours]**

Orthonormality of Vectors: Review of inner product space, orthonormality, Gram-Schmidt (GS) orthonormalization, QR decomposition through GS process, orthogonal complements, orthogonal projections, least square solutions. **Special Operators:** Self-adjoint, normal, and unitary operators

Unit-III **[8 Hours]**

Fundamental Matrix Subspaces: Null/kernel space, range/image space, row space, and column space of linear system $Ax = b$. **Pseudoinverse**: definition and properties of pseudoinverse of a matrix, solution of linear system using pseudoinverse. **Complex Matrices:** Hermitian, unitary, normal matrices and their fundamental properties, positive definite and negative definite matrices, and nonnegative matrices.

Unit-IV **[8 Hours]**

Norms for Vectors and Matrices: Definition of vector norm and it's properties, types of matrix norms including Frobenius norm, equivalence of matrix norms. **Sensitivity Analysis of Linear System:** Condition number of a matrix and it's properties, sensitivity analysis, residue theorem, Hager's algorithm for estimating condition number.

Unit-V **[9 Hours]**

Matrix Decompositions: Necessary and sufficient conditions for LU factorization of a matrix, types of LU factorization, spectral value decomposition for a symmetric matrix, singular value decomposition (SVD) of a matrix and it's properties, low rank approximations, least square solution of overdetermined linear system using SVD and pseudoinverse, principle component analysis in the context of SVD and it's consequences.

Suggested Readings:

Strang, G. "*Linear Algebra and Its Applications*" (latest ed.). Boston, MA: Cengage Learning.
Datta, B. N. "*Numerical Linear Algebra and Applications*" (latest ed.). PHI Learning.
Axler, S. "*Linear Algebra Done Right*" (latest ed.). Springer.

References:

Steven J. L. "*Linear Algebra with Applications*" (latest ed.). Pearson.
Demmel, J. W. "*Applied Numerical Linear Algebra*" (latest ed.). University Press.
Golub, G. H., & Van Loan, C. F. "*Matrix Computations*" (latest ed.). Hindustan Book Agency.
Peter, J.O & Chehrzad, S. "*Applied Linear Algebra*" (latest ed.). Springer.

SEMESTER-II

Course Code : **MAT201** Course Type : **Core** No. of Credits : **4.0** No. of Hours : **30T + 60L**	**Course Title** **Probability and Statistics with R Programming**

Course Objectives:

The main objectives of this course are to:

- Develop a strong foundation in probability theory, statistical inference, and stochastic processes.
- Equip students with skills to analyze data using statistical methods and R programming.
- Apply probabilistic and statistical models to real-world and interdisciplinary problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Recall and explain fundamental concepts of probability spaces, random variables, and distributions.
- **CO2:** Interpret and analyze joint distributions, limit theorems, and sampling techniques.
- **CO3:** Apply statistical methods, estimation techniques, and R programming for data analysis.
- **CO4:** Analyze and evaluate hypothesis testing methods, ANOVA.
- **CO5:** Develop and implement statistical models for real-world problems and research applications.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	1	1	2	–	–	1	1	-	-	-
CO2 Explain & interpret	3	3	1	2	3	-	–	1	2	1	-	-
CO3 Apply Models	3	3	3	3	3	2	1	3	2	1	-	1
CO4 Analyse & evaluate	3	3	2	3	3	1	2	2	2	1	-	1
CO5 Research & create	2	3	3	3	3	2	3	3	3	2	1	2

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I **[25 Hours]**

Probability Space: Algebra of sets, sigma (σ)-algebra, probability measurable space and its properties. **Introduction to Probability**: Axiomatic approach to probability, independent events, conditional probability, Bayes theorem. **Random Variables and Special Distributions**: Definition and types of random variables, cumulative distribution function and its properties, probability mass function and its properties, discrete probability distributions, probability density function and its properties, continuous probability distributions. **Moments of Random Variables:** Expectation and variance and their properties, moments of discrete and continuous probability distributions.

Unit-II **[20 Hours]**

Jointly Distributed Random Variables: Joint/bivariate probability mass and density functions and their properties, marginal probability mass and density functions, joint and marginal cumulative distribution function, independence of bivariate random variables, relation between independence and correlation, transformation of random variables. **Multivariate Random Variables:** Multivariate probability density function and independence, multivariate normal distribution and Wishart distribution and their properties.

Unit-III **[15 Hours]**

Sampling Distributions: Population, Sample, random sampling, Central limit theorem and its significance, covariance matrix and it's properties, $\chi 2$, *T*, and *F* distributions and their interrelations. **Methods of Estimation**: Point estimators, maximum likelihood estimator and its properties, confidence intervals for mean and variance.

Unit-IV **[15 Hours]**

Tests of Hypothesis: Most powerful and uniformly most powerful tests, likelihood ratio tests, $\chi 2$-test for goodness of fit, theory of analysis of variance (ANOVA).

Unit-V **[15 Hours]**

Lab Component: Introduction to R programming, exposure to R Programming discussed in this course.

Suggested Readings:

Rohatgi, V. K., & Saleh, A. K. Md. E. "*An Introduction to Probability and Statistics"* (latest ed.). Wiley.
Milton, J. S., & Arnold, J. C. "*Introduction to Probability and Statistics"* (latest ed.). McGraw-Hill.
Larson, H. J. "*Introduction to Probability Theory and Statistical Inference"* (latest ed.). Wiley.
Gupta, S. C., & Kapoor, V. K. "*Fundamentals of Mathematical Statistics*" (latest ed.). Sultan Chand & Sons.

References:

Casella, G., & Berger, R. L. (2002). "*Statistical Inference. Thomson Learning*" (latest ed.). Duxbury, Wadsworth Group.
Halmos, P. R. "*Measure Theory"* (latest ed.). Springer.
Ross, S. M. "*A First Course in Probability"* (latest ed.). Pearson.
Dudewicz, E. J., & Mishra, S. N. "*Modern Mathematical Statistics"* (latest ed.). Wiley.
Mood, A. M., Graybill, F. A., & Boes, D. C. "*Introduction to the Theory of Statistics"* (latest ed.). McGraw-Hill.

Course Code : **MAT202** Course Type : **Core** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Topology**

Course Objectives:

The main objectives of this course are to:

- Develop a rigorous understanding of topological spaces and continuous functions.
- Analyze fundamental concepts such as connectedness, compactness, and separation axioms.
- Build a strong theoretical foundation for advanced studies in analysis and geometry.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Recall and define fundamental concepts of topology, bases, subspaces, and continuous functions.
- **CO2:** Explain and interpret properties of connectedness, compactness, and topological structures.
- **CO3:** Apply topological concepts to analyze continuity, compactness, and convergence in abstract spaces.
- **CO4:** Analyze and evaluate separation axioms and major theorems such as Urysohn lemma and Tietze extension theorem.
- **CO5:** Develop mathematical reasoning to explore advanced theoretical problems and research in topology and related fields.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	1	1	-	–	–	1	1	-	–	–
CO2 Explain & interpret	3	3	1	2	-	-	–	1	1	1	–	–
CO3 Apply Models	3	3	1	2	-	-	1	1	2	1	–	1
CO4 Analyse & evaluate	3	3	1	2	-	-	2	1	1	1	–	1
CO5 Research & create	3	3	1	3	-	-	3	2	2	2	1	2

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I **[10 Hours]**

Topology: Definition and examples of topology, types of topologies, comparison of topologies, basis and subbasis for a topology, interior point, limit point, and closure of sets and their properties, order topology, subspace topology. **Continuous Functions on Topological Spaces:** Definition and properties of continuous function on topological spaces, continuous functions on metric spaces, product topology, and quotient topology.

Unit-II **[10 Hours]**

Connectedness: Definition of connected space, conditions for connectedness, connected subspace of the real line, connectedness of a linear continuum, intermediate value theorem, path-connected space, relation between connected space and path-connected space, connected and path connected components.

Unit-III	**[10 Hours]**

Compactness: Definition and properties of compact space**,** Tychonoff's theorem, compact metric spaces, Lebesgue number lemma, uniform continuity, sequential compactness.

Unit-IV	**[8 Hours]**

Separation Axioms: T_0 -spaces, T_1-spaces, T_2 -spaces (Hausdorff spaces), regular spaces, normal spaces, relationships among Hausdorff, regular, and normal spaces, compact Hausdorff spaces.

Unit-V	**[7 Hours]**

Important Theorems in the Context of Separation Axioms: Urysohn lemma on metric spaces, Dyadic rational, Urysohn lemma on arbitrary topological space, Tietze Extension Theorem, statement of Urysohn's metrization theorem.

Suggested Readings:

Simmons, G. F. "*Introduction to Topology and Modern Analysis*" (latest ed.). McGraw-Hill.
Munkres, J. R. "*Topology*" (latest ed.). Prentice Hall.
Willard, S. "*General Topology*" (latest ed.). Addison-Wesley.

References:

Patty, C. W. "*Foundations of Topology"* (latest ed.). Jones & Bartlett Publishers.
Joshi, K. D. "*An Introduction to General Topology"* (latest ed.). New Age International Private Limited.
Pervin, W. J. "*Foundations of General Topology"* (latest ed.). Academic Press.
Dugundji, J. "*Topology"* (latest ed.). Prentice Hall of India.

Course Code : **MAT203** Course Type : **Core** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Partial Differential Equations**

Course Objectives:

The main objectives of this course are to:

- To introduce the basic concepts, origin, and classification of partial differential equations (PDEs).
- Develop proficiency in classical methods such as separation of variables, method of characteristics, and integral transforms for solving PDEs.
- Apply PDEs in modeling and solving problems in dynamics, diffusion, wave propagation, and potential theory.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1**: Identify and classify first and second-order PDEs into hyperbolic, parabolic, and elliptic types.
- **CO2**: Apply the method of characteristics and complete integrals to solve semi-linear, quasi-linear, and non-linear first-order PDEs.
- **CO3**:Reduce second-order PDEs to canonical forms and solve homogeneous and non-homogeneous equations with constant or variable coefficients.
- **CO4**:Solve diffusion, wave, and Laplace equations in Cartesian, cylindrical, and spherical coordinates relevant to engineering and physics applications.
- **CO5**: Employ Fourier and Laplace transforms, along with Duhamel's principle, to obtain solutions for PDEs in complex domains.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	2	2	1	1	2	1	2	2	2	2
CO2 Explain & interpret	3	3	2	2	2	1	2	1	2	2	2	2
CO3 Apply Models	3	3	2	2	2	1	2	1	2	2	2	2
CO4 Analyse & evaluate	3	3	2	3	2	2	3	2	3	2	2	3
CO5 Research & create	3	3	2	3	3	2	3	2	3	2	2	2

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I **[10 Hours]**

First-Order Partial Differential Equations: Origin of partial differential equations (PDEs), order of PDEs, classification geometrical interpretation, Cauchy problems, method of characteristics for semi linear and quasi linear, Charpit's and Jacobi's methods for first order non linear PDEs.

Unit-II	**[10 Hours]**

Second Order Partial Differential Equations: Classification of second order linear partial differential equations, hyperbolic , parabolic and elliptic PDEs, linear second order PDEs with constant coefficients, reduction of second order linear PDEs into canonical forms, solution of linear Homogeneous and non-homogeneous with constant coefficients.

Unit-III	**[10 Hours]**

Diffusion/Heat Equation: Derivation of heat equation, fundamental solution by the method of variables, Duhamel's principle for non-homogeneous heat equation.

Unit-IV	**[8 Hours]**

Wave Equation: Derivation of wave equation, solution by the method of separation of variables, Duhamel's principle and Cauchy solution for wave equation.

Unit-V	**[7 Hours]**

Laplace Equation*:* Solution by the method of separation of variables, Neumann's, Dirichlet's problem for a rectangle.

Suggested Readings:

Sneddon, I. N. (2006). "*Elements of PDE's*". McGraw-Hill Book Company Inc.
Debnath, L. (2007). "*Nonlinear PDE's for Scientists and Engineers*." Birkhäuser, Boston.
John, F. (1971). "Partial Differential Equations." Springer.

References:

Sneddon, I. N. (2006). "*Elements of Partial Differential Equations*". Dover Publications.
John, F. (1979). "*Partial Differential Equations*" (3rd ed.). Narosa Publications.
Nandakumaran, K., & Datti, P. S. (2020). "Partial Differential Equations: Classical Theory with a Modern Touch". Cambridge University Press.
Zauderer, E. (1989). "*Partial Differential Equations of Applied Mathematics*" (2nd ed.). John Wiley & Sons.
Evans, L. C. (1998). "*Partial Differential Equations* (Graduate Studies in Mathematics, Vol. 19)". American Mathematical Society.

Course Code : **MAT204** Course Type : **Core** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Mathematical Foundations for Computer Science**

Course Objectives:

The main objectives of this course are to:

- To build a strong understanding of sets, propositions, and fundamentals of logic as the basis for discrete mathematics.
- To introduce recurrence relations, generating functions, relations, lattices, and algebraic systems essential for computer science applications.
- To apply graph theory and tree structures in solving computational problems such as shortest paths, spanning trees, and network optimization

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Use pigeonhole principle, Pascal's identity, and Ramsey theory to solve combinatorial problems.
- **CO2:** Analyze and solve linear homogeneous and non-homogeneous recurrence relations using generating functions.
- **CO3:** Examine properties of binary relations, equivalence relations, and lattices, applying duality and distributive properties.
- **CO4:** Apply graph theory concepts to determine Eulerian/Hamiltonian paths, shortest paths, and solve network problems using algorithms.
- **CO5:** Build spanning trees and apply Prim's and Kruskal's algorithms to find minimum spanning trees in weighted graphs.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	**3**	**3**	**2**	**2**	**1**	**–**	**–**	**–**	**-**	**1**	**1**	**2**
CO2 **Explain & interpret**	**3**	**3**	**2**	**2**	**1**	**-**	**–**	**–**	**-**	**1**	**2**	**2**
CO3 **Apply Models**	**3**	**2**	**3**	**2**	**1**	**-**	**–**	**–**	**1**	**1**	**2**	**2**
CO4 **Analyse & evaluate**	**3**	**3**	**3**	**2**	**2**	**-**	**-**	**-**	**1**	**1**	**2**	**3**
CO5 **Research & create**	**2**	**3**	**2**	**3**	**2**	**1**	**–**	**1**	**2**	**2**	**3**	**3**

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I	**[7 Hours]**

Sets and propositions: Fundamentals of logic, first order logic , ordered sets. **Counting**: Basics of counting, Pigeonhole principle , Pascal's Identity , Ramsey theory and applications.

Unit-II **[10 Hours]**

Recurrence relations: Solving recurrence relations, Linear Homogeneous and Non Homogeneous Recurrence relations, sorting algorithm. **Generating functions**: Coefficients of generating functions, solution by the method of generating functions applications of generating functions.

Unit-III **[10 Hours]**

Relations and functions: Properties of binary relations, equivalence relations and partitions, partial and total ordering relations, transitive closure and Warshal's algorithm, chains, lattices and algebraic systems, principle of duality, basic properties of algebraic systems, distributive and complemented lattices.

Unit-IV **[10 Hours]**

Graph Theory: Basic terminology, multigraphs and weighted graphs, paths and circuits, shortest paths in weighted graphs, Eulerian paths and circuits, Hamiltonian paths and circuits, shortest-path problems.

Unit-V **[7 Hours]**

Trees and Planarity in Graph Theory: Trees and cut-sets, rooted trees, path lengths in rooted trees, spanning trees and minimum spanning trees, Prims and Kruskal's algorithms.

Suggested Readings:

Mott, J. L., Kandel, A., & Baker, T. P. (2006). "*Discrete Mathematics for Computer Scientists*." PHI.
Liu, C. L. (1985). "*Elements of Discrete Mathematics*." McGraw Hill.

References:

Cameron, P. (1994). "*Combinatorics Topics, Techniques, Algorithms*." Cambridge University Press.
Matousek, J., & Nesetril, J. (1998). "*Invitation to Discrete Mathematics*." Oxford University Press.
Van Lint, J. H., & Wilson, R. M. (2001). "*Combinatorics* (2nd ed.)." Cambridge University Press.
Aigner, M., & Ziegler, G. M. (2014). "*Proofs from the Book*" (5th ed.). Springer.

Course Code :**MAT211** Course Type : **Elective II** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Calculus of Variation and Integral Equations**

Course Objectives:

- To understand Green's functions, calculus of variations and integral equations.
- To develop analytical skills for solving variational and integral equation problems.
- To apply mathematical methods in physics, engineering and optimization problems.

Course Outcomes (COs):

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

- **CO1:** Construct Green's functions and solve ordinary differential equations.
- **CO2:** Apply calculus of variations to obtain optimal solutions in physical problems.
- **CO3:** Solve Volterra integral equations using resolvent kernels and approximation methods.
- **CO4:** Analyze Fredholm integral equations and degenerate kernel problems.
- **CO5:** Apply Beta, Gamma and Abel integral equations in advanced mathematical modeling.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	3	2	2	1	–	–	–	-	1	1	2
CO2 Explain & interpret	3	3	2	2	1	-	–	–	-	1	2	2
CO3 Apply Models	3	2	3	2	1	-	–	–	1	1	2	2
CO4 Analyse & evaluate	3	3	3	2	2	-	-	-	1	1	2	3
CO5 Research & create	2	3	2	3	2	1	–	1	2	2	3	3

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I: **[7 Hours]**

Green's Functions and Variational Concepts : Green's functions for ordinary differential equations, construction methods, functionals, strong and weak variations, Euler's equations and fundamental lemma of calculus of variations.

Unit-II: **[8 Hours]**

Calculus of Variations and Applications: Minimum surface and minimum energy problems, Brachistochrone problem, isoperimetric problems, variational problems involving several functions and Euler–Poisson equation.

Unit-III: **[10 Hours]**

Hamiltonian Formulation and Volterra Integral Equations: Hamilton's principle, Lagrange's equations, Hamilton's equations, relationship between differential and Volterra integral equations, resolvent kernels and successive approximation methods.

Unit-IV: **[10 Hours]**

Volterra Equations and Integro-Differential Equations: Convolution type equations, integro-differential equations using Laplace transforms, Volterra integral equations of first kind and convolution type first-kind equations.

Unit-V: **[10 Hours]**

Fredholm Integral Equations and Special Functions: Beta and Gamma functions, Abel's integral equation, Fredholm integral equations of second kind, Fredholm determinants, iterated and degenerate kernels, Hammerstein equations, characteristic numbers and eigen functions.

Suggested Readings:

Krasnov, M., Kiselev, A., & Mekarenko, G. (1971). "*Problems and Exercises in Integral Equations.*" Visalaandhra Publishing House.

Elsgolts, L. (2003). "*Differential Equations and Calculus of Variations*." Mir Publishers.

Mesterton-Gibbons, M. (2009). "*A Primer on the Calculus of Variations and Optimal Control Theory*" (Vol. 50). American Mathematical Society.

References:

Warup, S. (2008). "*Integral Equations*". Krishna Prakashan Media (P) Ltd.

Course Code :**MAT211** Course Type : **Elective II** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Statistical Inference**

Course Objectives:

The main objectives of this course are to:

- Develop a comprehensive understanding of statistical inference, estimation theory, and hypothesis testing.
- Equip students with the ability to analyze data and draw valid conclusions using statistical methodologies.
- Apply inferential statistical techniques to solve research, scientific, and industrial problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Recall and explain fundamental concepts of sampling distributions, estimation, confidence intervals, and hypothesis testing.
- **CO2:** Interpret statistical models, estimator properties, and inferential procedures used in decision-making.
- **CO3:** Apply estimation methods, confidence interval construction, and parametric/non-parametric tests to analyze data.
- **CO4:** Analyze and evaluate statistical hypotheses, test procedures, and inferential results in diverse applications.
- **CO5:** Design and conduct statistical investigations, interpret outcomes, and formulate research-based conclusions using inferential techniques.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	2	2	1	1	3	–	-	1	1	-	-	-
CO2 **Explain & interpret**	2	3	1	1	3	-	1	1	1	1	-	-
CO3 **Apply Models**	2	3	2	2	3	1	1	2	2	1	-	1
CO4 **Analyse & evaluate**	2	3	2	2	3	1	2	2	2	1	-	1
CO5 **Research & create**	2	3	2	3	3	1	3	2	2	2	1	2

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I **[8 Hours]**

Sampling Distributions: Population, sample, parameter, statistic, sampling distributions, convergence in probability, convergence in distribution, Law of Large Numbers and Central Limit Theorem (statements only), Student's t-distribution, F-distribution, and χ^2-distribution, their definitions, properties, and applications.

Unit-II **[8 Hours]**

Theory of Estimation: Estimation of parameters, criteria of a good estimator, unbiasedness, consistency, efficiency, and sufficiency, Neyman's factorization theorem, method of moments and maximum likelihood estimation, estimation of parameters of Binomial, Poisson, and Normal distributions using the maximum likelihood method, Confidence intervals and their interpretation.

Unit-III **[9 Hours]**

Testing of Statistical Hypotheses: Statistical hypotheses, null and alternative hypotheses, critical region, level of significance, power of a test, and types of errors, one-tailed and two-tailed tests, Neyman–Pearson lemma, tests based on Binomial, Poisson, Exponential, and Normal distributions.

Unit-IV **[11 Hours]**

Large Sample Tests: Large sample tests for a single mean, difference of two means, single proportion, difference of proportions, standard deviation(s), and correlation coefficient(s), including confidence intervals for mean(s), t-test for a single mean, difference of means, and paired observations, χ^2-test for goodness of fit and independence of attributes, F-test for equality of variances.

Unit-V **[9 Hours]**

Non-Parametric Methods: Introduction to non-parametric tests, advantages and disadvantages, comparison with parametric tests, Nominal, ordinal, interval, and ratio scales, Runs test, sign test, and Wilcoxon signed-rank test for single and paired samples, Median test, Wilcoxon–Mann–Whitney U test, and Wald–Wolfowitz runs test.

Suggested Readings:

K.V.S. Sarma: "*Statistics Made Simple: Do it yourself*" on PC.PHI.

Casella, G and Berger, R. L. "*Statistical Inference*"

References:

S.C.Gupta & V.K. Kapoor "*Fundamentals Of Mathematical Statistics*" Chand.

Hogg Tanis Rao: "*Probability and Statistical Inference*". 7th edition. Pearson.

Course Code : **CCC213** Course Type : **CCC** No. of Credits : **4.00** No. of Hours : **30T + 60L**	**Course Title** **Introduction to Artificial Intelligence and Machine Learning**

Course Objectives:

- Provide To provide students with a strong foundation in the concepts, principles, and applications of Artificial Intelligence, including problem solving, knowledge representation, machine learning, and intelligent systems.
- To develop programming skills in Python, enabling students to write programs, apply control structures, functions, lists, and strings, and solve computational problems effectively.
- To enable students to understand and apply AI techniques such as machine learning, natural language processing, computer vision, and reasoning methods for solving real-world problems.

Course Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Explain the fundamental concepts, characteristics, and applications of Artificial Intelligence and intelligent agents.
- **CO2:** Apply problem-solving and searching techniques, including uninformed, informed, and constraint satisfaction approaches, to AI problems.
- **CO3:** Demonstrate knowledge representation, logical reasoning, probabilistic reasoning, and automated planning techniques in AI systems.
- **CO4:** Analyze basic machine learning models and AI applications such as NLP, speech recognition, and computer vision.
- **CO5:** Develop Python programs using functions, control structures, strings, and lists to solve computational and AI-related problems.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	–	–	1	–	–	–	–	–	–	2
CO2	3	3	2	1	2	–	–	–	–	–	–	2
CO3	3	3	2	2	2	–	–	–	–	–	–	2
CO4	3	3	2	2	3	–	–	–	–	–	–	2
CO5	3	2	3	2	3	–	–	–	1	1	–	2

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I: **[18 Hours]**

Introduction To Artificial Intelligence: Definition – Future of Artificial Intelligence - Characteristic of Intelligent Agents – Typical Intelligent Agents –Problem Solving Approach to Typical AI problems. Problem solving by Searching: Uninformed and informed strategies and implementation; Path planning; Constraint Satisfaction Problems (CSP).

Unit-II: **[16 Hours]**

Knowledge Representation: Logical Agents– Propositional and first order Predicate logic - inference - Knowledge representation and Automated Planning– Uncertain Knowledge and Reasoning: Quantifying uncertainty– probabilistic reasoning**.**

Unit-III: **[16 Hours]**

Machine learning & AI Applications: Machine learning basics - Learning from examples - forms of learning (supervised, unsupervised, reinforcement learning) - simple models (linear & logistic regression) - Deep Learning AI applications: Natural Language Processing - Language Models - Machine Translation; Speech Recognition; Computer Vision - Image classification.

Unit-IV: **[20 Hours]**

Python Programming: Introduction-The Python Programming Language, History, features, Installing Python, Running Python program, Debugging: Syntax Errors, Runtime Errors, Semantic Errors – Experimental Debugging, Formal and Natural Languages, The Difference between Brackets, Braces, and Parentheses. Variables and Expressions: Values and Types - Variables, Variable & Keyword Type conversion - Operator and Operands – Expressions – Interactive – Mode and script Mode, Order of Operations. Conditional Statements: if, if- else, nested if –else -Looping: for, while, nested-loops. Control statements: Terminating loops, skipping specific conditions.

Unit-V: **[20 Hours]**

Functions: Function Calls, Type Conversion Functions, Math Functions, Adding New Functions, Definitions and Uses, Flow of Execution, Parameters and Arguments, Variables and Parameters. Strings: Strings, String Slices, Strings are immutable, and Searching–Looping–and counting String methods - the in operator–String Comparison – String operations Lists: Values and Accessing Elements, Lists are mutable, traversing a List, Deleting elements from List–, Built-in List Operators, Concatenation, In Operator, Built-in List functions and methods.

Suggested Readings:

M.Tim Jones (2008), *Artificial Intelligence: A Systems Approach (Computer Science)* (1 st Edition). Jones and Bartlett Publishers, NC.

Burkahard A Meier, *Python GUI programming Cookbook* (2nd Edition), Packt Publication.

S. Russell and P. Norvig (2022), *Artificial Intelligence: A Modern Approach* (4th Edition), Prentice Hall.

References:

Barry, P., Head first (2016), *Python: A brain-friendly guide*. O'Reilly Media.

Lavika Goel (2021), *Artificial Intelligence: Concept and Applications*, Willy.

Mark Lutz (2013), *Learning python: Powerful object-oriented programming*. O'Reilly Media.

Nils J. Nilsson (2009), *The Quest for Artificial Intelligence*, Cambridge University Press.

SEMESTER-III

Course Code : **MAT301** Course Type : **Core** No. of Credits : **4** No. of Hours : **60**	**Course Title** **Fluid Dynamics**

Course Objectives:

- To provide a strong foundation in Hamiltonian mechanics, variational principles, and canonical transformations.
- To develop analytical and computational skills for studying fluid kinematics and fluid dynamics.
- To apply mathematical methods and computational techniques to solve problems in classical mechanics and fluid flow.

Course Outcomes (COs):

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

- **CO1:** Understand fluid motion description, deformation, streamlines, material derivative, acceleration, and vorticity concepts.
- **CO2:** Apply continuity, Euler's, and Bernoulli's equations for one-dimensional inviscid incompressible flows.
- **CO3:** Analyze two and three-dimensional incompressible flows using circulation, velocity potential, Laplace equation, and boundary conditions.
- **CO4:** Apply complex potential theory and theorems for two-dimensional irrotational flow analysis.
- **CO5:** Understand viscous flow concepts, Navier–Stokes equations, and solve basic viscous flow problems.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	**3**	**2**	**2**	**1**	**1**	**–**	**–**	**–**	**-**	**-**	**-**	**1**
CO2 **Explain & interpret**	**3**	**3**	**2**	**2**	**1**	**-**	**–**	**–**	**-**	**-**	**-**	**1**
CO3 **Apply Models**	**3**	**3**	**3**	**2**	**1**	**-**	**–**	**–**	**-**	**-**	**-**	**1**
CO4 **Analyse & evaluate**	**3**	**2**	**3**	**2**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**1**
CO5 **Research & create**	**3**	**3**	**2**	**2**	**2**	**-**	**–**	**-**	**-**	**-**	**-**	**1**

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I: **[14 Hours]**

Kinematics of Fluid Motion: Methods of describing fluid motion, Lagrangian method, Eulerian method, deformation, streamlines, path lines and streak lines, material derivative and acceleration, vorticity in polar coordinates, vorticity in orthogonal curvilinear coordinates.

Unit-II: **[10 Hours]**

One-Dimensional Inviscid Incompressible Flow: Equation of continuity, stream tube flow, equations of motion, Euler's equation, Bernoulli's equation, applications of Bernoulli's equation.

Unit-III: **[14 Hours]**

Two and Three-Dimensional Incompressible Flow: Basic equations and concepts of flow, equation of continuity, Eulerian equation of motion, circulation theorem, circulation concepts, Stokes' theorem, Kelvin's theorem, constancy of circulation, velocity potential, irrotational flow, moment theorem, moment of momentum theorem, simple flows, Laplace's equation, Laplace equation in Cartesian coordinates, boundary conditions.

Unit-IV: **[10 Hours]**

Complex Potential Theory of Two-Dimensional Flow: Complex potential for 2-D irrotational incompressible flow, complex velocity potentials for standard 2-D flows, Milne-Thomson circle theorem, Blasius theorem.

Unit-V: **[12 Hours]**

Viscous Flows: Stress, rate of strain, relation between stress and rate of strain, Navier-Stokes equations, solvable problems in viscous flows, steady motion between parallel planes, Poiseuille flow, viscous flow between concentric rotational cylinders, Kármán integral theorem.

Suggested Readings:

G. K. Batchelor, *An Introduction to Fluid Dynamics*, 2nd Edition, Cambridge University Press, 2000.
Yuan, S. W. (1976). "*Foundations of Fluid Mechanics*." Prentice Hall.
Yih, C. S. (1969). "*Fluid Mechanics*." McGraw-Hill.

References:

Chorlton, F. (1985). "*Fluid Dynamics*. 1st Edition, CBS Publishers & Distributors", New Delhi.
A.J. Chorin and J. E. Marsdon, "*A Mathematical Introduction to Fluid Mechanics*, 3rd Edition, Springer, 2000.

Course Code : **MAT302** Course Type : **Core** No. of Credits : **4.0** No. of Hours : **30T+60L**	**Course Title** **Numerical Analysis and Scientific Computing with MATLAB**

Course Objectives:

- To understand fundamental and advanced numerical methods used in scientific computing for solving mathematical problems.
- To develop analytical and computational skills for solving linear systems, nonlinear equations, interpolation, integration, and differential equations.
- To implement and visualize numerical algorithms using MATLAB for real-world scientific and engineering applications.

Course Outcomes (COs):

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

- **CO1:** Explain floating-point representation, numerical errors, and stability in scientific computations.
- **CO2:** Apply numerical methods for solving linear systems and eigenvalue problems.
- **CO3:** Solve nonlinear equations and construct interpolation polynomials using numerical techniques.
- **CO4:** Apply numerical methods for differentiation, integration, and differential equations.
- **CO5:** Implement and analyze scientific computing algorithms using MATLAB and visualize results effectively.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	3	2	1	-	1	–	–	–	-	-	1	-
CO2 **Explain & interpret**	3	3	2	1	2	-	1	–	-	-	1	1
CO3 **Apply Models**	3	3	2	2	2	1	1	–	-	-	1	1
CO4 **Analyse & evaluate**	3	3	2	2	2	2	1	-	-	-	1	1
CO5 **Research & create**	2	2	3	2	3	1	1	1	1	1	2	2

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I: **[10 Hours]**

Principle of Scientific Computing: Errors, floating-point approximation of a number, loss of significance and error propagation, Stability in numerical computation.

Unit-II: **[11 Hours]**

Linear Systems: Gaussian elimination with pivoting strategy, LU factorization, Residual corrector method, **Iteration Methods:** Jacobi and Gauss -Seidal with convergence analysis, SOR method, matrix norms, error in approximate solution, eigen value problem (Power method).

Unit-III: **[14 Hours]**

Nonlinear Equations: Bisection method, fixed-point iteration method, secant method, Newton's method, rate of convergences, solution of a system of nonlinear equations. **Interpolation by Polynomials:** Lagrange interpolation, Newton interpolation and divided differences, Error of the interpolating polynomials.

Unit-IV: **[10 Hours]**

Cuve Fitting: Data fitting and least squares approximation problem. **Differentiation and Integration**: Difference formulae, some basic rules of integration, Gaussian rules, composite rules, error formulas, Euler method, Runge-Kutta methods, Multi-step methods, Predictor-Corrector methods, Stability and convergence.

Unit-V: **[30 Hours]**

Lab Component: Explore to MATLAB programming for scientific computing of Numerical solutions in the course.

Suggested Readings:

Atkinson, K. E. (1989). "*An Introduction to Numerical Analysis*" (2nd ed.). Wiley-India.
Conte, S. D., & de Boor, C. (1981). "*Elementary Numerical Analysis – An Algorithmic Approach*" (3rd ed.). McGraw-Hill.
Jain, M. K., Satteluri, R. K. Iyengar, & Jain, R. K. (2007). "*Numerical Methods: Problems and Solutions*." New Age International.

References:

Chapra, S. C. (2017). "*Applied Numerical Methods with MATLAB for Engineers and Scientists*." McGraw-Hill Science Engineering.
Burden, R. L., & Faires, J. D. (2001). "*Numerical Analysis (7th ed.)*." Thomson.
Gupta, R. S. (2009). "*Elements of Numerical Analysis*". Macmillan India Ltd.

Course Code : **MAT303** Course Type : **Core** No. of Credits : **4.0** No. of Hours : **30T+60L**	**Course Title** **Data Structures**

Course Objectives:

- To introduce the fundamental concepts of Abstract Data Types (ADTs) and various linear and non-linear data structures used in solving computational problems.
- To develop programming skills for implementing and analyzing data structures such as linked lists, stacks, queues, trees, and graphs using appropriate algorithms.
- To enable students to apply searching and sorting techniques and select suitable data structures and algorithms for efficient problem-solving.

Course Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Explain the concepts of Abstract Data Types (ADTs), classify data structures, and implement linear data structures such as arrays and linked lists.
- **CO2:** Design and implement stack and queue data structures, and apply them to solve problems such as expression evaluation, notation conversion, and recursion-based applications.
- **CO3:** Construct and implement binary trees, binary search trees, and perform tree traversals to solve hierarchical data representation problems.
- **CO4:** Represent graphs using appropriate data structures and apply graph traversal and optimization algorithms, including connected components, minimum spanning tree, and shortest path algorithms.
- **CO5:** Analyze and implement various searching and sorting algorithms, compare their performance, and select appropriate algorithms for different computational problems.

COs /POs Mapping:

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Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	1	2	3	1	1	1	–	2	1	-	–	-
CO2 Explain & interpret	1	3	3	2	2	1	-	3	2	1	-	-
CO3 Apply Models	1	3	3	2	2	2	1	3	3	1	–	1
CO4 Analyse & evaluate	1	3	3	2	2	2	2	3	2	1	-	1
CO5 Research & create	1	3	3	2	3	2	3	3	3	2	1	2

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline::

Unit-I	**[15 Hours]**

Concept of Abstract Data Types (ADTs): Data Types, Data Structures– Storage Structures and File Structures– Primitive and Non-primitive Data Structures– Linear and Non-linear Data Structures. **Linear Lists:** ADT– Array and Linked Representations**, Linked Lists**: Single, Double, Circular Linked List, Applications.

Unit-II: **[16 Hours]**

Stacks: Array and Linked representations– Implementations– Evaluation of Arithmetic Expression using StackPrefix –Infix-Postfix-Notations– Converting Infix Expressions to Postfix– Towers of Hanoi Problem. **Queues:** Array and Linked Representations– Circular Queues– Dequeues– Priority Queues– Implementations and Applications.

Unit-III: **[16 Hours]**

Trees: Binary Tree, Properties, Array and Linked representations– Binary Tree Traversals, Implementations and Applications. Binary Search Trees (BST) –Operations and Implementations– BST Applications.

Unit-IV: **[20 Hours]**

Graphs: Graph and its Representation– Graph Traversals– Connected Components– Basic Searching Techniques – Minimal Spanning Tree- The Shortest Path Algorithm.

Unit-V: **[20 Hours]**

Sorting and Searching: Selection, Insertion, Bubble, Merge, Quick, Heap Sort, Sequential & Binary Searching.

Suggested Readings:

Balaguruswamy, E. "*C and Data Structures*" (latest ed.). Tata Mc Graw Hill.
Kernighan, B. W., & Ritchie, D. M. "*The C Programming Language"* (latest ed.). Prentice Hall of India.
Aho, A. V., Hopcroft, J. E., & Ullman, J. D. "*Data Structures and Algorithms"* (latest ed.). Pearson Education.
Sedgewick, R., Wayne, K., & Dondero, R. "*Introduction to Programming in Python"* (latest ed.). Addison-Wesley.

References:

Ranade, A. "*An Introduction to Programming through C++* "(latest ed.). McGraw Hill.
Kernighan, B. W., & Pike, R. "*The Practice of Programming"* (latest ed.). Pearson Education.
Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. "*Introduction to Algorithms*"(latest ed.). MIT Press.

Course Code : **MAT304** Course Type : **Core** No. of Credits : 3.**0** No. of Hours : 45	**Course Title** **Functional Analysis**

Course Objectives:

The main objectives of this course are to:

- Develop a rigorous understanding of normed spaces, Banach spaces, and Hilbert spaces.
- Analyze linear operators and fundamental theorems in functional analysis.
- Apply abstract functional analytic techniques to solve advanced mathematical problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Recall and define concepts of normed spaces, Banach spaces, Hilbert spaces, and linear operators.
- **CO2:** Explain and interpret properties of bounded operators, dual spaces, and orthogonality in Hilbert spaces.
- **CO3:** Apply functional analytic techniques to solve problems involving operators and inner product spaces.
- **CO4:** Analyze and evaluate major theorems such as Hahn-Banach, Open Mapping, and spectral theorems.
- **CO5:** Develop advanced mathematical reasoning for research-oriented problems in functional analysis and related areas.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	3	2	1	1	–	–	–	1	1	-	–	–
CO2 **Explain & interpret**	3	3	1	1	–	-	–	1	1	1	–	–
CO3 **Apply Models**	3	3	1	2	–	-	1	1	2	1	–	1
CO4 **Analyse & evaluate**	3	3	1	2	–	-	2	1	1	1	–	1
CO5 **Research & create**	2	3	1	2	–	-	3	2	2	2	1	2

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I **[10 Hours]**

Inequalities and Metric Spaces: Holder's inequality, Cauchy- Schwarz's inequality, Minkowski's inequality, review of metric spaces and vector norms. **Normed Linear and Banach Spaces**: Definition and examples of normed linear space and banach spaces, convexity of the closed unit sphere of a Banach Space. **Linear Operators**: Bounded linear transformation, norm of linear transformation, continuity of linear transformation, linear functionals on finite dimensional spaces, dual spaces.

Unit-II **[10 Hours]**

Inner Product Spaces: Review of inner product space, parallelogram law, polarization identity, orthogonality, orthonormal basis. **Hilbert Spaces**: Definition and examples of Hilbert Spaces, application of parallelogram, orthonormal sets in Hilbert spaces, Bessel's inequality, orthogonal completement of Hilbert Spaces, decomposition/projection theorem, complete orthonormal sets, conjugate space H^*, Riesz representation theorem.

Unit-III **[10 Hours]**

Fundamental Theorems on Normed and Banach Spaces: Review of POSET, Zorn's lemma, Hahn Banach theorems, uniform boundedness principle, closed graph theorem, open mapping theorem, bounded inverse theorem.

Unit-IV **[8 Hours]**

Operators on Hilbert spaces: Definition and properties of adjoint operator, closed range operators, self-adjoint, normal, and unitary operators and their properties.

Unit-V **[7 Hours]**

Spectral Operators: Eigen values and eigen space of an operator on a Hilbert space, spectrum of an operator on a finite dimensional Hilbert space, finite dimensional spectral theorem.

Suggested Readings:

Kreyszig. "*Introductory Functional Analysis With Applications*" (latest ed.) John Wiley & Sons
Limaye, B. V. "*Functional Analysis*" (latest ed.). New Age International.

References:

Bachmann, G., & Naricii, L. "*Functional Analysis*" (latest ed.). Academic Press.
Bollabas, B. "*Linear Analysis* (Indian edition)". Cambridge University Press.
Taylor, A. E., & Lay, D. C. "*Introduction to Functional Analysis*" (latest ed.). Wiley.
Conway, J. B. "*A Course in Functional Analysis*" (latest ed.). Springer.

Course Code : **MAT305** Course Type : **Core** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Complex Analysis**

Course Objectives:

The main objectives of this course are to:

- Introduce the fundamental concepts of complex variables, metrics in the complex plane, stereographic projection, and analytic functions governed by Cauchy–Riemann equations.
- To develop proficiency in contour integration, Cauchy's theorems, power series, and Laurent series for analyzing analytic and singular functions.
- Apply key results such as residue theorem, maximum modulus theorem, Schwarz's lemma, and conformal mappings in solving real integrals and practical problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Understand the geometry of the complex plane, stereographic projection, analytic functions, Augustin-Louis Cauchy-Riemann equations, harmonic functions, and elementary complex functions such as exponential, logarithmic, trigonometric, and hyperbolic functions.
- **CO2:** Apply contour integration techniques to evaluate complex integrals using curves, piecewise smooth paths, Cauchy's theorem, and Cauchy's integral formulas**.**
- **CO3:** Analyze power series, determine the radius and domain of convergence, and characterize analyticity of complex functions through power series representations**.**
- **CO4:** Examine zeroes of analytic functions, identity theorem, maximum modulus theorem, Hermann Schwarz's lemma, isolated singularities, and Laurent series with their applications.
- **CO5:** Apply the residue theorem and calculation of residues to evaluate improper integrals and understand the fundamentals of conformal mappings in complex analysis.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	2	2	1	1	2	1	2	2	2	2
CO2 Explain & interpret	3	3	2	2	2	1	2	1	2	2	2	2
CO3 Apply Models	3	3	2	2	2	1	2	1	2	2	2	2
CO4 Analyse & evaluate	3	3	2	2	2	1	3	1	2	2	2	3
CO5 Research & create	3	3	2	3	2	2	3	2	2	2	2	2

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline:

Unit-I **[10 Hours]**

Complex Analysis Foundations: Metric in complex plane, Stereographic projection, analytic functions Cauchy-Riemann equations, harmonic functions. **Elementary Functions**: Exponential function, hyperbolic and trigonometric functions, logarithmic functions.

Unit-II **[8 Hours]**

Complex Itegration: Curves in the complex plane, integral along piecewise smooth curves, Contour integration, Cauchy's theorem, Cauchy's integral formulas.

Unit-III **[9 Hours]**

Power series: Domain and radius of convergence, characterization of analyticity via power series, Taylors and Laurent series.

Unit-IV **[8 Hours]**

Zeros and Singularities in Complex Analysis: Zeroes of analytic functions, Identity theorem, Maximum modulus theorem, Schwarz's lemma and it's consequences.

Unit-V **[10 Hours]**

Residues and Real Integrals: Residue theorem, calculation of residues, evaluation of improper integrals, argument principle and Rouche's theorem, conformal mapping, linear fractional transformations.

Suggested Readings:

Sarason, D. (2010). "*Complex Function Theory*." TRIM Series.
Conway, J. B. (1978). "*Functions of One Complex Variable" (2nd ed.). Graduate Texts in Mathematics*, 11. Springer-Verlag.
Shastri, A. R. (2010). "*Basic Complex Analysis of One Variable*." Department of Mathematics, Indian Institute of Technology, Bombay.

References:

Stein, E. M., & Shakarchi, R. (2003). "*Complex Analysis: Princeton Lectures in Analysis*.'' Princeton University Press.
Ahlfors, L. V. (1966). "Complex Analysis: *An Introduction to the Theory of Analytic Functions of One Complex Variable*" (2nd ed.). McGraw-Hill Book Co.

Course Code: **MAT311** Course Type: **Elective III** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Database Management Systems**

Course Objectives:

The main objectives of this course are to:

- Understand the fundamental concepts of database systems, data models, database architecture, and Entity-Relationship (ER/EER) modeling for designing database applications.
- Apply relational database concepts, normalization techniques, relational algebra, and SQL to design, query, and manage relational databases efficiently.
- Develop database applications using PL/SQL by implementing procedures, functions, cursors, and triggers to solve real-world database problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Explain the fundamental concepts of database systems, DBMS architecture, data models, schemas, and the database environment**.**
- **CO2:** Design conceptual database models using ER and Enhanced ER (EER) diagrams, and transform them into relational database schemas.
- **CO3:** Apply relational algebra operations, normalization techniques (1NF, 2NF, and 3NF), and ER-to-relational mapping to develop efficient relational database designs.
- **CO4:** Construct and execute SQL queries using DDL, DML, DCL, joins, aggregate functions, views, subqueries, constraints, and embedded SQL for database management.
- **CO5:** Develop PL/SQL programs incorporating control structures, cursors, procedures, functions, and database triggers to implement secure and efficient database applications.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	**2**	**2**	2	**1**	1	3	**1**	**1**	**1**	-	-	**-**
CO2 **Explain & interpret**	**2**	3	2	2	2	3	**1**	2	2	1	-	**-**
CO3 **Apply Models**	**2**	3	3	**3**	2	3	**1**	**3**	**3**	1	-	**1**
CO4 **Analyse & evaluate**	**2**	3	**2**	2	2	3	**2**	2	2	1	-	**1**
CO5 **Research & create**	**2**	3	2	3	2	3	**3**	3	3	2	**1**	**2**

Note:

- 3 → High**,** 2 → Medium**,** 1 → Low**,** – → No direct mapping

Course Outline

Unit-I **[10 Hours]**

Introduction: Characteristics of Database Approach – Advantages of Using DBMS Approach – Data Models, Schemas, and Instances – Three Schema Architecture – Database Languages and Interfaces – The Database System Environment.

Unit-II **[9 Hours]**

Entity-Relationship Model: Using High-Level Conceptual Data Models for Database Design – Entity Types, Entity Sets, Attributes and Keys – Relationship Types Relationship Sets, Roles, and Structural Constraints –Weak Entity Types – Refining the ER Design and Design Issues. Enhanced Entity-Relationship Model (EER Model), Generalization and Specialization

Unit-III **[7 Hours]**

Relational Model and Relational Algebra: Relational Model Constraints and Database Schemas - Update Operations - Unary and Binary Relational Operations - Relational Algebra Operations from Set Theory - Relational Database Design Using ER to Relational Mapping- Database Design – Normal Forms Based on Primary KeysSecond and Third Normal Forms.

Unit-IV **[10 Hours]**

Structured Query Language: Introduction, History of SQL Standard – Commands in SQL – Data Types in SQL – Data Definition Language – Selection Operation, Projection Operation – Aggregate Functions – Data Manipulation Language – Table Modification Commands – Table Truncation – Imposition of Constraints – Join Operation – Set Operations – Views – Sub Query– Embedded SQL.

Unit-V **[9 Hours]**

Sequence Models: PL/SQL: Introduction, Shortcoming in SQL – Structure of PL/SQL – PL/SQL Language Elements – Data Types –Operators Precedence – Control Structure – Steps To Create A PL/SQL Program – Iterative Control – Cursors – Procedure –Function – Database Triggers.

Suggested Readings:

Abraham Silberschatz, Henry Korth, and S. Sudarshan, “Database System Concepts,” McGraw-Hill, 7th Edition, 2019.

References:

R. Elmasri and S. Navathe, “Fundamentals of Database Systems”, Pearson Education, 7th Edition, 2016.
Raghu Ramakrishnan, “Database Management Systems”, McGraw-Hill, 3rd Edition, 2014.
C.J. Date, A. Kannan, S. Swaminathan, “An Introduction to Database Systems”, Pearson Education, 8th Edition, 2006

Course Code: **MAT311** Course Type: **Elective III** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Machine Learning Foundations and Techniques**

Course Objectives:

The main objectives of this course are to:

- Develop a strong foundation in the mathematical, statistical, and optimization principles underlying machine learning algorithms.
- Equip students with the ability to apply supervised and unsupervised learning techniques to analyze and model complex datasets.
- Introduce modern machine learning methods and computational tools for solving real-world interdisciplinary problems.

Course Learning Outcomes (COs):

By the end of the course, students can be able to:

- **CO1:** Recall and explain the mathematical, statistical, and optimization foundations of machine learning algorithms.
- **CO2:** Interpret the working principles of supervised and unsupervised learning techniques and their applications.
- **CO3:** Apply machine learning models such as regression, classification, clustering, and dimensionality reduction to solve real-world problems.
- **CO4:** Analyze and evaluate the performance, strengths, and limitations of various machine learning algorithms.
- **CO5:** Design and develop machine learning solutions for research and interdisciplinary applications using modern computational tools.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	2	1	1	2	2	-	1	1	-	-	-
CO2 Explain & interpret	3	3	2	2	2	3	–	2	2	1	-	-
CO3 Apply Models	2	3	3	3	3	3	1	3	3	1	-	1
CO4 Analyse & evaluate	2	3	3	2	3	3	2	2	2	1	-	1
CO5 Research & create	2	3	3	3	3	3	3	3	3	2	1	2

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I **[8 Hours]**

Linear Algebra: least square solutions to linear systems, eigen values and eigen vectors, singular value decomposition and its applications, dimensionality reduction techniques and applications.

Unit-II **[12 Hours]**

Optimization: Convex function and its properties Gradient and sub-gradient descent methods, constrained optimization, Lagrange multipliers. **Statistical Foundations:** maximum likelihood estimation in binomial, multinomial, Gaussian/normal, exponential family, Bayesian estimation.

Unit-III **[8 Hours]**

Types of Learning: Unsupervised Learning – Reinforcement Learning – Supervised Learning – Learning A Class from Examples. Supervised Learning (Classification). **Basic methods:** Distance- Based methods, Nearest-Neighbours, Decision Trees, Naive Bayes, Support Vector Machines, Nonlinearity and Kernel Methods, Beyond BinaryClassification: Multi- class/Structured Outputs, Ranking.

Unit-IV **[12 Hours]**

Supervised Learning (Regression): Linear Models, Linear Regression, Logistic Regression, Bayesian logistic regression, Generalized Linear Models, Support Vector Machines, Nonlinearity

Unit-V **[11 Hours]**

Unsupervised Learning: Clustering: K-means/Kernel K-means, DimensionalityReduction: PCA and kernel PCA, Matrix Factorization and Matrix Completion, Generative Models (mixture models and latent factor models).

Suggested Readings:

Deisenroth, M. P., Faisal, A. A., & Ong, C. S. "*Mathematics for Machine Learning*" (latest ed.). Cambridge University Press.
Strang, G. "*Introduction to Linear Algebra*" (latest ed.). Wellesley-Cambridge Press.
Kay, S. M. "*Intuitive Probability and Random Processes using MATLAB*" (latest ed.).
Springer. Bishop, C. M., & Nasrabadi, N. M. "*Pattern Recognition and Machine Learning*" (latest ed.). Springer.
Shalev-Shwartz, S., & Ben-David, S. "*Understanding Machine Learning: From Theory to Algorithms*" (latest ed.). Cambridge University Press.

References:

Strang, G. "*Linear Algebra and Learning from Data*" (latest ed.). Wellesley-Cambridge Press. Johnson, R. A., & Wichern, D. W. "*Applied Multivariate Statistical Analysis*" (latest ed.). Pearson. Murphy, K. P. "*Probabilistic Machine Learning: An Introduction*" (latest ed.). MIT Press.
Goodfellow, I., Bengio, Y., & Courville, A. "*Deep Learning*" (latest ed.). MIT Press.

Course Code :**CCC313** Course Type : **CCC** No. of Credits : **2.00** No. of Hours : **30**	**Course Title** **Building Mathematical Ability and Financial Literacy**

Course Objectives:

The main objectives of this course are:

- Solving skills through mathematical reasoning, quantitative aptitude, and data interpretation, enabling them to apply these concepts in academic, professional, and real-life scenarios.
- Familiarize students with investment options, banking structures, financial institutions, taxation, insurance, and the roles of RBI and SEBI in the financial system.
- Enable students to make informed financial decisions through understanding of investment planning, risk management, digital payments, and awareness of financial frauds.

Course Learning Outcomes (COs):

By the end of the course, students can be able to;

- **CO1:** Enhance logical thinking and decision-making through structured problem-solving.
- **CO2:** Demonstrate competence in fractions, simple and compound interest ratio and proportion, and percentage-based problems.
- **CO3:** Calculate mean, median, and mode to summarize data effectively. Present data using bar charts, pie charts, and line charts for clear communication.
- **CO4:** Prepare budgets, track expenses, manage savings, and set financial goals using basic money management principles.
- **CO5:** Evaluate financial risks, use digital payment systems securely, and adopt appropriate strategies for financial planning and risk reduction.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	✓	–	–	–	–	–	–	–	–	–	–	–
CO2 Explain & interpret	✓	✓	–	–	–	–	–	✓	–	–	–	–
CO3 Apply Models	✓	✓	✓	–	✓	–	–	–	–	–	–	–
CO4 Analyse & evaluate	–	✓	–	✓	–	✓	✓	–	–	–	–	✓
CO5 Research & create	–	–	✓	✓	✓	–	✓	✓	–	–	–	–

Course Outline:

Unit-I **[7 Hours]**

Logical Reasoning: Number series, letter series, coding-decoding, problems on ages. **Basic Set Theory**: Operations on sets, Venn diagrams, and cardinality of sets.

Unit-II **[5 Hours]**

Mathematical aptitude: Fractions, time and work, time and distance, ratio and proportion, percentage, profit and loss, discount, simple interest, compound interest, mensuration.

Unit-III **[6 Hours]**

Basic Statistics: Sources and classification of data, data interpretation, quantitative and qualitative data, graphical representation (bar chart, pie chart, line chart), mean, median, and mode for ungrouped data.

Unit-IV **[5 Hours]**

Foundations of Financial Literacy: Introduction to financial literacy and its process and structure, personal finance, income, expenditure, savings, and budgeting, financial goals, financial discipline, money management skills, awareness of financial frauds, basic budgeting and expense tracking activities.

Unit-V **[7 Hours]**

Financial Institutions: Banking system and credit process, recent innovations in the banking system, Reserve Bank of India role and functions, monetary policy tools. **Capital Market;** Primary market, secondary market, financial decision-making,SEBI. **Digital Finance:** Digital payments system and digital currency.

Suggested Readings:

Arihant, (2019). *Teaching and Research Aptitude (General Paper 1)*. Arihant Publication (India) Limited.
Jain, L. & Vashistha, K. C. (2024). *Teaching and Research Aptitude (General Paper 1)*. Upkar Prakashan Agra.
Lewis, M. K. (2000). *Monetary economics*. Oxford University Press, New York.

References:

Aggarwal, R.S. (n.d). *Quantitative Aptitude*. S. Chand.
C Rangarajan. (1991). *Indian economy: Essays in money and finance*. UBS Publishers' Distributors Ltd.
Lewis, M. K. (2000). *Monetary economics*. Oxford University Press.

SEMESTER-IV

Course Code : **MAT401** Course Type : **Core** No. of Credits : **4** No. of Hours : **60**	**Course Title** **Advanced Numerical Analysis and Scientific Computing**

Course Objectives:

- To understand the fundamental concepts of differential equations and their numerical solutions and various numerical methods for solving ordinary and partial differential equations.
- To develop proficiency in implementing numerical algorithms using computational tools and analyze the accuracy, stability, and convergence of numerical methods.
- To apply numerical techniques to solve practical problems from engineering and scientific domains.

Course Outcomes (COs):

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

- **CO1:** Demonstrate understanding of different types of differential equations and their applications in modeling real-world phenomena.
- **CO2:** Evaluate the accuracy, stability, and convergence of numerical methods and select the most suitable method for a given problem.Solve Volterra integral equations using resolvent kernels and approximation methods.
- **CO3:** Utilize computational tools and programming languages to implement numerical algorithms for solving differential equations and analyze and interpret numerical results obtained from computational simulations, identifying trends and patterns.
- **CO4:** Apply numerical techniques to solve practical problems from engineering, physics, and other scientific domains, demonstrating the ability to translate real-world problems into mathematical models and computational solutions.
- **CO5:** Understand the various advanced numerical techniques.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 Recall & define	3	3	2	2	1	–	–	–	-	1	1	2
CO2 Explain & interpret	3	3	2	2	1	-	–	–	-	1	2	2
CO3 Apply Models	3	2	3	2	1	-	–	–	1	1	2	2
CO4 Analyse & evaluate	3	3	3	2	2	-	-	-	1	1	2	3
CO5 Research & create	2	3	2	3	2	1	–	1	2	2	3	3

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I: [10 Hours]

IVPs and BVPs of Differential Equations: Definition and classification of differential equations, initial value problems (IVPs) and boundary value problems (BVPs), analytical versus numerical solutions.

Unit-II: **[13 Hours]**

Numerical Methods for IVPs: Euler's method and its extensions (improved Euler, Runge-Kutta methods) - Multistep methods (Adams-Bashforth, Adams-Moulton methods), stability and convergence analysis.

Unit-III: **[13 Hours]**

Numerical Methods for BVPs: Finite difference methods for BVPs, shooting method and finite element method, application of boundary conditions.

Unit-IV: **[12 Hours]**

Numerical Methods for PDEs: Classification of PDEs (elliptic, parabolic, hyperbolic), finite difference methods for solving PDEs, Explicit and implicit methods for time-dependent problems.

Unit-V: **[12 Hours]**

Advanced Techniques for PDEs: Finite element method for PDEs, spectral methods and collocation methods stability and convergence analysis of numerical PDE solvers.

Suggested Readings:

Butcher, J. C. (2016). "*Numerical methods for ordinary differential equations*". John Wiley & Sons.
Jain, Mahinder Kumar. (2003) "*Numerical methods for scientific and engineering computation*". New Age International.
Smith, G. D. (1985). "*Numerical solution of partial differential equations: finite difference methods*". Oxford university press.
Reddy, J. N. (1993). "*An introduction to the finite element method*". New York, 27, 14.

References:

Press, W. H. (1989). "*Numerical recipes in Pascal: the art of scientific computing*". Cambridge university press.
LeVeque, R. J. (2007). "*Finite difference methods for ordinary and partial differential equations: steady-state and time-dependent problems.*" Society for Industrial and Applied Mathematics.
Farlow, S. J. (1993). "*Partial differential equations for scientists and engineers*." Courier Corporation.

Course Code : **MAT402** Course Type : **Core** No. of Credits : **3.0** No. of Hours : **45**	**Course Title** **Operations Research**

Course Objectives:

- To develop mathematical models for optimization and decision-making problems.
- To apply linear, transportation, assignment, integer and dynamic programming techniques for solving real-life problems.
- To analyze and interpret optimal solutions using advanced optimization methods and sensitivity analysis.

Course Outcomes (COs):

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

- **CO1:** Formulate and solve linear programming problems using graphical and simplex methods.
- **CO2:** Apply duality concepts and sensitivity analysis in optimization problems.
- **CO3:** Solve transportation and assignment problems using standard optimization techniques.
- **CO4:** Develop and solve integer programming and dynamic programming models.
- **CO5:** Interpret optimization results for effective decision-making in engineering and management applications.

COs /POs Mapping:

Cos/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1 **Recall & define**	3	3	2	2	1	–	–	–	-	1	1	2
CO2 **Explain & interpret**	3	3	2	2	1	-	–	–	-	1	2	2
CO3 **Apply Models**	3	2	3	2	1	-	–	–	1	1	2	2
CO4 **Analyse & evaluate**	3	3	3	2	2	-	-	-	1	1	2	3
CO5 **Research & create**	2	3	2	3	2	1	–	1	2	2	3	3

Note:

- 3 → High, 2 → Medium, 1 → Low, – → No direct mapping

Course Outline:

Unit-I: **[10 Hours]**

Linear Programming and Simplex Method : Introduction to Operations Research and LPP, formulation of LPP, graphical method, feasible and optimal solutions, standard and canonical forms, matrix representation, slack and surplus variables, simplex method and Big-M technique.

Unit-II: **[8 Hours]**

Advanced Simplex and Duality: Two-phase simplex method, degeneracy and cycling, revised simplex method, duality theory, formulation of dual problems, dual simplex method, primal-dual relationships and sensitivity analysis.

Unit-III: **[8 Hours]**

Transportation Problems: Balanced and unbalanced transportation models, feasible solutions, degeneracy, North-West Corner Rule, Least Cost Method, Vogel's Approximation Method, MODI and Stepping Stone optimality methods.

Unit-IV: **[10 Hours]**

Assignment Problems: Mathematical formulation of assignment problems, balanced and unbalanced models, Hungarian method, restricted assignments, degeneracy, travelling salesman problem and sequencing applications.

Unit-V: **[9 Hours]**

Integer and Dynamic Programming: Integer programming models, dynamic programming concepts, Bellman's principle, Inventory model, EOQ (Economic Order Quantity).

Suggested Readings:

Swarup, K., Gupta, P. K., & Mohan, M. (2001). "*Operations Research*" (9th ed). Chennai: Sultan Chand & Sons.
Gauss, S. I. (1964). "*Linear Programming*" (2nd ed). New York, NY: McGraw-Hill Book Company.
Taha, H. A. (2017). "*Operations Research: An Introduction*" (9th ed). Pearson.

References:

Ravindran, D. T., Phillips, J. J., & Solberg, J. J. (1987). "*Operations Research: Principles and Practice*": (2nd ed). John Wiley & Sons.
Hillier, F. S., & Lieberman, G. J. (2001). "*Introduction to Operations Research*" (8th ed) . McGraw-Hill.