2-YEARS NEP PG CURRICULUM

M.Sc. MATHEMATICS PROGRAMME

SUBJECT CODE = MAT

FOR POSTGRADUATE COURSES UNDER RANCHI UNIVERSITY, RANCHI

Implemented w.e.f.
Academic Session 2025-26 Onwards

UNIVERSITY DEPARTMENT OF MATHEMATICS
RANCHI UNIVERSITY

Morabadi Campus, Ranchi 834008, Jharkhand. (Ph. 0651-6555611)

Dr. Abrar Ahmad, Head, Associate Professor, Ranchi University, Ranchi.

Ref: **Date:** 20/08/2025

Meeting of Board of Studies

A meeting of Board of Studies was convened in the office of the Head of University Department of Mathematics, Ranchi University, Ranchi on 20/08/2025 at 02:30 PM.

The agenda of the meeting was to approve the draft syllabus of F.Y.U.G. program and Post Graduate Programme of Mathematics according to NEP 2020.

After detailed discussion, the Board of Studies have finalized and approved the draft syllabus of F.Y.U.G. program and Post Graduate Programme which is to be implemented from 2025 onwards.

1. Dr. C. S.P. Lugun, Retired & Former Head, Univ. Deptt. of Mathematics, R. U. Ranchi 20/8/25
2. Dr. Ashalata Keshri, Retired & Former Head, Univ. Deptt. of Mathematics, R. U. Ranchi 20.8.25.
3. Dr. Ashish Kumar Jha, Univ. Deptt. of Mathematics, R. U. Ranchi 20.8.25
4. Mrs. Rimil Nidhi Bhuinyan, Univ. Deptt. of Mathematics, R. U. Ranchi. 20/08/2025
5. Dr. Sheet Nihal Topno, Univ. Deptt. of Mathematics, R. U. Ranchi. 20.08.2025
6. Mr. Amit Bara, Univ. Deptt. of Mathematics, R. U. Ranchi. 20.08.25
7. Dr. B. P. Verma, Prinicipal, S. S. Memorial College, Ranchi.
8. Dr. Raman Kumar Das, HOD, Department of Mathematics, St. Xavier's College, Ranchi. 20.08.2025
9. Dr. M. R. Nagalakshmi, HOD, Department of Mathematics, Nirmala College, Ranchi. Nagalakshmi 20/8/25
10. Dr. Anita Kumari, Head, Deptt. of Mathematics, D. S. P. M.U. Ranchi 20/8/25
11. Dr. P. K. Parida, Department of Mathematics, C.U.J. Ranchi 20/8/25
12. Dr. Shyam Saurabh, HOD, Department of Mathematics, Chaibasa College, Kolhan University. S. Saurabh 20.8.25

Abrar 20/08/25

Head
Department of Mathematics
Ranchi University, Ranchi

Dr. Abrar Ahmad
Chairman
Univ. Department of Mathematics
Ranchi University, Ranchi

verified 20/8/25

Approval by the Members of the NEP Implementation and Monitoring Committee of Ranchi University, Ranchi

The prepared Curriculum of the Master's Degree has been approved by the NEP Implementation and Monitoring Committee of R.U., duly forwarded by the Head of the Department; it will be offered to the Students of the 1-year and 2-year Postgraduate Programme. It is implemented from the 1st Semester of the Academic Session 2025-26 and onwards.

Raj Kr Singh 10/9/25

10/9/25

10/9/2025

Anushka Rani 10/09/25

10/9/25

10/9/25

10/9/25

10/9/25

10/09/2025

Choudhary 10/09/2025

10/09/25

Member Secretory

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HIGHLIGHTS OF NEP PG CURRICULUM

CREDIT OF COURSES

The term 'credit' refers to the weightage given to a course, usually in terms of the number of instructional hours per week assigned to it. The workload relating to a course is measured in terms of credit hours. It determines the number of hours of instruction required per week over a semester (minimum 15 weeks).

a) One hour of teaching/ Lectures or two hours of laboratory /practical work will be assigned per class/interaction.
   One credit for Theory = 15 Hours of Teaching
   One credit for Practicum = 30 Hours of Practical work
   One credit for Internship = 02 Weeks of Practical experience

b) For credit determination, instruction is divided into three major components:
   Hours (L) – Classroom Hours of one hour duration.
   Tutorials (T) – Special, elaborate instructions on specific topics of one hour duration
   Practical (P) – Laboratory or field exercises in which the student has to do experiments or other practical work of a two-hour duration.

   Internship – For the Exit option after 1st year of the 2-year P.G. Programme for the award of P.G. Diploma, Level 6.5, Students can either complete two 4-week internships worth 2 credits each or one 8-week internship for all 4 credits. This practical experience connects academic learning with real-world applications, offering valuable exposure to professional environments in their fields of study

PG CURRICULUM

1. The PG Curriculum will be either of 1-year duration for students who studied the four-year UG Programme (FYUGP) or a 2-year duration for students who studied a three-year UG programme from a CBCS/LOCF/FYUGP Curriculum.
2. There is a flexible mode in the PG programme offered to the students of Ranchi University, Ranchi. The total credit for any semester will be 20 credits.
3. **Two-year PG curriculum:** The First year of the PG curriculum offers coursework only. There will be 3 courses at level 400 and 2 courses at level 500 in the first and the second semesters of any 2-year PG programme.
4. **One-year PG curriculum:** The Courses in the 1-year PG programme and the second year of the 2-year PG programme are the same.
   a. **Course work only**: There will be 5 courses at level 500 of 4 credits each in every semester for the coursework offered in the programme.
   b. **Course work and Research**: There will be 5 courses at the level 500 bearing 4 credits each in the first semester of a 1-year PG or in the third semester of a 2-year PG. There will be Research work offered in the next semester for this mode offered in the programme. The eligibility for this mode is available in the NEP PG curriculum of Ranchi University, Ranchi.
   c. **Research work only**: The eligible student will be offered this mode to conduct extensive research under the supervision of a guide. Each semester will be equivalent to 20 credits. The selection of a candidate for the research mode will depend upon the eligibility of the student, availability of the guide and seat in the department/institution of Ranchi University, Ranchi.

PROMOTION CRITERIA

Two Years Post-graduation programme having coursework only:

i. Each course shall be of **100 marks** having two components: **30 marks for Sessional Internal Assessment (SIA), conducted by the Department/College and 70 marks shall be assigned to the End Semester University Examination (ESUE), conducted by the University**.
ii. The marks of SIA shall further break into, 20 for Internal Written Examinations, 05 for Written Assignment/ Seminar presentation and 05 for overall performance of a student including regularity in the class room lectures and other activities of the Department/College.

iii. The Requisite Marks obtained by a student in a particular subject will be the criteria for promotion to the next Semester.
iv. There shall be two written internal examinations, each of 1 hour duration and each of 20 marks, in a semester out of which the '**Better One out of Two**' shall be taken for computation of marks under SIA.
v. If a student failed to secure pass marks in Mid Semester, he/she has to reappear in Mid & End Semester Examinations.
vi. In case a student is fail to secure pass marks in End Semester Examination, then he/she has to appear only in End Semester Examination of following Sessions within period of Upper Limit of Four Years and the Marks of Mid Semester will be carried for the preparation of result.
vii. Students' final marks and the result will be based on the marks obtained in Mid Semester and End Semester Examination organized taken together.
viii. The pass marks in the programme will be 45% of the total marks obtained in each Core/ Elective/ Other Courses offered.
ix. In absolute terms of marks obtained in a course, **a minimum of 28 marks is essential in the ESUE** and **a minimum of 17 marks is to be secured in the SIA** to clear the course. In other words, a student shall have to pass separately in the ESUE and in the SIA by securing the minimum marks prescribed here.
x. Every candidate seeking to appear in the ESUE shall be issued an Admit Card by the University. **No candidate will be permitted to appear in the examination without a valid admit card.**
xi. A candidate shall be permitted to proceed in next Semester (2^{nd}, 3^{rd} and 4^{th}) **provided he/she has passed at least in <u>3 courses</u> out of 5 courses** in the respective semester in theory and practical/ project courses taken together.
xii. A student will have to clear all his papers within maximum of Four Years of duration to qualify for the degree.

However, it will be necessary to procure pass marks in each of the papers before completion of the programme.

VALUE ADDED COURSES

1. The Value added course will be of **2 credits** to be covered during the first semester.
2. There will be objective-type questions asked in the End Semester University Examination (ESUE).
3. There will be OMR-based examination and the correct answer is to be marked by a black ballpoint pen only on the OMR sheet provided by the University.
4. For **50 Marks Examination** the student will be provided **Two hours** for marking their responses.
5. Students are not allowed to choose or repeat courses already undergone at the undergraduate level in the proposed major and minor streams.
6. The performance in this course will not influence the SGPA or CGPA of the PG Programme where the student is registered to obtain the Master's Degree. <u>However, it will be mandatory to secure minimum pass marks in the course before exit from the PG Programme.</u>
7. If the student fails to secure the minimum pass marks in the Value added course in the first semester, he may appear in the examination of the said course with the following batch of the next session.
8. The student may appear in the examination of the said course further if could not clear the course in the following attempt, subject to the date of validation of the Registration.

The Regulations related to any concern not mentioned above shall be guided by the existing Regulations of the PG Curriculum of Ranchi University, Ranchi.

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COURSE STRUCTURE FOR PG **'PG DIPLOMA/ COURSEWORK ONLY/ COURSEWORK WITH RESEARCH/ RESEARCH ONLY'**

Table 1: Credit Framework for One Year Postgraduate Programme (PG) [Total Credits = 80]

Academic Level	**Level of Courses**	**Semester**	**Coursework** Level 400	**Coursework** Level 500	**Research Preparedness**	**Research thesis/ Project/ Patent**	**Total Credits**
YEAR 1							
Level 6.5	**Coursework**	**I**	**4+4+4**	**4+4**	**---**	**---**	**20**
		II	**4+4+4**	**4+4**	**---**	**---**	**20**
YEAR 2:	**Exit Point: Having an Internship of 4 credits Exit allowed with PG Diploma Certificate**						
Level 6.5	**Coursework**	**III**	**---**	**4+4+4+4+4**	**---**	**---**	**20**
		IV	**---**	**4+4+4+4+4**	**---**	**---**	**20**
OR							
Level 6.5	**Coursework + Research**	**III**	**---**	**4+4+4+4+4**	**---**	**---**	**20**
		IV	**---**	**---**	**20**		**20**
OR							
Level 6.5	**Research**	**III**	**---**	**---**	**20**	**---**	**20**
		IV	**---**	**---**	**---**	**20**	**20**
							Total credits of P.G. Programme = **80**

Note: **Having Internship of 4 credits 'Exit' is allowed with awarding the PG Diploma Certificate**.

Implemented from Academic Session 2025-26 & Onwards

AIMS OF MASTER'S DEGREE PROGRAMME IN MATHEMATICS

The aim of Master's degree programme in Mathematics is intended to provide:

1. A rigorous and broad-based understanding of advanced mathematical concepts, including real and complex analysis, algebra, topology, differential equations, functional analysis, and mathematical modelling, building upon the foundational knowledge acquired at the undergraduate level.
2. The ability to think critically and abstractly, formulate precise mathematical arguments, and construct rigorous proofs, thereby deepening the student's capacity for independent inquiry and research.
3. Advanced exposure to the rich **Indian contributions to mathematics**—such as the works of Aryabhata, Bhāskara, Madhava, and others—embedding elements of the **Indian Knowledge Systems (IKS)** into the curriculum to foster historical, philosophical, and cultural awareness of the subject.
4. Training in the use of mathematics in solving real-world problems arising in natural sciences, engineering, and data sciences, alongside a firm grasp of modern mathematical methods including conformal mapping, variational principles, and computational techniques.
5. Preparation for careers in higher education, scientific research, and industry by cultivating technical skills, academic writing proficiency, and the ability to conduct independent research culminating in a dissertation.
6. A commitment to ethical reasoning, intellectual integrity, and appreciation of mathematics as both a universal and culturally grounded discipline, nurturing a lifelong love for learning and discovery.

PROGRAMME LEARNING OUTCOMES

The broad aims of Master's degree programme in Mathematics are:

1. **Advanced Mathematical Competence**: Acquire in-depth understanding of core areas such as real and complex analysis, abstract algebra, functional analysis, differential equations, and topology, and apply this knowledge to both theoretical investigations and applied contexts.
2. **Analytical and Logical Thinking:** Demonstrate expertise in formulating precise mathematical statements, constructing proofs, solving abstract problems, and developing algorithms for both classical and contemporary mathematical challenges.
3. **Research and Communication Skills:** Gain proficiency in mathematical writing, literature review, and research methodology. Communicate mathematical ideas clearly through presentations and a structured dissertation based on independent or guided research.
4. **Mathematical Modelling and Applications:** Apply mathematical techniques to real-world scenarios, including problems from physics, fluid dynamics, engineering, and finance. Develop and analyze models using tools such as differential equations, numerical methods, and complex functions.
5. **Integration of Indian Knowledge Systems (IKS):** Appreciate the historical development and indigenous contributions to mathematics in India, including ancient number systems, combinatorics, calculus precursors, and astronomical mathematics, thereby recognizing mathematics as a culturally embedded discipline.
6. **Ethical and Professional Responsibility:** Adhere to high standards of academic integrity, responsible use of mathematics in social and technological applications, and sensitivity to the ethical dimensions of quantitative reasoning.
7. **Career and Higher Education Readiness:** Be well-prepared for doctoral research, academic and teaching careers, as well as roles in government, data science, finance, and industries that value analytical and quantitative skills.
8. **Lifelong Learning and Interdisciplinary Outlook:** Cultivate curiosity, adaptability, and a mindset of lifelong learning, with openness to new areas such as mathematical computing, data-driven mathematics, and interdisciplinary collaboration.

The Courses in One Year P.G. Programme and in the Second year of Two years P.G. Programme are Common.

Table 2: Semester-wise Course Code and Credit Points

Sem	Core, AE/ GE/ DC/ EC & Compulsory FC Courses				Examination Structure		
	Paper	**Paper Code**	**Credit**	**Name of Paper**	**Mid Semester Evaluation (F.M.)**	**End Semester Evaluation (F.M.)**	**End Semester Practical/ Viva (F.M.)**
I	Foundation Course	FCMAT101	4	Real Analysis	30	70	----
	Core Course	CCMAT102	4	Ordinary Differential Equations	30	70	----
	Core Course	CCMAT103	4	Research Methodology	30	70	----
	Core Course	CCMAT104	4	Metric Space and It's Applications	30	70	----
	Core Course	CCMAT105	4	Complex Analysis	30	70	----
II	Core Course	CCMAT201	4	Analytical Dynamics and Calculus of Variations	30	70	----
	Core Course	CCMAT202	4	Measure Theory	30	70	----
	Core Course	CCMAT203	4	Topology	30	70	----
	Core Course	CCMAT204	4	Programming in Python and MATLAB (Theory)	30	70	----
	Core Course	CPMAT205	4	Programming in Python and MATLAB (Practical)	30	70	----
III	Core Course	CCMAT301	4	IKS in Mathematics	30	70	----
	Skill Enhancement Course	ECMAT302	4	A. Fourier and Wavelet Analysis/ B. Hadamard Matrices and Combinatorial Designs/ C. Advance Discrete Mathematics/ D. Fluid Dynamics	30	70	----
	Core Course	CCMAT303	4	Advanced Algebra	30	70	----
	Core Course	CCMAT304	4	Differential Geometry and Tensor Analysis	30	70	----
	Core Course	CCMAT305	4	Partial Differential Equations	30	70	----
IV	Elective	ECMAT401	4	A. Optimization Techniques/ B. Integral Transforms/ C. Stochastic Process	30	70	----
	Elective	ECMAT402	4	A. Operations Research/ B. Integral Equations/ C. Mathematical Modeling	30	70	----
	Core Course	CCMAT403	4	Functional Analysis	30	70	----
	Core Course	CCMAT404	4	Numerical Solutions of PDE	30	70	----
	PROJECT	PRMAT405	4	Dissertation/ Project Work/ Teaching Aptitude	----	----	100

*** Either One Internship of 4 credits or Two Internships of 2 credits each is required before opting for the 'Exit' option after First year of the P.G. Programme.**

INSTRUCTION TO QUESTION SETTER

SEMESTER INTERNAL EXAMINATION (SIE):

There **Marks Weightage of a Course:** Each non-practical/non-project course shall be of **100 marks** having two components: **70 marks shall be assigned to the End Semester University Examination (ESUE), conducted by the University, and, 30 marks for Sessional Internal Assessment (SIA), conducted by the Department/College**.

The marks of SIA shall further break into, 20 for Internal Written Examinations, 05 for Written Assignment/ Seminar presentation and 05 for overall performance of a student including regularity in the class room lectures and other activities of the Department/College. There shall be two written internal examinations, each of 1-hour duration and each of 20 marks, in a semester out of which the **'Better One out of Two'** shall be taken for computation of marks under SIA.

In absolute terms of marks obtained in a course, **a minimum of 28 marks is essential in the ESUE and a minimum of 17 marks is to be secured in the SIA to clear the course**. In other words, a student shall have to pass separately in the ESUE and in the SIA by securing the minimum marks prescribed here.

A. (SIE 20+5=25 marks):

There will be a uniform pattern of questions for mid semester examinations in all the courses and of all the programmes. There will be **two** groups of questions in 20 marks written examinations. **Group A is compulsory** and will contain five questions of **very short answer type** consisting of 1 mark each. **Group B will contain descriptive type five** questions of five marks each, out of which any three are to be answered. Department may conduct Sessional Internal Examinations in other format as per need of the course.

The Semester Internal Examination shall have two components. (a) One Semester Internal Assessment Test (SIA) of 20 Marks, (b) Class Attendance Score (CAS) of 5 marks.

Conversion of Attendance into score may be as follows:
Attendance Upto 45%, 1mark; 45<Attd.<55, 2 marks; 55<Attd.<65, 3 marks; 65<Attd.<75, 4 marks; 75<Attd, 5 marks.

END SEMESTER UNIVERSITY EXAMINATION (ESUE):

A. (ESUE 70 marks):

There will be a uniform pattern of questions for all the courses and of all the programmes. There will be **two** groups of questions. **Group A is compulsory** and will contain two questions. **Question No.1 will be very short answer type** consisting of five questions of 1 mark each. **Question No.2 will be short answer type** of 5 marks. **Group B will contain descriptive type six** questions of fifteen marks each, out of which any four are to be answered. The questions will be so framed that examinee could answer them within the stipulated time.

[**Note:** There may be subdivisions in each question asked in Theory Examinations]

B. (ESUE 100 marks):

Practical/ Project courses would also be of 100 marks but there **shall be no internal written examinations** of the type specified above. The total 100 marks will have two components: **70 marks for the practical ESUE and 20 marks for the Viva-voce examination** conducted during the ESUE to assess the applied and practical understanding of the student.

The written component of the project (**Project Report**) shall be of **70 marks and 20 marks will be for the Viva-voce examination** jointly conducted by an external examiner, appointed by the University, and the internal supervisor/guide.

10 marks will be assigned on cumulative assessment of examinee during the semester and will be awarded by the department/faculty concerned.

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FORMAT OF QUESTION PAPER FOR MID/ END SEMESTER EXAMINATIONS

Question format for **20 Marks**:

Subject/ Code

F.M. =20 **Time**=1Hr. Exam Year

General Instructions:

i. **Group A** carries very short answer type compulsory questions.
ii. **Answer 1 out of 2** subjective/ descriptive questions given in **Group B**.
iii. Answer in your own words as far as practicable.
iv. Answer all sub parts of a question at one place.
v. Numbers in right indicate full marks of the question.

Group A

1. [5x1=5]
   i. ....
   ii. ....
   iii. ....
   iv. ....
   v. ....
2. .... [5]

Group B

3. .... [10]
4. .... [10]

Note: There may be subdivisions in each question asked in Theory Examination.

Question format for **70 Marks**:

Subject/ Code

F.M. =70 **Time**=3HrS. Exam Year

General Instructions:

i. **Group A** carries very short answer type compulsory questions.
ii. **Answer 4 out of 6** subjective/ descriptive questions given in **Group B**.
iii. Answer in your own words as far as practicable.
iv. Answer all sub parts of a question at one place.
v. Numbers in right indicate full marks of the question.

Group A

1. [5x1=5]
   i. ....
   ii. ....
   iii. ....
   iv. ....
   v. ....
2. .... [5]

Group B

3. .... [15]
4. .... [15]
5. .... [15]
6. .... [15]
7. .... [15]
8. .... [15]

Note: There may be subdivisions in each question asked in Theory Examination.

SEMESTER I

I. FOUNDATION COURSE [FCMAT101]

REAL ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	**Pass Marks: (MSE: 17 + ESE: 28) = 45**

(Credits: Theory-04, 60 Hours)

Course Objectives:

By the end of this course, students will be able to:

1. Understand fundamental concepts in metric spaces including open/closed sets, limit points, and subspaces.
2. Analyze convergence, completeness, and continuity in metric spaces using key theorems.
3. Explore and apply criteria for compactness and sequential compactness in metric spaces.
4. Examine connectedness in metric spaces and apply related theorems to subsets and functions.

Course Learning Outcomes:

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

1. Identify and describe open spheres, closed sets, closures, interiors, and other topological properties in metric spaces.
2. Determine completeness of metric spaces and verify continuity using concepts like uniform continuity and Banach's contraction principle.
3. Apply the Heine-Borel theorem and other compactness criteria to solve problems in analysis.
4. Classify connected and disconnected sets, and analyze the behavior of continuous functions on connected spaces.

Course Content:

UNIT-I: Concepts in Metric Spaces (18 Hours) [2 Questions]

Definition and examples of metric spaces, Open spheres and closed spheres, Neighbourhoods, Open sets, Interior, exterior and boundary points, Closed sets, Limit points and isolated points, Interior and closure of a set, Boundary of a set, Bounded sets, Distance between two sets, Diameter of a set, Subspace of a metric space.

UNIT-II: Complete Metric Spaces and Continuous Functions (18 Hours) [2 Questions]

Cauchy and Convergent sequences, Completeness of metric spaces, Cantor's intersection theorem, Dense sets and separable spaces, Nowhere dense sets and Baire's category theorem, Continuous and uniformly continuous functions, Homeomorphism.

UNIT-III: Compact Metric Space (14 Hours) [1 Question]

Compact spaces, Sequential compactness, Bolzano-Weierstrass property, Compactness and finite intersection property, Heine-Borel theorem, Totally bounded sets, Equivalence of compactness and sequential compactness, Continuous funnctions on compact spaces, Lebesgue covering lemma, locally compact spaces.

UNIT-IV: Connectedness in Metric Space (10 Hours) [1 Question]

Separated sets, Disconnected and connected sets, Properties of connected and disconnected sets, Components, Connected subsets of $\mathbb{R}$, Continuous functions on connected sets.

Reference books:

1. P. K. Jain & Khalil Ahmad (2019). *Metric Spaces*. Narosa.
2. G. F. Simmons (2004). *Introduction to Topology and Modern Analysis*. McGraw-Hill.
3. Shanti Narayan & M. D. Raisinghania (2020). *Elements of Real Analysis.* S. Chand.
4. Satish Shirali & Harikishan L. Vasudeva (2006). *Metric Spaces*. Springer-Verlag.
5. S. C. Mallik and Savita Arora (2022). *Mathematical Analysis*. New Age International.
6. Mícheál O'Searcoid (2007). *Metric Spaces*. Springer.

II. CORE COURSE [CCMAT102]
ORDINARY DIFFERENTIAL EQUATIONS

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE :28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the existence and uniqueness theorems for first-order differential equations and apply iterative methods to approximate solutions.
2. Analyze second and higher-order differential equations using algebraic methods, Wronskian properties, and solution techniques for both homogeneous and non-homogeneous cases.
3. Study linear systems of ODEs, their solutions using eigenvalue methods, and techniques for reduction to first-order systems.
4. Learn to solve boundary value problems using Sturm–Liouville theory and Green's function techniques.

Course Learning Outcomes:

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

1. Determine the existence and uniqueness of solutions to first-order ODEs using Picard's theorem and apply successive approximation techniques.
2. Analyze and solve second and higher-order ODEs using Wronskian, annihilator method, and initial value problem techniques.
3. Solve linear systems of ODEs using eigenvalues and eigenvectors, and reduce higher-order equations to first-order systems.
4. Formulate and solve Sturm–Liouville boundary value problems using Green's functions for self-adjoint differential operators.

Course Content:

UNIT-I: First Order ODE (12 Hours) [1 Question]

Existence and uniqueness of the solution to ODE, Picard's existence theorem, Lipschitz condition, Uniqueness theorem, Picard's method of successive approximation.

UNIT-II: Second and Higher Order ODE (18 Hours) [2 Questions]

Algebraic properties of solutions of homogeneous equations & Wronskian of second order ODE, n^{th} order ODE, Wronskian of a functions and its properties, Annihilator method to solve non homogeneous ODE with constant coefficients, initial value problem, Existence and uniqueness theorem.

UNIT-III: Linear System of ODE's (18 Hours) [2 Questions]

Linear system of ODEs, Existence and Uniqueness of linear system, linear homogeneous system with constant coefficients, method of eigen value and eigen vectors, Fundamental solution, Reduction of higher order linear equation into first order linear equations

UNIT-IV: Boundary Value Problem (12 Hours) [1 Question]

Strum-Lioville boundary value problem with homogenous boundary conditions. Green's function, Green's function techniques for solving self-adjoint boundary value problem

Reference books:

1. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). Wiley.
2. E.A. Coddington and N. Levinson (1955). *Theory of Ordinary Differential Equations*. Mc Graw-Hill, NY.
3. M. Brawn (1992). *Differential equations and their applications*. Springer-Verlag New York.
4. A. Chakrabarti (1990). *Elements of ordinary differential equations and special functions.* New Age, Int. Publ.
5. M. D. Raisinghania (2001). *Advanced differential equations.* S. Chand and Company.
6. A. Coddington (1987). *An introduction to Ordinary Differential equations.* Prentice Hall of India, New Delhi

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III. CORE COURSE [CCMAT103]

RESEARCH METHODOLOGY

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the fundamental concepts of research methodology, including research problems, objectives, design, and the overall research process.
2. Develop skills in scientific writing for proposals, research papers, dissertations, and theses with proper structure, clarity, and referencing.
3. Gain awareness of research ethics and publication integrity, including issues of plagiarism, misconduct, authorship, and research metrics.
4. Acquire proficiency in using digital tools, presentation techniques, and online resources for effective research communication.

Course Learning Outcomes:

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

1. Formulate well-defined research problems, design research plans, and conduct literature surveys effectively.
2. Write high-quality research proposals, papers, dissertations, and theses following academic and scientific standards.
3. Apply principles of research ethics and publication practices to ensure integrity, originality, and responsible authorship.
4. Use LaTeX, MS Office, PowerPoint, Beamer, and online databases to prepare and present professional research outputs.

Course Content:

UNIT-I: Introduction of Research Methodology (12 Hours) **[1 Question]**

Introduction to Research: Meaning of research, objectives of research, types of research, significance of research, research and scientific method, research process. *Research Problem*: Definition, necessity and techniques of defining research problem. Formulation of research problem. Objectives of research problem. *Research Design*: Meaning, need and features of good research design. Literature survey of the topic and a problem, Role of a supervisor, Funding agencies.

UNIT-II: Scientific Writing (18 Hours) **[2 Questions]**

Research Proposal: Title, State of the Art, Research Problem, Objective, Significance, Contribution to the society, Methodology, Tools to be used, References; *Research Papers:* Title, Running Title, Authors- Single and Multiple-authorship, Abstract, Key Words, Introduction section, Formulation of problem, method of solution/Analytical proofs, Result Section, Figures- Design Principles, Legends, fable components. Graphs; Types, Style. Discussion Section: Format. Grammar Style, Content, Acknowledgements, References and citations; *Dissertation/ Thesis:*Format of a dissertation/ thesis; Review of literature, formulation; Writing methods, results; preparation of tables, figures; writing discussion; writing conclusion; writing summary and synopsis; Reference citing and listing/bibliography.

UNIT-III: Ethics in Research and Scholarly Publishing (18 Hours) **[2 Questions]**

Scientific Conduct: Ethics with respect to science and research, Intellectual honesty and research integrity; *Scientific misconducts*: Falsification, Facbrication and Plagiarism; *Redundant publications*: Duplicate and overlapping publications, salami slicing; Selective reporting and misrepresentation of data. *Publication Ethics:* Definition, introduction and importance of publication ethics; Conflicts of interest; *Publication misconduct*: Definition, concept, problems that led to unethical behaviour and vice versa, types; Violation of publication ethics, authorship and contributorship; *Journals*: Predatory publishers and journals, Open Access Publishing. *Database*: Indexing databases; Citation databases: Web of science, Scopus, etc.; *Research Metrics*: Impact factor of journal, CiteScore; *Metrics*: h-index, g index, i10 index.

UNIT-IV: Tools and Techniques for Research Communication (12 Hours) **[1 Question]**

Writing tools: MS Office 2007- Word basics, Macros, Math Type, Equation Editor; LaTeX. *Presentation tools*: Power Point basics; Animations; Poster and Oral; Beamer as a tool for paper and thesis presentations. *Web Search*: Search engines; Searching hints; Using advanced search techniques; Mathematical & Scientific Websites & Databases.

Reference Books:

1. C. R. Kothari and Gaurav Garg (201 0). *Research Methodology (Methods & Techniques*), New Age Int. Pub.
2. Ranjit Kumar (2019). *Research Methodology: A Step-by-Step Guide for Beginners*, SAGE Pub.
3. Gurumani, N. (2010). *Scientific Thesis Writing and Paper Presentation*. MJP Publishers.
4. Santosh Kumar Yadav (2023). *Research and Publication Ethics,* Springer.
5. M. **Otey (2013).** *Creating Research and Scientific Documents Using Microsoft Word*. **O'Reilly Media.**
6. **S. Kottwitz (2015).** *LaTeX Cookbook*. **Packt Publishing.**

IV. CORE COURSE [CCMAT104]
METRIC SPACE AND IT'S APPLICATIONS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

By the end of this course, students will be able to:

1. Understand fundamental concepts in metric spaces including open/closed sets, limit points, and subspaces.
2. Analyze convergence, completeness, and continuity in metric spaces using key theorems.
3. Explore and apply criteria for compactness and sequential compactness in metric spaces.
4. Examine connectedness in metric spaces and apply related theorems to subsets and functions.

Course Learning Outcomes:

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

1. Identify and describe open spheres, closed sets, closures, interiors, and other topological properties in metric spaces.
2. Determine completeness of metric spaces and verify continuity using concepts like uniform continuity and Banach's contraction principle.
3. Apply the Heine-Borel theorem and other compactness criteria to solve problems in analysis.
4. Classify connected and disconnected sets, and analyze the behavior of continuous functions on connected spaces.

Course Content:

Unit-I: Concepts in Metric Spaces (12 Hours) [1 Question]

Definition and examples of metric spaces, Open spheres and closed spheres, Neighbourhoods, Open sets, Interior, exterior and boundary points, Closed sets, Limit points and isolated points, Interior and closure of a set, Boundary of a set, Bounded sets, Distance between two sets, Diameter of a set, Subspace of a metric space.

Unit-II: Complete Metric Spaces and Continuous Functions (18 Hours) [2 Questions]

Cauchy and Convergent sequences, Completeness of metric spaces, Cantor's intersection theorem, Dense sets and separable spaces, Nowhere dense sets and Baire's category theorem, Continuous and uniformly continuous functions, Homeomorphism.

Unit-III: Compact Metric Space (17 Hours) [2 Question]

Compact spaces, Sequential compactness, Bolzano-Weierstrass property, Compactness and finite intersection property, Heine-Borel theorem, Totally bounded sets, Equivalence of compactness and sequential compactness, Continuous funnctions on compact spaces, Lebesgue covering lemma, locally compact spaces.

Unit-IV: Connectedness and Contraction Mapping Principle (13 Hours) [1 Question]

Separated sets, Disconnected and connected sets, Properties of connected and disconnected sets, Components, Connected subsets of $\mathbb{R}$, Continuous functions on connected sets. Contraction mapping, Fixed point with examples, Banach fixed point theorem. Banach contraction principle.

Reference books:

1. P. K. Jain & Khalil Ahmad (2019). *Metric Spaces*. Narosa.
2. G. F. Simmons (2004). *Introduction to Topology and Modern Analysis*. McGraw-Hill.
3. Shanti Narayan & M. D. Raisinghania (2020). *Elements of Real Analysis.* S. Chand.
4. Satish Shirali & Harikishan L. Vasudeva (2006). *Metric Spaces*. Springer-Verlag.
5. S. C. Mallik and Savita Arora (2022). *Mathematical Analysis*. New Age International.
6. Mícheál O'Searcoid (2007). *Metric Spaces*. Springer.

V. CORE COURSE [CCMAT105]
COMPLEX ANALYSIS

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE :28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the theory of complex integration and fundamental results like Cauchy's theorems and their consequences.
2. Analyze singularities, compute residues, and apply the residue theorem and Jordan's lemma to evaluate complex integrals.
3. Explore the nature and behavior of meromorphic and entire functions using powerful results like Rouche's theorem and the principle of argument.
4. Learn the concept of analytic continuation and methods to extend analytic functions beyond their original domains.

Course Learning Outcomes:

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

1. Evaluate complex integrals using Cauchy's theorems, and apply the maximum and minimum modulus principles and Liouville's theorem.
2. Identify and classify singularities, calculate residues at poles and infinity, and apply the residue theorem to solve contour integrals.
3. Analyze meromorphic functions, apply Mittag-Leffler's theorem, and use Rouche's theorem to determine zeros and poles.
4. Perform analytic continuation using power series methods, and determine the uniqueness and behavior near singularities on the circle of convergence.

Course Content:

Unit –I: Complex Integration (18 Hours) [2 Question]

Line integral, Path independence, Complex integration, Cauchy-Goursat Theorem, Cauchy's Integral formula, Higher order derivatives, Morera's Theorem, Cauchy's inequality, Liouville's theorem, Maximum modulus principle, Minimum modulus principle.

Unit-II: Singularities and Cauchy Residue Theorem (18 Hours) [2 Questions]

Zero of a function, Singular point, Types of singularities, isolated poles and zeros, limiting point of poles and zeros, Residue at a pole, Residue at infinity, Cauchy Residue theorem, Jordan's lemma, Evaluation of integrals.

Unit-III: Meromorphic Functions(12 Hours) [1 Question]

Definitions of Meromorphic and entire functions, Mittag-Lefler's expansion, Number of poles and zeros of a meromorphic function, Principle of argument, Rouche's theorem, Fundamental theorem of Algebra.

Unit-IV: Analytic Continuation and Its Application (12 Hours) [1 Question]

Definition of Analytic continuations and related problems, Uniqueness theorem of Analytic continuation, Standard method/ Power series method of Analytic continuation along a curve, Singularity on the circle of convergence of power series.

Reference books:

1. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). Wiley
2. Churchill and Brown (2009), *Complex variables and applications.* McGraw-Hill Pub.Company.
3. Walter Rudin (1966). *Real and Complex Analysis*. Mc Graw Hill Book Co.
4. E.C. Titchmarsh (1976). *The Theory of Functions.* Oxford University Press. London.
5. J. N. Sharma (2014). *Functions of a complex variable.* Krishna Prakashan.
6. J. K. Goyal & K. P. Gupta (2008). *Functions of a complex variable.* Pragati Prakashan.
7. H. K. Pathak (2021). *Complex Analysis.* Shree Shiksha Sahitya Prakashan

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SEMESTER II

I. CORE COURSE [CCMAT201]

ANALYTICAL DYNAMICS & CALCULUS OF VARIATIONS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the foundational principles of Lagrangian mechanics and apply them to different types of mechanical systems.
2. Formulate and analyze physical systems using Hamiltonian and Routhian dynamics.
3. Apply techniques from the calculus of variations to solve classical optimization problems in physics and geometry.
4. Explore variational principles in dynamics and use bracket operations to study symmetries and conserved quantities.

Course Learning Outcomes:

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

1. Formulate equations of motion using Lagrange's first and second kind, and derive energy relations in conservative systems.
2. Derive and apply Hamilton's canonical equations and Routh's equations for dynamical systems involving cyclic coordinates.
3. Solve variational problems involving geodesics, shortest paths, and minimal surfaces using Euler's equation.
4. Apply Hamilton's principle, derive Hamilton–Jacobi equations, and use Lagrange and Poisson brackets in the study of dynamical systems and symmetries.

Course Content:

UNIT-I: Lagrangian Dynamics (19 Hours) [2 Questions]

Moment of Inertia, Generalized coordinates, Holonomic and Non-holonomic systems, Scleronomic and Rheonomic systems, Generalized potential. Lagrange's equations of first and second kind, Energy equation for conservative fields.

UNIT-II: Equations of Hamilton and Routh (12 Hours) [1 Question]

Hamilton canonical equations. Equation of energy from Hamilton's equations, Cyclic coordinates, Routh's equations, Jacobi-Poisson Theorem.

UNIT-III: Calculus of Variations (12 Hours) [1 Question]

Motivating problems of calculus of variations fundamental lemma of calculus of variations Euler's equation, Brachistochrone problem Shortest distance, Geodesic, Minimum surface of revolution.

UNIT-IV: Variational Principal in Dynamics and Brackets (17 Hours) [2 Questions]

Hamilton's Principle, Principle of least action. Jacobi's equations. Hamilton-Jacobi equations. Jacobi theorem. Lagrange brackets and Poisson brackets. Invariance of Langrange brackets and Poisson brackets under canonical transformations.

Reference Books:

1. H.Goldstein (1980). *Classical Mechanics*(2nd edition),Narosa Publishing House, New Delhi.
2. I.M.Gelfand and S.V.Fomin (2000). *Calculus of variation*, prentice Hall.
3. S.L. Loney (1979). *An elementary treatise on Statics*, Kalyani Publishers, N. Delhi.
4. A.S.Ramsey (1940), *Newtonian Gravitation*. The English Language Book Society and the Cambridge University Press.
5. N.C. Rana & P.S.Chandra Joag (1991). *Classical Mechanics*. Tata McGraw Hill.
6. Lours N. Hand and Janel, D. Finch (1999). *Analytical Mechanics*, Cambridge University Press.
7. P. P. Gupta and G. S. Malik (2008). *Rigid Dynamics-I & II*. Krishna Prakashan.

II. CORE COURSE [CCMAT202]
MEASURE THEORY

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:
By the end of the course, students will be able to:
1. Understand the concept of measure, outer measure, and measurable sets including examples like Cantor and non-measurable sets.
2. Develop the ability to identify and work with measurable functions, including step and Borel measurable functions, and apply foundational principles.
3. Learn the construction and properties of the Lebesgue integral and compare it with the Riemann integral.
4. Explore various modes of convergence of measurable functions and apply major convergence theorems in integration.

Course Learning Outcomes:
After successful completion of this course, the students will be able to:
1. Define and identify measurable sets, explain outer measure, Carathéodory's criterion, and describe examples like the Cantor ternary set and Borel sets.
2. Analyze measurable functions and their properties, and explain the significance of Littlewood's three principles.
3. Compute Lebesgue integrals for different classes of functions and distinguish them from Riemann integrals.
4. Apply theorems related to convergence in measure, including Egoroff's, Riesz, Fatou's lemma, and the Dominated and Monotone Convergence Theorems.

Course Content:

UNIT-I: Measurable Sets (18 Hours) [2 Questions]
Motivation and Concept of Measure of a set, Outer measure, Caratheodory postulates. Measurable sets, Cantor Ternary Set. Lebesgue measures, Properties of Measurable Sets, Borel Sets. A non-measurable set,

UNIT-II: Measurable Functions (12 Hours) [1 Question]
Measurable functions, Properties of measurable functions. Step function, Characteristic function, Continuous function, Borel measurable functions. Littlewood's three principles.

UNIT-III: The Lebesgue Integral (12 Hours) [1 Question]
Lebesgue integral of a bounded function over a finite measure, First Mean Value Theorem, The integral of a non-negative function, The general Lebesgue integral, Theorems on General Lebesgue integrals. Riemann vs Lebesgue integrals.

UNIT-IV: Convergence in Measure (18 Hours) [2 Questions]
Definitions. Convergence in measure, Riesz theorem, Egoroffs theorem, Bounded convergence theorem, Dominated Convergence theorem, Monotone convergence theorem. Fatou's lemma.

Reference books:

1. G. de Barra (2013). *Measure Theory and Integration*. New Age Int.
2. P. K. Jain, V. P. Gupta and P. Jain (2011). *Lebesgue Measure and Integration*. New Age International.
3. I. K. Rana (2007). *An Introduction to Measure and Integration.* Narosa.
4. H. K. Pathak (2021). *Real Analysis.* Shree Shiksha Sahitya Prakashan.
5. P. P. Gupta, G. S. Malik & S. K. Mittal (2008). *Measure Theory.* Pragati Prakashan..

III. CORE COURSE [CCMAT203]

TOPOLOGY

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the basic definitions, examples, and fundamental structures of topological spaces including subspaces and quotient topology.
2. Explore the concepts of continuity, homeomorphism, and connectedness in topological spaces.
3. Study countability properties and separation axioms with the help of essential theorems like Urysohn's Lemma and Tietze extension theorem.
4. Examine the concept of compactness and its implications, including important results like Tychonoff's theorem and one-point compactification.

Course Learning Outcomes:

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

1. Define and work with topological spaces, closed sets, interiors, closures, derived sets, and construct topologies using bases, subbases, and quotient topology.
2. Analyze continuous functions and homeomorphisms, and determine connectedness and related properties in topological spaces.
3. Apply countability conditions and separation axioms, and utilize Urysohn's Lemma and Tietze extension theorem to study space separation.
4. Determine compactness using finite intersection property, apply Tychonoff's theorem, and understand compactification techniques like one-point compactification.

Course Content:

UNIT-I: Fundamentals of A Topological Space (18 Hours) [2 Questions]

Definition and examples of topological spaces. Closed sets, Closure. Dense subsets. Neighbourhoods, Interior, exterior and boundary. Accumulation points and derived sets. Bases and sub-bases. Subspaces and relative topologies. Quotient topology

Unit-II: Continuity and Connectedness (10 Hours) [1 Question]

Continuity and homeomorphism, Product of topological spaces, connected space and its properties.

Unit-III: Countability and Separation Axioms (18 Hours) [2 Questions]

First and Second countable spaces. Lindelof's theorem, separable spaces, second countability and separability. Separation axioms To, T1, T2, T3, T4: their Characterizations and basic properties. Urysohn's Lemma. Tietze extension theorem.

Unit-IV: Compactness (14 Hours) [1 Question]

Compactness. continuous image of compact sets. Basic property of compactness. Compactness and finite intersection property Tychonoff's Theorem, One point compactification of a topological space.

Reference books:

1. K.D. Joshi (1983). *Introduction to General Topology.* Wiley Eastern Ltd.
2. W.J. Pervin (1964). *Foundations of General Topology.* Academic Press Inc. New York.
3. G.F. Simmons (2017). *Introduction to Topology and Modern Analysis.* Mc Graw Hill Int. book company.
4. J.R. Munkres (1974). *Topology A first course.* Prentice hall India Pvt. Ltd.
5. S. Lipschutz (1968). *General Topology.* Schaum's outline series..

IV. CORE COURSE [CCMAT204]

PROGRAMMING IN PYTHON AND MATLAB

(Theory)

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Develop basic programming skills using Python for general-purpose and mathematical computing.
2. Utilize Python libraries such as NumPy, Pandas and Matplotlib for numerical computation and visualization.
3. Learn the MATLAB environment and perform mathematical operations using arrays, matrices, and scripts.
4. Apply programming concepts in MATLAB to solve problems involving numerical analysis and data visualization.

Course Learning Outcomes:

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

1. Write Python programs using control structures, built-in data types, functions, and modules.
2. Perform mathematical operations, matrix manipulations, and visualize data using NumPy, Pandas and Matplotlib.
3. Use MATLAB for performing element-wise and matrix operations, scripting, and 2D plotting.
4. Solve mathematical problems in MATLAB involving polynomials, curve fitting, interpolation, and numerical methods such as root finding and numerical integration.

Course Content:

UNIT-I: Introduction to Python Programming (12 Hours) [1 Question]

***Basics of Python*:** Installing Python and Jupyter Notebook, IDEs: IDLE, Anaconda, VS Code, Syntax, indentation, keywords, Variables and data types: int, float, str, bool, complex, Input/output: `input()`, `print()`,Operators: arithmetic, logical, relational, assignment. ***Control Structures*:** Conditional statements: `if`, `if-else`, `elif`, Loops: `for`, `while`, Loop control statements: `break`, `continue`, `pass`. ***Data Structures*:** Lists, Tuples, Sets, Dictionaries, Indexing and slicing, Iterating through collections, Built-in functions: `len()`, `sum()`, `sorted()`, etc. ***Functions and Modules*:** Defining and calling functions, Arguments, return values, `import` and using built-in modules: `math`, `random`.

UNIT-II: Python for Mathematical Computing and Visualization (18 Hours) [2 Questions]

***Mathematical Operations*:** Large integers, floating point, and complex numbers, Using `math`, `cmath`, `decimal` modules, List comprehensions for generating sequences, Error handling with `try/except`. ***NumPy for Mathematical Computation*:** Creating and using arrays, Indexing, slicing, reshaping arrays, Vectorized operations, broadcasting, Matrix operations: addition, multiplication, transpose, inverse, Solving systems of equations using `numpy.linalg.solve`. ***Visualization with Matplotlib*:** Introduction to Matplotlib, Line, bar, scatter plots, Customizing plots: titles, labels, colors, legends, Plotting mathematical functions like `sin(x)`, `exp(x)`. ***Applications in Mathematics*:** Programs for: Factorial, GCD, LCM, Fibonacci sequence, Root finding (e.g., Newton-Raphson), *Basic statistics:* mean, median, mode, variance. ***Data Handling and Basic Analysis with Pandas*:** Introduction to Pandas: Series and DataFrame structures, Creating DataFrames from lists, dictionaries, and CSV files, Indexing and slicing data in DataFrames, Basic operations: selecting rows/columns, filtering, sorting, Descriptive statistics: `mean()`, `median()`, `mode()`, `std()`, `describe()`, Handling missing data: `isnull()`, `dropna()`, `fillna()`, Data visualization using `pandas.plot()` for quick plots.

UNIT-III: Introduction to MATLAB (12 Hours) [1 Question]

Elementary Math Built-in Functions. Common constants. ***Creating Arrays*:** One-dimensional arrays, Two-dimensional arrays (matrices), Indexing, slicing, modifying elements. ***Variables and Strings*:** Variable naming, assignment, workspace management, String handling and operations. ***Mathematical Operations with Arrays*:** Element-wise vs matrix operations. ***Script Files*:** Writing and running script (.m) files, Commenting, formatting code, Use of `clc`, `clear`, `disp`, `input`. ***Two-Dimensional Plots*:** `plot()`, `fplot()`, `bar()`, `stem()`, Titles, axes labels, legends, grids, Plotting multiple functions on the same graph. ***Functions and Function Files*:** Defining custom functions, Function inputs, outputs, and scope, Built-in functions vs user-defined functions

UNIT-IV: Programming in MATLAB (18 Hours) [2 Questions]

Relational and Logical Operators. ***Conditional Statements*****:** `if`, `if-else`, `if-elseif-else`, `switch-case-otherwise`. ***Loops*****:** `for`, `while` loops, Nested loops and nested conditional statements, Use of `break` and `continue`. ***Polynomials*****:** Representing polynomials as vectors, `polyval`, `polyfit`, `roots`, `conv`, `deconv`. ***Curve Fitting and Interpolation*****:** Linear and polynomial fitting using `polyfit`, Interpolation using `interp1`, `interp2`, `spline`. ***Applications to Numerical Analysis*****:** Solving equations using `fzero`, `fsolve`, Numerical differentiation and integration (`diff`, `trapz`, `integral`).

Reference books:

1. Zelle, J. M. (2017). *Python programming: An introduction to computer science* (3rd ed.). Franklin, Beedle & Associates Inc.
2. Saha, A. (2015). *Doing math with Python: Use programming to explore algebra, statistics, calculus, and more!* No Starch Press.
3. Kinder, J. M., & Nelson, P. (2018). *A student's guide to Python for physical modeling* (2nd ed.). Princeton University Press.
4. Johansson, R. (2019). *Numerical Python: Scientific computing and data science applications with NumPy, SciPy and Matplotlib* (2nd ed.). Apress.
5. Amos Gilat (2012). *MATLAB- An Introduction with Applications.* Wiley India..

V. CORE COURSE [CPMAT205]
PROGRAMMING IN PYTHON AND MATLAB
(Practical)

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 6 Hrs) = 100	Pass Marks: = 45

(Credits: Theory-04, 60 Hours)

Instruction to Question Setter for

End Semester Examination (ESE Pr):
There will be one Practical Examination of 3Hrs duration. Evaluation of Practical Examination may be as per the following guidelines:
Experiment/Lab work = 70 marks
Practical record notebook = 05 marks
Attendance = 05 marks
Viva-voce = 20 marks

Course Objectives:
By the end of the course, students will be able to:
1. Develop practical programming skills in Python and MATLAB for solving mathematical problems.
2. Implement mathematical operations, matrix computations, and visualization techniques using code.
3. Apply built-in libraries and functions in Python and MATLAB to model and analyze real-world data.
4. Strengthen logical thinking and problem-solving abilities through coding-based mathematical exercises.

Course Learning Outcomes:
After successful completion of this course, the students will be able to:
1. Write and execute Python scripts involving loops, functions, and mathematical operations.
2. Create and manipulate arrays and matrices using Python and MATLAB.
3. Generate and customize 2D plots to visualize mathematical functions and data.
4. Implement programs to solve equations, perform statistical analysis, and carry out numerical methods such as differentiation, integration, and root-finding using both Python and MATLAB.

Course Content:
PYTHON PRACTICAL:

1. Python Basics and Control Structures
- Writing simple scripts using variables and input/output
- Programs using conditional statements (`if`, `elif`, `else`)
- Iterative structures: `for` and `while` loops
- Loop control: `break`, `continue`, `pass`

2. Data Structures and Built-in Functions
- Programs using lists, tuples, sets, and dictionaries
- Indexing, slicing, and iteration over collections
- Use of functions: `len()`, `sum()`, `sorted()`, `max()`, `min()`

3. User-defined Functions and Modules
- Writing and calling functions with parameters and return values
- Importing and using built-in modules: `math`, `random`, `decimal`

4. NumPy for Mathematical Computing
- Creating and manipulating 1D and 2D NumPy arrays
- Array slicing, reshaping, broadcasting
- Matrix operations: addition, multiplication, transpose, inverse
- Solving systems of equations using `numpy.linalg.solve`

5. Visualization with Matplotlib
- Line, bar, and scatter plots
- Plotting mathematical functions: `sin(x)`, `exp(x)`, etc.
- Customizing plots with labels, titles, colors, legends

6. Applications

- Programs for:
    - Factorial, Fibonacci, GCD, LCM
    - Basic statistics: mean, median, mode, variance
    - Root-finding using Newton-Raphson method

7. Data Analysis with Pandas

- Creating Series and DataFrames from lists and dictionaries
- Reading data from CSV and displaying basic info (`head()`, `info()`, `describe()`)
- Accessing and filtering data using `loc`, `iloc`, conditions
- Handling missing data: `isnull()`, `fillna()`, `dropna()`
- Performing basic statistical operations: `mean()`, `std()`, `value_counts()`

MATLAB PRACTICAL:

1. MATLAB Basics

- Using MATLAB interface and command window
- Defining variables and using elementary math functions
- Working with arrays: creation, indexing, modification
- Using constants: `pi`, `eps`, `inf`, `NaN`

2. Script Files and Functions

- Writing script files and using basic commands: `clc`, `clear`, `disp`, `input`
- Writing and calling user-defined functions
- Differentiating between built-in and custom functions

3. Array and Matrix Operations

- Element-wise and matrix operations (`.*`, `./`, `.^`, matrix multiplication)
- Operations: transpose, inverse, sum, mean, standard deviation
- Matrix-based problem-solving

4. 2D Plotting in MATLAB

- Creating line, bar, and stem plots
- Customizing plots with titles, labels, legends, grid
- Plotting multiple functions on one graph

5. Polynomial and Interpolation Tasks

- Representing polynomials as vectors
- Using `polyval`, `polyfit`, `roots`, `conv`, `deconv`
- Interpolation using `interp1`, `interp2`, and `spline`

6. Numerical Methods Applications

- Solving equations using `fzero`, `fsolve`
- Numerical differentiation using `diff`
- Numerical integration using `trapz`, `integral`

SEMESTER III

I. CORE COURSE [CCMAT301]
IKS IN MATHEMATICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

At the end of the course, students will be able to:

1. Explain and interpret mathematical concepts and problem-solving methods from *Brāhmasphuṭasiddhānta*, including algebraic, geometric, and indeterminate equation techniques.
2. Analyze and apply advanced algebraic methods from *Bījagaṇita*, especially the Cakravāla method and solutions of quadratic indeterminate equations.
3. Explore and utilize mathematical results from *Gaṇitakaumudī*, including combinatorics, number theory, and algorithmic solutions to Diophantine problems.
4. Apply iterative approximations, infinite series, and logical proof methods in the Indian mathematical tradition to solve complex computational problems.

Course Learning Outcomes:

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

1. Solve problems involving surds, progressions, plane figures, cyclic quadrilaterals, and indeterminate equations using Brahmagupta's rules and methods.
2. Implement and compare solutions of Pell's-type equations using the Cakravāla method, continued fractions, and related historical approaches.
3. Construct and analyze combinatorial structures, sequences, and number factorization techniques as presented by Nārāyaṇa Paṇḍita.
4. Compute approximations of π, Rsine series, and other infinite series, and critically evaluate the role of *upapatti* in mathematical reasoning and proofs.

Course Content:

UNIT-I: Brähmasphuṭasiddhänta of Brahmagupta (17 Hours) [2 Questions]

Introduction. Twenty logistics. Cube root. Rule of Three, Five Seven, etc. Mixtures. Interest calculations, etc. Progressions: Arithmetic and Geometric. Plane figures. Triangles, right triangles and quadrilaterals Diagonals of a cyclic quadrilateral. Rational triangles and quadrilaterals. Chords of a circle. Volumes with uniform and tapering cross-sections. Pyramids and frustum. Shadow problems. Mathematical operations with plus, minus and zero. Rules in handling surds (karani) Operations with unknowns (uvyakta-ṣadvidha). Equations with single unknowns (ekavarna-samikaraṇa). Equations with multiple unknowns (anekavarṇa-samikaraṇa). Equations with products of unknowns (bhävita). Brahmagupta on kuttaka. The Second order indeterminate equation (Vargapraksti). Bhavană principle and its applications

UNIT-II: Bijagaṇita of Bhaskarācārya (13 Hours) [1 Question]

Development of Bijaganita or Avyaktagaṇita (Algebra) and Bhaskara's treatise on it. Understanding of negative quantities. Development of algebraic notation. The Vargaprakṛti equation X^2 - DY^2 = K and Brahmagupta's bhāvanä process. The Cakraväla method of solution of Jayadeva and Bhaskara. Bhliskara's examples $X^2 - 61Y^2 = 1$, $X^2 - 67Y^2 = 1$. The equation $X^2-DY^2 = -1$ Solution of general quadratic indeterminate equations. Bhäskara's solution of a bi-quadratic equation Review of the Cakravila method. Analysis of the Cakraväla method by Krishnaswami Ayyangar. History of the solution of the "Pell's Equation" $X^2- Y^2 = 1$ Solution of "Pell's equation" by expansion of $\sqrt{D}$ into a simple continued fraction. Bhäskara semi-regular continued fraction expansion of $\sqrt{D}$. Optimality of the Cakravila method.

UNIT-III: Ganitakaumudi of Narayana Pandita (12 Hours) [1 Question]

Importance of Gaṇitakaumudi Solutions of quadratic equations. Double equations of second and higher degree rational solutions. Determinations pertaining to the mixture of things, Interest calculations-payment in installments Meeting of travelers. Progressions. Vārasankalita: Sum of sums. The kth sum. The kth sum of a series in A.P. The Cow problem.

Diagonals of a cyclic quadrilateral Third diagonal, area of a cyclio quadrilateral. Construction of rational triangles with rational sides, perpendiculars, and segments whose sides differ by unity Generalisation of binomial coefficients and generalized Fibonacci numbers. Vargaprakrti Näräyana's variant of Cakravāla algorithm. Solutions of Vargaprakṛti and approximation of square roots. Bhagadana Näräyana's method of factorisation of numbers. Ankapāśa (Combinatorics). Enumeration (prastara) of generalised mäträ-vrttas (moric metres with more syllabic units in addition to Laghu and Guru). Some sequences (pankti) and tabular figures (meru) used in combinatorics Enumeration (prastira) of permutations with repetitions. Enumeration (prastärm) of combinations

UNIT-IV: Iterative Approximations, Rsine Series and the Logic of Proofs (18 Hours) [2 Questions]

Irrationals and iterative approximations Second order differences and interpolation in computation of Rsines. Summation of infinite geometric series. Instantaneous velocity (tätkälika-gati). Surface area and volume of a sphere. Irrationality of x (Nilakantha). Nilakantha and the notion of the sum of infinite geometric series, Binomial series expansion. Estimating the sum $1^k+2^k+\ldots+n^k$ for large n. Madhava Series for π. End-correction terms and Mädhava continued fraction. Transformed series for which are rapidly convergent. Nilakantha's derivation of the Aryabhata relation for second-order Rsine differences. Madhava series for Rsine and Reosine. Nilakantha and Acyuta formulae for instantaneous velocity Upapattis or proofs in Indian mathematical tradition. Bhäskarācārya II on the nature and purpose of upapatti. Upapatti of bhuja-koṭi-karna-nyaya (Baudhayana-Pythagoras theorem). Upapatti of kuttaka process. Restricted use of tarka (proof by contradiction) in Indian Mathematics. The cyclic quadrilateral. Expression for the diagonals in terms of the sides. Expression for the area in terms of the diagonals.

Reference Books:

1. Datta and A. N. Singh (1938). *History of Hindu Mathematics*, 2 Parts, Lahore. Reprint, Asia Publishing House, Bombay 1962, Reprint, Bharatiya Kala Prakashan, Delhi 2004
2. N. Srinivasiengar (1967). *History of Indian Mathematics*, The World Press, Calcutta.
3. TA. Saraswati Amma (1979). *Geometry in Ancient and Medieval India*, Motilal Banarsidass, Varanasi.
4. S. Balachandra Rao (2004). *Indian Mathematics and Astronomy Some Landmarks*, 3rd Ed. Bhavan's Gandhi Centre, Bangalore.
5. G. G. Emch, M. D. Srinivas and R. Sridharan, Eds. (2005). *Contributions to the History of Mathematics in India*, Hindustan Book Agency, Delhi.
6. S. Seshadri, Ed. (2010). *Studies in History of Indian Mathematics*, Hindustan Book Agency, Delhi.
7. G. G. Joseph (2016). Indian *Mathematics Engaging the World from Ancient to Modern Times*, World Scientific, London.
8. PP Divakaran (2018). *The Mathematics of India Concepts Methods Connections*, Hindustan Book Agency 2018. Rep Springer New York.
9. Ganitayuktibhāsā (c.1530) of Jyesthadeva (in Malayalam), Ed. with Tr. by K. V. Sarma with Explanatory Notes by K. Ramasubramanian, M. D. Srinivas and M. S. Sriram, 2 Volumes, Hindustan Book Agency, Delhi, 2008

II. SKILL ENHANCEMENT COURSE - A [ECMAT302A]
FOURIER AND WAVELET ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand and apply the theory of Fourier series and integrals for periodic and non-periodic functions.
2. Study the properties and applications of the Fourier Transform and its discrete versions.
3. Explore the Haar system and its role in function approximation and image analysis.
4. Analyze wavelet bases, discrete and continuous wavelet transforms, and multiresolution analysis.

Course Learning Outcomes:

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

1. Compute Fourier coefficients and apply convergence theorems using Dirichlet and Fejér kernels.
2. Apply Fourier and inverse Fourier transforms, convolution, and Plancherel's theorem to solve problems in function analysis.
3. Construct Haar bases, implement discrete Haar transforms, and use them for signal/image analysis.
4. Build orthonormal wavelet bases, perform discrete and continuous wavelet transforms, and apply multiresolution analysis to finite signals.

Course Content:

UNIT-I: Fourier series of periodic functions (13 Hours) [1 Question]

Fourier Coefficients, partial sums, the Dirichlet and Fejer kernels, convergence theorems. Fourier integrals: convolution, inversion, Plancherel's formula. Generalized Fourier Series, Orthogonality and completeness

UNIT-II: The Fourier Transform (17 Hours) [2 Questions]

Basic properties, Inversion, Convolution, Plancherrel Theorem, The Fourier Transform for L2 functions, Dilatations, Translations, and Modulations. Windowed Fourier Transform, Discrete Fourier Transform.

UNIT-III: Haar System And Haar Transform (13 Hours) [1 Question]

The Haar System, Dyadic Step Functions, Haar bases on [0, 1]. Comparison of Haar series and Fourier Series. The Discrete Haar Transform (DHT), the DHT in two dimensions, Image analysis with the DHT.

UNIT-IV: Orthognormal wavelet bases and Multi resolution analysis (17 Hours) [2 Questions]

Definition and examples, Construction of Orthonormal wavelet bases, Scaling functions and their properties. The Discrete Wavelet Transform, Wavelet frames, Multiscale Analysis, DWT for finite signals.The Continuous Wavelet Transform, Inverse CWT and admissibility conditions.

Reference Books:

1. D F Walnut (2004), *An Introduction to Wavelet Analysis*, Birkhauser
2. M A Pinsky (2001). *Introduction to Fourier Analysis and Wavelets*,AMS.
3. J S Walker (1999). *A Primer on Wavelets and Their Scientific Applications*, CRC.
4. R M Rao, A S Bopardikar (2010). *Wavelet Transforms*, Pearsons, India.
5. I. Daubechies (1992). *Ten Lectures on Wavelets*, SIAM.
6. Y Meyer (1993). *Wavelets: Algorithms and Applications*, SIAM.

OR SKILL ENHANCEMENT COURSE - B [ECMAT302B]

HADAMARD MATRICES AND COMBINATORIAL DESIGNS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	**Pass Marks: (MSE: 17 + ESE: 28) = 45**

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the foundational structure, properties, and equivalence notions of Hadamard matrices.
2. Apply classical and modern construction techniques to build Hadamard and generalized matrices.
3. Analyze the interplay between Hadamard matrices, orthogonal designs, and matrix structures like weighing and conference matrices.
4. Explore and implement applications of Hadamard matrices in combinatorial designs and coding theory.

Course Learning Outcomes:

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

1. Define and distinguish various forms of Hadamard matrices (symmetric, skew, regular, circulant) and explain the Hadamard conjecture.
2. Construct Hadamard and generalized Hadamard matrices using Paley, Williamson, Goethals–Seidel, and difference-set-based methods.
3. Describe and build orthogonal designs, weighing matrices, and conference matrices, and relate them to Hadamard matrices.
4. Construct BIBDs and GDDs from Hadamard matrices and explain their applications in error-correcting codes.

Course Content:

UNIT-I: Foundations of Hadamard Matrices (13 Hours) [1 Question]

Definition and basic properties of Hadamard matrices, Symmetric and skew Hadamard matrices. Regular hadamard matrix, Order of Hadamard matrices and the Hadamard Conjecture, Equivalence of Hadamard matrices, Sylvester's construction and Kronecker product method, Determinant bound. Circulant, Back-Circulant, Type I and Type II matrices.

UNIT-II: Construction and Generalizations (17 Hours) [2 Questions]

Classical Construction Methods*:* Paley Type I and Type II constructions using finite fields, Williamson's construction, Goethals–Seidel construction, Difference set-based constructions. Enumeration of inequivalent Hadamard matrices. ***Generalizations****:* Definitions and examples of Quaternion Hadamard matrices, Complex Hadamard matrices, Butson type Hadamard matrices and Generalized Hadamard Matrices (GHM) over finite groups.

UNIT-III: Orthogonal Designs and Matrix Structures (12 Hours) [1 Question]

Orthogonal Designs*:* Definition, examples, and link with Hadamard matrices, ***Weighing Matrices****:* Definition and properties, Construction using Kronecker product technique, circulant matrices and Paley-type ideas. ***Conference Matrices****:* Definition (symmetric/skew-symmetric), existence conditions, Construction using Paley method. ***Baumert–Hall Arrays*** for constructing Hadamard matrices.

UNIT-IV: Combinatorial Designs and Applications (18 Hours) [2 Questions]

Classical Application: Maximum Determinant Theorem. ***Balanced Incomplete Block Designs (BIBDs)****:* Definitions, parameters, examples, Construction of BIBDs from Hadamard matrices, *Group Divisible Designs (GDDs)*: Definition, parameters, examples, Constructions of GDDs from Hadamard matrices. ***Coding Theory****:* Construction of error-correcting codes (Hadamard codes).

Reference Books:

1. Marshal Hall (Jr.) (1986). *Combinatorial Theory*, Blaisdel Publishing house.
2. **K. J. Horadam** (2007). *Hadamard Matrices and Their Applications.* Princeton University Press.
3. A. Hedayat and W. D. Wallis (1978). *Hadamard Matrices and Its Applications*. The Annals of Statistics, Vol. 6(6).
4. **C. J. Colbourn and J. H. Dinitz (Eds.)** (2006). *Handbook of Combinatorial Designs,* 2nd ed. CRC Press.
5. **Jennifer Seberry and Mieko Yamada (1972).** *Hadamard Matrices, Sequences, and Block Designs*
6. **Douglas R. Stinson (2004)**. *Combinatorial Designs: Constructions and Analysis.*Springer.

OR SKILL ENHANCEMENT COURSE - C [ECMAT302C]
ADVANCE DISCRETE MATHEMATICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Explain the principles of automata theory and describe the working of various finite automata and Turing machines.
2. Identify and analyze properties of Eulerian and Hamiltonian graphs using appropriate characterizations and conditions.
3. Apply graph theory concepts to planar graphs, vertex coloring, and related theorems to solve classification and coloring problems.
4. Implement and evaluate algorithms in graph theory for shortest path, network connectivity, and optimization problems.

Course Learning Outcomes:

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

1. Define and differentiate between deterministic, non-deterministic finite automata, Moore machines, Mealy machines, and Turing machines.
2. Determine whether a given graph is Eulerian or Hamiltonian using theoretical characterizations and sufficient conditions.
3. Compute chromatic numbers, chromatic polynomials, and apply vertex/edge coloring theorems, including the Five Color Theorem.
4. Apply and implement algorithms such as Kruskal's, Dijkstra's, and solutions for NP-complete graph problems like the Chinese Postman Problem.

Course Contents:

UNIT-I: Automata Theory (17 Hours) [2 Question]

Finite state automata & types of automata, deterministic and non deterministic finite state automata, non deterministic finite state automata (NDFSA), transition diagram. Moor Machine, Mealy Machine Turing Machine.

UNIT-II: Eulerian and Hamiltonian Graphs (13 Hours) [1 Question]

Eulerian graph and its characterizations, Hamiltonian graph and sufficient conditions for a graph to be Hamiltonian.

UNIT-III: Planar graph and vertex coloring of a graph (13 Hours) [1 Question]

Planar graphs, Platonic graphs. Euler's theorem for planar graphs. Vertex coloring, chromatic number, chromatic polynomial, Brooks theorem, edge coloring, chromatic index, map coloring, Five color theorem.

UNIT-IV: Algorithms in graph theory (17 Hours) [2 Questions]

NP - complete problems, good algorithms, Connector problem and Kruskal's algorithm. Algorithms for Chinese postman problem. The Shortest path problem, Dijkstra's algorithm.

Reference Books:

1. R. J. Wilson (2012). *Introduction to Graph Theory,* 5th ed., Addison Wesley.
2. John Clark and Derek Allan Holton (1991). *A first look at Graph Theory*. World Sc.
3. Narsingh Deo (2012). *Graph theory*, PHI New Delhi.
4. Uday Singh Rajpoot (2012). *Advanced Discreet Mathematics,* PHI (Eastern economic edition).

OR SKILL ENHANCEMENT COURSE - D [ECMAT302D]

FLUID DYNAMICS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand various models of finite automata and Turing machines to analyze formal languages.
2. Learn foundational concepts of Eulerian and Hamiltonian graphs along with their properties.
3. Explore key results in planar graphs and vertex coloring, including famous theorems.
4. Apply graph theory algorithms to solve optimization problems like shortest paths and traversals.

Course Learning Outcomes:

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

1. Describe and distinguish between DFA, NFA, Moore, Mealy, and Turing machines with appropriate transition diagrams.
2. Analyze graphs to determine whether they are Eulerian or Hamiltonian using necessary and sufficient conditions.
3. Apply Euler's formula, chromatic number, chromatic polynomials, and theorems such as Brooks' and the Five Color Theorem in planar graphs.
4. Implement and evaluate graph algorithms such as Kruskal's algorithm, Dijkstra's algorithm, and algorithms for NP-complete problems like the Chinese Postman problem.

Course Content:

UNIT-I: Kinematics (18 Hours) [2 Question]

Lagrangian and Eulerian methods, Equation of continuity in different coordinate systems, Boundary surfaces, Stream lines, Path lines and streak lines. Velocity potential, Irrotational and rotational motions. Vortex lines.

UNIT-II: Equations of Motion (18 Hours) [2 Question]

Lagrange's and Euler's equations of motion. Bernoulli's theorem. Equation of motion by flux method. Impulsive actions. Stream function, Irrotational motion.

UNIT-III: Complex Potential and Conformal Mapping (12 Hours) [1 Question]

Complex velocity potential. Sources, sinks doublets and their images in two dimension. Conformal mapping. Milne-Thomson circle theorem.

UNIT-IV: Flow Around Bodies and Applications (12 Hours) [1 Question]

Two-dimensional Irrotational motion produced by motion of circular, co-axial and elliptic cylinders in an infinite mass of liquid. Theorem of Blasius. Motion of a sphere through a liquid at rest at infinity. Liquid streaming past a fixed sphere. Equation of motion of a sphere.

Reference Books:

1. W. H. Besant,A. S. Ramsey (2006). *A Treatise on Hydro Mechanics Part II*. CBS Publ.
2. G. K. Batchelor (2000). *An Introduction of Fluid Mechanics*. Camb. UnIv. Press.
3. F. Choriton (1985). *Textbook of Fluid Dynamics*. C.B.S. Publishers.Delhi.
4. R. K. Bansal (2008). *A Text Book of Fluid mechanics*, Laxmi Publ.
5. M. D. Raisinghania (2003). *Fluid dynamics*, S Chand Publ.

III. CORE COURSE [CCMAT303]

ADVANCED ALGEBRA

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

By the end of this course, students will be able to:

1. Understand group actions, conjugacy, and apply Sylow theorems and solvability concepts in abstract algebra.
2. Analyze linear transformations using canonical forms and apply structural theorems in vector spaces.
3. Explore various types of field extensions and classify them based on algebraic properties.
4. Understand the structure of finite fields and apply Galois theory to study field automorphisms and extensions.

Course Learning Outcomes:

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

1. Apply class equations, orbit-stabilizer theorem, and Sylow theorems to determine properties of finite groups.
2. Represent linear transformations using matrices and reduce them to Jordan and diagonal forms using canonical methods.
3. Distinguish between algebraic and transcendental extensions and construct splitting and normal extensions.
4. Prove results about finite fields, find primitive elements, and apply the Fundamental Theorem of Galois Theory to field extensions.

Course Content:

Unit-I: Solvable Groups and Sylow Theorems (18 Hours) [2 Questions]

Finite permutation groups S_n and A_n, Group action, Conjugate class, Class equation, Orbit -stabilizer theorem, Sylow's theorems (proofs using group actions), Normal and Subnormal series, Composition Series, Jordan-Holder theorem, Solvable groups, Nilpotent groups.

Unit-II: Linear Algebra (12 Hours) [1 Question]

Matrix of a linear transformation, Canonical Forms – Similarity of linear transformations, Quadratic Forms, Invariant subspaces, Reduction to diagonal, triangular and Jordan forms, The primary decomposition theorem.

Unit-III: Field Extension (18 Hours) [2 Questions]

Extension fields, Finite extension, Algebraic and transcendental extensions, Splitting fields, Existence and uniqueness, Separable and inseparable extension, Normal extensions, Perfect fields.

Unit-IV: Finite Field (12 Hours) [1 Question]

Finite fields, Theorems on finite fields, Primitive elements, Algebraically closed fields, Automorphism of extensions, Galois extension, Fundamental theorem of Galois Theory.

Reference books:

1. D.S. Dummit and R.M. Foote (2003). *Abstract Algebra*. John Wiley & Sons.
2. I.N. Herstein (1975). *Topics in Algebra.* Wiley Eastern Ltd., New Delhi.
3. M. Artin (1991). *Algebra.* Prentice-Hall of India.
4. K. Hoffman and R. Kunze (1997). *Linear Algebra* (2nd edition). Prentice Hall of India, New Delhi.
5. N.S. Gopala Krishnan (2008). *University Algebra.* New Age Int. Publ.
6. William J Gilbert (2005). *Modern Algebra with Applications.* Wiley India.
7. K. B. Dutta (2004). *Matrix and Linear Algebra*. PHI.

IV. CORE COURSE [CCMAT304]
DIFFERENTIAL GEOMETRY AND TENSOR ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the geometry of curves in space using curvature, torsion, and Serret-Frenet formulas.
2. Analyze curves and directions on surfaces through fundamental magnitudes and curvature concepts.
3. Study and describe one-parameter families of surfaces and curvature properties such as Gaussian curvature.
4. Gain foundational knowledge of tensor algebra and apply it to metric geometry and vector analysis.

Course Learning Outcomes:

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

1. Compute curvature, torsion, and osculating elements of space curves, and characterize special curves like helices and Bertrand curves.
2. Analyze curves on surfaces, determine principal curvatures and directions, and apply theorems such as Euler's and Dupin's.
3. Identify and construct envelopes and developable surfaces, and evaluate Gaussian curvature and properties of surfaces of constant curvature.
4. Perform basic tensor operations, including contraction and application of the quotient theorem, and compute angles using metric tensors.

Course Content:

UNIT-I: Curves in Space (18 Hours) [2 Questions]

Curvature and torsion. Serret-Frenet formula. Circular helix, the circle of curvature. Osculating sphere, Bertrand curves.

UNIT-II: Curves on a Surface (18 Hours) [2 Questions]

Curves on a surface-parametric curves. fundamental magnitude, curvature of normal section. Principal directions and principal curvatures, lines of curvature, Rodrigue's formula. Dupin's theorem, theorem of Euler, Conjugate directions and Asymptotic lines.

UNIT-III: Family of Surfaces (12 Hours) [1 Question]

One parameter family of surfaces – Envelope the edge of regression, Developables associated with space curves. Gaussian curvature, Surface of constant curvature.

UNIT-IV: Basics of Tensor (12 Hours) [1 Question]

Tensors, Tensor Algebra, Contraction, Quotient theorem. Metric Tensor, Angle between two vectors.

Reference Books:

1. C. E. Weatherburn (1955). *Differential geometry of three dimensions*. Cambridge University Press.
2. C.E. Weatherburn (1938). *Tensor calculus*. Cambridge University press.
3. R.S. Mishra (1965). *Tensor Calculus and Riemanian Geometry*. Pothishala Pvt. Ltd.

V. CORE COURSE [CCMAT305]

PARTIAL DIFFERENTIAL EQUATIONS

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE :28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Classify second-order partial differential equations and reduce them to canonical forms.
2. Derive and solve the heat and wave equations in one-dimensional Cartesian form.
3. Apply separation of variables and transform methods to solve standard PDEs.
4. Use Green's function and Laplace transform methods to solve boundary value problems.

Course Learning Outcomes:

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

1. Classify second-order PDEs and reduce them to their canonical forms using appropriate transformations.
2. Derive the one-dimensional heat and wave equations and find their fundamental solutions.
3. Solve partial differential equations using separation of variables, Fourier transform, and Laplace transform techniques.
4. Apply Green's function and Laplace transformation methods to solve boundary value problems arising in physical applications.

Course Content:

UNIT-I: Classification of 2nd order PDE & Laplace equation (18 Hours) [2 Questions]

Classification of second order PDE & reduction to Canonical forms, Fundamental solutions of two dimensional Laplace equation in Cartesian form.

UNIT-II: Heat equation (12 Hours) [1 Question]

Derivation and fundamental solution of one dimensional Heat equation in Cartesian form. Application problems.

UNIT-III: Wave equation (12 Hours) [1 Question]

Derivation and fundamental solution of one dimensional wave equation in Cartesian form. Application problems.

UNIT-IV: Integral Transforms and Green's function Methods of Solution (18 Hours) [2 Questions]

Solutions of PDE using Separation of variables, Fourier transform and Laplace transform, Green's function and solutions of boundary value problems using Laplace transformation.

Reference Books:

1. L.C. Evans (1998). *Partial Differential Equations*, Graduate Studies in Mathematics, Volume 19,AMS.
2. I.N. Sneddon (1972). *Use of integrals transforms*, McGraw Hill.
3. P. Prasad and R. Ravindran (1984). *Partial Differential equation*. Wiley Eastern Ltd.
4. K. Sankara Rao(2011). Partial diffential eqution, PHI.
5. E. Kreyszing (2011). *Advanced Engineering Mathematics*, John Wiley & Sons. .

SEMESTER IV

I. ELECTIVE COURSE-A [ECMAT401A]
OPTIMIZATION TECHNIQUES

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:
By the end of the course, students will be able to:
1. Understand and apply the dual simplex method to solve linear programming problems with infeasible initial solutions.
2. Analyze the impact of changes in the parameters of a linear programming problem through sensitivity analysis.
3. Study basic concepts of game theory and solve two-player zero-sum games using strategic and linear programming approaches.
4. Understand and analyze various queueing models and evaluate their steady-state performance measures.

Course Learning Outcomes:
After successful completion of this course, the students will be able to:
1. Solve linear programming problems using the dual simplex method and compare its efficiency with the simplex method.
2. Perform sensitivity analysis to understand the effects of modifications in the objective function, variables, and constraints.
3. Formulate and solve two-person zero-sum games using maximin and minimax strategies, and apply linear programming techniques for games without saddle points.
4. Analyze M/M/1 and M/M/C queueing models (with and without capacity limitations) and compute key performance metrics.

Course Content:

UNIT-I: Dual Simplex Method (12 Hours) [1 Question]
Infeasible optimal initial solution, Dual simplex method, Its advantage over simplex method, difference between simplex and dual simplex method.

UNIT-II: Sensitivity Analysis (18 Hours) [2 Questions]
Changes in coefficients in the objective function, Changes in the structure of the LPP due to addition of new variable/Deleting of existing variable/ Addition of new constraints/Deletion of existing constraints.

UNIT-III: Theory Of Games (12 Hours) [1 Question]
Characteristics of game theory, maximin criteria and optimal strategy, solution of game with saddle points, Rectangular games without saddle points and its solutions by linear programming.

UNIT-IV: Queuing Theory (18 Hours) [2 Questions]
Basic characteristics of queueing system, different performance measures, Steady state solution of Markovian queueing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space.

Reference Books:

1. S.D.Sharma (1972). *Operation Research*, Kedar Nath, Ram Nath and Company.
2. H.A.Taha (2003). *Operations Research*, Prentice-Hall of India Private Limited.
3. R. K. Gupta (2023). *Operations Research*, Krishna Prakashan.

OR ELECTIVE COURSE-B [ECMAT401B]

INTEGRAL TRANSFORMS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the definitions, convergence theorems, and applications of Laplace and Stieltjes transforms.
2. Study Fourier transforms and their properties, and apply them to solve problems involving integral equations and transforms.
3. Learn the fundamental concepts and properties of Mellin transforms and apply them to integral equations.
4. Explore the theory and applications of the Hankel transform and understand its relation to other transforms.

Course Learning Outcomes:

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

1. Apply Laplace and Stieltjes transforms to analyze functions, prove convergence results, and use inversion and convolution theorems.
2. Compute Fourier, cosine, and sine transforms, and apply Parseval's and inversion theorems to suitable problems.
3. Use Mellin transforms and their properties to evaluate transforms of derivatives and integrals and solve integral equations.
4. Evaluate Hankel transforms of elementary functions, apply inversion theorems, and relate Hankel transforms to Fourier transforms.

Course Content:

UNIT-I: Laplace and Stieltjes Transforms (17 Hours) [2 Questions]

Laplace Transform: Definition and convergence theorems, Absolute convergence, Uniform Convergence, Complex inversion formula. Convolution theorem, Tauberian Theorems. Stieltjes Transform: Definition and convergence theorem, Hardy and Littlewood theorem.

UNIT-II: Fourier Transforms (32 Hours) [1 Question]

Fourier Transform, Fourier Cosine Transform, Fourier Sine Transform, Conditions for existence of Fourier Transforms, Convolution Integral, Parseval's Theorem, Inversion Theorem.

UNIT-III: Mellin Transform (13 Hours) [1 Question]

Definition and elementary properties of Mellin transform, Mellin Transform of derivatives and integrals, The Mellin inversion theorem, Convolution theorems, solution of some integral equations via Mellin transform.

UNIT-IV: Hankel Transform (17 Hours) [2 Questions]

Definition and elementary properties of Hankel Transform, Inversion theorem, Transform of elementary functions, Transform of derivatives of functions, Parseval relation, Relation between Fourier and Hankel transform.

Reference Books:

1. D V Widder (1946). *The Laplace Transform*, Princeton Univ. Press.
2. Ian N. Sneddon (1979). *The use of Integral Transforms*, McGraw Hill.
3. Ian N. Sneddon (2010). *Fourier Transforms*, Dover Publications.
4. Loknath Debnath (2006). *Integral Transforms and their Applications*, Chapman and Hall/CRC; 2nd ed.

OR ELECTIVE COURSE-C [ECMAT401C]

STOCHASTIC PROCESS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the core concepts and classifications of stochastic processes.
2. Learn the principles of Poisson processes, renewal theory, and Markov models.
3. Apply stochastic calculus methods including martingales and Brownian motion.
4. Gain an introductory understanding of fractional calculus in stochastic modeling.

Course Learning Outcomes:

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

1. Classify and describe the properties of various stochastic processes.
2. Solve applied problems using Poisson, renewal, and Markovian models.
3. Apply martingale theory and Brownian motion in stochastic problem-solving.
4. Explain basic fractional calculus concepts and their applications in stochastic processes.

Course Content:

UNIT–I: Stochastic Process (12 Hours) **[1 Questions]**

Introduction to Stochastic Process, Poisson Process: Homogeneous and Non-homogeneous Poisson Process, Compound and Conditional Poisson Processes. Moment Generating and Characteristic Functions. Lack of Memory and Hazard Rate Functions.

UNIT–II: Renewal Theory (12 Hours) **[1 Questions]**

Introduction to Renewal Theory, Wald's Equation, Important Renewal Theorem and its Applications, Alternating Renewal Processes, Age-Dependent Branching Processes, Delayed Renewal Processes, Renewal Reward Processes, Regenerative Processes, Stationary Point Processes.

UNIT–III: Markovian Chains (18 Hours) **[2 Questions]**

Introduction to Markov Chains, Chapman–Kolmogorov Equations with Classification of States, Transitions among Classes, Gambler's Ruin Problem and Mean Times in Transient States, Applications of Markov Chains, Time-Reversible Markov Chains, Semi-Markov Processes, Continuous-Time Markov Chains, Kolmogorov Differential Equations and Computation of Transition Probabilities, Time Reversibility, Stochastic Population Model.

UNIT–IV: Stochastic Calculus (18 Hours) **[2 Questions]**

Introduction to Stochastic Calculus, Martingales, Stopping Times, Azuma's Inequality for Martingales, Submartingales, Martingale Convergence Theorems, Introduction to Fractional Calculus, Introduction to Brownian Motion, Variations on Brownian Motion, Brownian Motion with Drift, Backward and Forward Diffusion Equations, Markov Shot-Noise Process, Stationary Processes.

Reference Books:

1. J. Medhi (2009). *Introduction to Stochastic Processes*. New Age International Publishers.
2. Sheldon M. Ross (2014). *Stochastic Processes*. Wiley India Pvt. Ltd.
3. Liliana Blanco Castañeda, Viswanathan Arunachalam, Selvamuthu Dharmaraja (2014). *Introduction to Probability and Stochastic Processes with Applications*. Wiley India Pvt. Ltd.
4. K. B. Oldham and J. Spanier (1974). *The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order*, Academic Press.
5. Igor Podlubny (1999). *Fractional Differential Equations*, Academic Press.

II. ELECTIVE COURSE-A [ECMAT402A]

OPERATIONS RESEARCH

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Learn methods for solving integer programming problems using branch-and-bound and cutting plane techniques.
2. Understand the theory and techniques of unconstrained and constrained nonlinear programming.
3. Explore deterministic and probabilistic inventory models for effective inventory management.
4. Apply project planning and control techniques using PERT and CPM for efficient time and resource management.

Course Learning Outcomes:

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

1. Solve integer programming problems using branch-and-bound and Gomory's cutting plane methods.
2. Apply Kuhn-Tucker conditions, and solve nonlinear and quadratic programming problems using Wolfe's and Beale's methods.
3. Formulate and analyze inventory models under known and probabilistic demand conditions.
4. Construct project networks, compute critical paths, and evaluate project schedules using PERT and CPM techniques.

Course Content:

UNIT-I: Integer Programming (18 Hours) [2 Questions]

Branch and bound technique, Gomory's cutting plane method.

UNIT-II: Non Linear Programming (18 Hours) [2 Questions]

One and multi variable, Unconstrained optimization, Kuhn-Tucker Conditions for costrained optimization, Quadratic programming, Wolf's and Beal's method.

UNIT-III: Inventory (12 Hours) [1 Question]

Known demand, probabilistic demand, Deterministic Models and probabilistic models without lead-time.

UNIT-IV: Project Planning and Control With PERT-CPM (12 Hours) [1 Question]

Rules of network construction, Time calculation in networks, Critical path method, PERT, PERT calculation, advantages of network (PERT/CPM), Difference between CPM and PERT.

Reference Books:

1. S.D.Sharma (1972). *Operation Research*, Kedar Nath, Ram Nath and Company.
2. H.A.Taha (2003). *Operations Research*, PHI,
3. R. K. Gupta, *Operations Research,* Krishna Prakashan.

OR ELECTIVE COURSE-B [ECMAT402B]

INTEGRAL EQUATIONS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	**Pass Marks: (MSE: 17 + ESE: 28) = 45**

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Classify various types of integral equations and understand their relation to differential equations.
2. Explore analytical and numerical techniques for solving Fredholm integral equations.
3. Study and apply methods for solving Volterra integral equations using various approximation techniques.
4. Solve singular integral equations and analyze existence and uniqueness of solutions using fixed-point theory and transform methods.

Course Learning Outcomes:

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

1. Classify Fredholm, Volterra, integro-differential, and singular integral equations, and convert initial/boundary value problems into equivalent integral equations.
2. Solve Fredholm integral equations using decomposition methods, direct computation, successive approximation, and substitution techniques.
3. Apply Adomian decomposition, series solutions, and other iterative methods to solve Volterra integral equations, and compare the effectiveness of different methods.
4. Solve singular and generalized Abel-type integral equations, and analyze solution existence using fixed-point theorems and transform-based techniques such as Laplace and Fourier methods.

Course Content:

UNIT-I: Classification of Linear Integral Equations (13 Hours) [1 Question]

Fredholm, Volterra, Integro-Differential Equations, Singular Integral Equations, Converting Volterra Equation to ODE, Conversion of IVP to Volterra equation, Conversion of BVP to Fredholm equation.

UNIT-II: Fredholm Integral Equations (17 Hours) [2 Questions]

Decomposition method, Modified decomposition method, Direct Computation method, successive approximation method, method of successive substitutions, Homogeneous Fredholm Equations, Comparison between alternative methods.

UNIT-III: Volterra Integral Equation (17 Hours) [2 Questions]

Solution of VIE, Adomain Decomposition method, Modified Decomposition method, Series solution method, Successive Approximation method, Successive substitution method, Comparison between alternative methods.

UNIT-IV: Singular Integral Equations (13 Hours) [1 Question]

Abel problem, Generalized Abel Integral Equation, Existence and uniqueness of solutions using fixed-point theorems in case of Linear and nonlinear Volterra and Fredholm integral equations. Solution of Integral equations by Laplace, Fourier transforms methods.

Reference Books:

1. Murry R. Spiegal (1965). *Laplace Transform* (SCHAUM Outline Series), McGraw-Hill.
2. Abdul J. Jerri (1985). *Introduction to integral equations with applications*, Marcel Dekkar Inc. NY.
3. R. P. Kanwal (1997). *Linear Integral equations*, Springer Sc.
4. Harry Hochsdedt (1989). *Integral Equations*, John Wiley & Sons.

OR ELECTIVE COURSE-C [ECMAT402C]

MATHEMATICAL MODELING

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the fundamental concepts, types, and limitations of mathematical modeling.
2. Develop mathematical models using ordinary differential equations for dynamic systems.
3. Construct and analyze discrete models using linear difference equations.
4. Apply mathematical modeling techniques to problems in economics, finance, genetics, and population dynamics.

Course Learning Outcomes:

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

1. Identify real-world problems suitable for mathematical modeling and describe the classification and features of different models.
2. Develop and solve continuous-time models such as growth, decay, and compartmental systems using first-order differential equations.
3. Formulate and analyze discrete-time models using linear difference equations with constant coefficients.
4. Apply difference equation-based models to problems in economics, finance, genetics, and population dynamics.

Course Content:

UNIT-I: Introduction to mathematical modeling (12 Hours) [1 Question]

Simple situations requiring mathematical modeling, techniques of mathematical modeling, classifications, characteristics and limitations of mathematical models, some simple illustrations.

UNIT-II: Mathematical modeling through differential equations (18 Hours) [2 Questions]

Linear growth and decay models, nonlinear growth and decay models, Compartment models, Mathematical modeling in dynamics through ordinary differential equations of first order.

UNIT-III: Mathematical models through difference equations (18 Hours) [2 Questions]

Some simple mathematical models, basic theory of linear difference equations with constant coefficients

UNIT-IV: Application of mathematical modeling in economics, finance & genetics (12 Hours) [1 Question]

Mathematical modeling through difference equations in economics and finance, mathematical modeling through difference equations in population dynamics and genetics.

Reference Books:

1. J. N. Kapur (1998). *Mathematical Modeling*, Wiley Eastern.
2. D. N. Burghes (1980). *Mathematical modeling in social Management and Life Science*, Ellie Herwood and John Wiley.
3. F. Charlton (1965). *Ordinary Differential and Difference Equations*, Van Nostrand..

III. CORE COURSE [CCMAT403]

FUNCTIONAL ANALYSIS

Marks: 30 (MSE: 20 Th. 1 Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE: 28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand the structure and properties of normed linear spaces and Banach spaces.
2. Study bounded linear transformations, dual spaces, and fundamental theorems in functional analysis.
3. Explore inner product spaces, orthonormal systems, and properties of Hilbert spaces.
4. Analyze linear operators on Hilbert spaces, including self-adjoint, unitary, and positive operators.

Course Learning Outcomes:

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

1. Define and work with normed linear spaces, determine completeness, and compare equivalent norms.
2. Identify and analyze bounded linear transformations and dual spaces, and apply the Hahn-Banach, open mapping, and closed graph theorems.
3. Utilize orthonormal sets in Hilbert spaces and apply the Projection Theorem and Parseval's identity.
4. Evaluate different classes of operators in Hilbert spaces, such as adjoint, self-adjoint, unitary, and positive operators.

Course Content:

UNIT-I: Normed Linear Spaces (18 Hours) [2 Questions]

Normed Linear Space: Definition and Examples, NLS as a metric space, Open sets, closed sets etc in a NLS, Convergence and Continuity. Banach spaces and examples. Quotient space of normed linear spaces and its completeness, equivalent norms.

UNIT-II: Transformation on Linear Spaces (17 Hours) [2 Questions]

Bounded linear transformations, normed linear spaces of bounded linear transformations, dual spaces with examples. Hahn-Banach theorem Open mapping and closed graph theorem, the natural imbedding of N in N**. Reflexive spaces.

UNIT-III: Hilbert Space (13 Hours) [1 Question]

Inner product spaces. Hilbert spaces. Orthonormal Sets. Bessel's inequality. Complete orthonormal sets and Parseval's identity. Projection theorem. Rietz representation theorem Reflexivity of Hilbert spaces

UNIT-IV: Operators in Hilbert Space (12 Hours) [1 Question]

Linear transformation & linear functionals. Adjoint of an operator on a Hilbert space. Self-adjoint operators. Positive, normal and Unitary operators.

Reference Books:

1. G.F. Simmons (1983). *Topology and modern analysis* TMH.
2. G. Bachman and L. Narici (1966). *Functional Analysis*, Academic Press.
3. R.E. Edwards (1995). *Functional Analysis. Holt Rinehart and Winston*, Dover.
4. C. Goffman and G. Pedrick (1983). *First Course in Functional Analysis*, PHI.
5. E. Kreyszig (1989). *Functional analysis with application*, John Wiley and sons.

IV. CORE COURSE [CCMAT404]
NUMERICAL SOLUTIONS OF PDE

Marks: 30 (MSE: 20 Th. 1Hr + 5 Attd. + 5 Assign.) + 70 (ESE: 3 Hrs) = 100	Pass Marks: (MSE: 17 + ESE :28) = 45

(Credits: Theory-04, 60 Hours)

Course Objectives:

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

1. Understand finite difference methods for solving parabolic partial differential equations (PDEs) in one space dimension and analyze their convergence and stability.
2. Apply implicit and alternating direction implicit (ADI) methods for solving parabolic PDEs in higher dimensions and in curvilinear coordinates.
3. Learn explicit and implicit schemes for solving hyperbolic PDEs in one and two space dimensions.
4. Develop numerical methods for solving elliptic equations and boundary value problems involving Laplace and biharmonic operators.

Course Learning Outcomes:

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

1. Formulate and implement two- and three-level explicit and implicit finite difference schemes for parabolic PDEs, and analyze their stability and convergence.
2. Apply ADI methods and handle nonlinear boundary value problems for second-order parabolic PDEs, including solutions in cylindrical and spherical coordinates.
3. Develop and analyze explicit and implicit numerical schemes for hyperbolic PDEs in one and two space dimensions, including first-order equations.
4. Solve elliptic PDEs numerically using difference approximations of Laplace and biharmonic operators, and address Dirichlet, Neumann, and mixed boundary conditions.

Course Content:

UNIT-I: Numerical solutions of parabolic PDE in one space (18 Hours) [2 Questions]

Two and three levels explicit and implicit difference schemes. Convergence and stability analysis.

UNIT-II: Numerical solutions of parabolic PDE of second order in two space dimension (18 Hours) [2 Question]

Implicit methods, alternating direction implicit (ADI) methods. Nonlinear initial BVP. Difference schemes for parabolic PDE in spherical and cylindrical cooprdinate systems in one dimension.

UNIT-III: Numerical solutions of hyperbolic PDE in one and two space dimension (12 Hours) [1 Questions]

Explicit and implicit schemes. ADI methods. Difference schemes for first order equations.

UNIT-IV: Numerical Solutions of some equations and Operators (12 Hours) [1 Question]

Numerical solutions of elliptic equations, approximation of Laplace and biharmonic operators. Solution of Dirichlet, Neuman and mixed type problems.

Note: *Use of Scientific calculator is allowed in the exam.*

Reference Books:

1. M. K. Jain, S. R. K. Iyenger and R. K. Jain (1994), *Computational Methods for Partial differential equations*, Wiley eastern.
2. M. K. Jain (1984). *Numerical solution of Differential Equations*, second edition, Wiley Eastern.
3. S. S. Sastry (2002). *Introductory methods of Numerical Analysis*, Prentice Hall India.
4. V. Griffiths and I. M. Smith (1993). *Numerical Methods of Engineers*, Oxford University Press.
5. F. General and P.O. Wheatley (1998). *Applied Numerical Analysis*, Addison-Wesley.
6. K E Atkinson (1989). *An Introduction to Numerical Analysis*, John Wiley & Sons.

V. PROJECT [PRMAT405]

DISSERTATION/ PROJECT/ TEACHING APTITUDE

Marks: 30 (MSE: 20 Viva + 5 Attd. + 5 RMATrd) + 70 (ESE Pr: 6 Hrs) = 100	**Pass Marks: = 45**

(Credits: Theory-04, 120 Hours)

Guidelines for Dissertation / Project

1. **Types of Work Permitted**

   Students may undertake one of the following:

   a) **Theoretical Research Project**
   - Development of new theorems, proofs or methods.
   - Exploration or extension of existing mathematical results.
   - Critical review of advanced topics in pure or applied mathematics.

   b) **Computational / Experimental Mathematics Project**
   - Implementation of mathematical algorithms using tools such as Python, MATLAB, SageMath etc.
   - Simulation and numerical analysis for real-world or theoretical models.

   c) **Application-Oriented Project**
   - Mathematical modeling of problems in science, engineering, economics or social sciences.
   - Use of statistical, optimization or data analysis techniques for practical problem-solving.

2. **Approval of Topic**
   - ➢ The project/dissertation topic must be approved by the **Supervisor** or **Head of the Department.**
   - ➢ Topics should align with the student's area of specialization or interest.
   - ➢ Interdisciplinary topics are encouraged, provided there is substantial mathematical content.

3. **Project Team**
   - ➢ Work may be undertaken **individually** or in **groups of up to five students**.
   - ➢ In the case of group projects, individual contributions must be clearly indicated in the final report.

4. **Supervision & Monitoring**
   - ➢ A faculty supervisor will be assigned to each project/group.
   - ➢ Progress will be reviewed at **regular intervals** (as scheduled by the Supervisor).
   - ➢ Students are expected to maintain a project logbook or progress report.

5. **Structure of the Dissertation**

   A typical PG mathematics dissertation should follow this structure:
   - ➢ **Title Page**
   - ➢ **Certificate from Supervisor**
   - ➢ **Acknowledgements**
   - ➢ **Abstract** (300–500 words)
   - ➢ **Table of Contents**
   - ➢ **List of Figures / Tables (if applicable)**

   Chapter 1 – Introduction & Motivation
     - o Problem statement
     - o Motivation and relevance
     - o Scope and limitations
   - ➢ **Chapter 2 – Literature Review**
     - o Summary of existing work
     - o Identification of research gaps
   - ➢ **Chapter 3 – Methodology**
     - o Theoretical framework
     - o Mathematical tools and techniques

    - Model development / Algorithm design
- **Chapter 4 – Results and Discussion**
    - Analytical or numerical results
    - Interpretation and implications
- **Chapter 5 – Conclusions and Future Scope**
- **References** (as per a recognized citation style, e.g., APA, AMS, IEEE)
- **Appendices** (if required)

6. **Evaluation Criteria**

The final project/dissertation will be evaluated under the following heads:

Project model (if any) and the Project record notebook = 70 marks

Project presentation and viva-voce = 30 marks

7. **Presentation & Viva-Voce**

- Each student/group must present their work to an evaluation panel.
- Presentations should include problem background, methodology, results, and conclusions.
- Viva-voce will assess both conceptual understanding and technical execution.

8. **Submission Requirements**

- Three hard-bound copies and one digital copy in PDF format.
- All codes, datasets and supplementary materials (if applicable) should be submitted alongside.

9. **Project Based on Special Paper**

- If the project is based on any one of the **special papers** studied, it should demonstrate the application of theory learned in that paper to a well-defined problem or case study.

Teaching Aptitude: Only selected candidates, in alternative to the Dissertation, may be provided duty to teach the assigned topics in selected colleges. The performance may be evaluated based on the organized feedback for the candidate.
