



DEPARTMENT OF MATHEMATICS
DHANAMANJURI UNIVERSITY, MANIPUR

LEARNING OUTCOME-BASED
CURRICULUM FRAMEWORK AND SYLLABUS FOR THE M.A./M.SC.
PROGRAMME IN MATHEMATICS

(based on Post Graduate Curriculum Framework (PGCF) -2024

UNDER
NATIONAL EDUCATION POLICY(NEP) 2020

Effective from Academic Session 2026-27

May 2026

PROGRESSION FROM UG TO PG

Programme of study and the corresponding qualifications levels

First year UG Programme=Level 4.5

Second year UG Programme=Level 5

Third year UG Programme=Level 5.5

Fourth year UG Programme=Level 6

First year of Two year PG Programme= Level 6

Post Graduate Diploma

(Exit after First year of PG Programme)=Level 6

Second year of Two year PG Programme= Level 6.5

One year of PG Programme after 4 year UG=Level 6.5

First year of Two year PG Programme after 4 year UG= Level 6.5

Second year of Two year PG Programme after 4 year UG= Level 7

INTRODUCTION

About the University

Dhanamanjuri University (DM University) has come into existence during the current year under The Dhanamanjuri University Act, 2017 which came into force on the 6th of April, 2018 through a notification in Manipur Gazette published by the Department of Higher and Technical Education, Government of Manipur. The Dhanamanjuri University Bill, 2017 was passed on the floor of Manipur Legislative Assembly on 3rd August, 2017. The University was established under the National Scheme of Rashtriya Uchchatar Shiksha Abhiyan (RUSA). Dhanamanjuri University is a long cherished dream of our founding fathers and Maharani Dhanamanjuri, the mother spirit in the birth of this seat of learning, translated into action. Manipur, an ancient Kingdom, had a composite traditional system of education in the field of warfare, martial arts, games and sports, culture and many other schools of thought training the people in various professional activities in ancient forms. The people have carried down this legacy of quest for knowledge and civilized existence since time immemorial. Ancient works of knowledge in the original scripts of Manipur stand as testimony to the nurturing of the idea of a University in the minds of our forefathers and foremothers. The state has celebrated the tradition of a purely intellectual pursuit which conserves the original ethos of the land and its people while receptive with an open mind to change in course of time.

The University was established under the National Scheme of Rashtriya Uchchatar Shiksha Abhiyan (RUSA) as fulfillment of one of its primary components i.e., to convert colleges to cluster Universities. Maharani Dhanamanjuri gifted us Dhanamanjuri College and in recognition of her contribution to the development of Higher Education, the university is named after Maharani Dhanamanjuri. The University is built up of the three Dhanamanjuri Colleges namely DM College of Science, DM College of Arts, DM College of Commerce along with G.P. Women's College and LMS Law College, all of which occupy common, adjoining or neighbouring physical spaces. DM University at present is functioning from DM College campus situated in the heart of Imphal city and the campus is bounded by National Highway No.2 in the East, Thangmeiband road in the West and North, and the Naga River in the South. Ghanapriya Women's College is located at the South West of Kangla, the Old palace of Manipur near the Raj Bhavan and LMS Law College is located just in-front of the DM Campus crossing the National Highway No.2.

Vision of the University

To emerge as a centre of excellence in higher education and research by nurturing intellectual growth, innovation, ethical values, and social responsibility for the advancement of society and the nation.

Mission of the University

- To provide quality and outcome-based education that promotes academic excellence and critical thinking.
- To encourage research, innovation, and interdisciplinary learning in diverse fields of knowledge.
- To develop competent, responsible, and socially committed human resources with moral and ethical values.

- To create an inclusive academic environment that supports holistic development and lifelong learning.
- To contribute to regional and national development through education, research, and community engagement

DEPARTMENT OF MATHEMATICS

The Department of Mathematics of Dhanamanjuri University is committed to promoting excellence in mathematical education, research, and innovation. The department strives to build a strong academic foundation in both pure and applied mathematics while nurturing analytical thinking, problem-solving abilities, and scientific temperament among students. The department actively encourages research activities, interdisciplinary learning, and participation in academic seminars, workshops, and conferences.

Vision and Mission of the Department

To emerge as a centre of excellence in mathematical education and research by fostering intellectual growth, innovation, ethical values, and scientific inquiry for the development of society and the nation.

Mission is

- To provide quality and outcome-based education in mathematics through modern teaching and learning practices.
- To develop strong analytical, computational, and research skills among students.
- To encourage innovative research in pure and applied mathematics and related interdisciplinary areas.
- To prepare students for higher studies, competitive examinations, teaching, research, and professional careers.
- To promote ethical values, critical thinking, and lifelong learning among students.

Courses offered by the Department

The Department of Mathematics offers undergraduate, postgraduate, and research-oriented programmes in Mathematics under Dhanamanjuri University and its constituent colleges.

Undergraduate Programmes:

- B.Sc. Mathematics (Honours)
- B.A. Mathematics (Honours)
- Mathematics as a subject combination in various B.Sc. programmes

Postgraduate Programme:

- Master of Arts/Science (M. A./M.Sc.) in Mathematics

Research Programme:

- Ph.D. in Mathematics

PROGRAMME OBJECTIVES AND OUTCOMES

PROGRAMME OBJECTIVES:

The M.A/M.Sc. Mathematics programme's main objectives are to:

- 1) Inculcate and develop mathematical aptitude and the ability to think abstractly in the students.
- 2) Develop computational abilities and programming skills of the students.
- 3) Develop the ability to read, follow and appreciate mathematical text among the students.
- 4) Train students to communicate mathematical ideas in a lucid and effective manner.
- 5) Train students to apply their theoretical knowledge to solve real-life problems.
- 6) Prepare the students for higher education and research in mathematics.

PROGRAMME OUTCOMES:

On successful completion of the M.Sc. Mathematics programme, a student will:

- 1) have a strong foundation in core areas of Mathematics, both pure and applied.
- 2) be able to apply mathematical skills and logical reasoning for problem solving.
- 3) communicate mathematical ideas effectively, in writing as well as orally.
- 4) have sound knowledge of mathematical modelling, programming and computational techniques as required for employment in industry.

CURRICULUM AND CREDIT FRAMEWORK FOR POST GRADUATE PROGRAMMES

Sl. No.	Programme	Eligibility	Curricular Components	NHQP Level	Minimum credits	Credit Points (Level x Minimum credits)
1	1-Yr. PG (2-Semester PG)	4-Yr. UG (Honours/Honours with Research) with a minimum of 160 credits	1stSem: Course Work 2ndSem: Course Work & Research Work	6.5	20 22	273
					42	
2	PG Diploma (2-Semester PG)	3-Yr. UG with a minimum of 120 credits or 4-Yr. UG (Honours/Honours with Research) with a minimum of 160 credits	1stSem: Course Work 2ndSem: Course Work	6	24 18	252
					42	
3	2-Yr. PG (4-Semester PG)	3-Yr. UG with a minimum of 120 credits or 4-Yr. UG (Honours/Honours with Research) with a minimum of 160 credits	1stSem: Course Work 2ndSem: Course Work 3rdSem: Course Work 4thSem: Course Work & Research Work	6.5	24 18 20 20	273 260
					82	

COURSE STRUCTURE OF 1-YEAR PG PROGRAMME IN MATHEMATICS
(2-SEMESTER PG PROGRAMME)

Semester	DSC	DSE	Dissertation/Academic Project/ Entrepreneurship/VAC/AE C	Total Credit
Semester-I	DSC-11 DSC-12 (8 credits)	DSE-1 DSE-2 DSE-3 (12 Credits)	NIL	20
Semester- II	DSC-13 DSC-14 (8 credits)	DSE-4 (4 credits)	Research Methodology/Theory (2 credits) VAC/AEC (2 credits) Research (Thesis/Project/Field Work/Patent) (6 credits)	22

COURSE STRUCTURE OF 2-YEAR PG PROGRAMME IN MATHEMATICS
(4-SEMESTER PG PROGRAMME)

Semester	DSC	DSE	Dissertation/Academic Project/ Entrepreneurship/VAC/AEC	Total Credit
Semester-I	DSC-1 DSC-2 DSC-3 DSC-4 DSC-5 DSC-6 (24 credits)		NIL	24
Semester-II	DSC-7 DSC-8 DSC-9 DSC-10 (16 credits)		VAC/AEC (2 credits)	18
Semester-III	DSC-11 DSC-12 (8 credits)	DSE-1 DSE-2 DSE-3 (12 Credits)	NIL	20
Semester-IV	DSC-13 DSC-14 (8 credits)	DSE-4 (4 credits)	Research Methodology/Theory (2 credits) Research (Thesis/Project/Field Work/Patent) (6 credits)	20

COURSE DETAILS OF 1-YEAR PG COURSE IN MATHEMATICS

Semester	DSC 4 credits	DSE 4 credits	Dissertation/Academic Project/ Entrepreneurship/VA C/AEC	Total Credit
Semester-I	CMAT-501: Functional Analysis CMAT-502: Measure and Integration (8 credits)	DSE-1: (Choose only one) i) EMAT-507:Graph Theory ii) EMAT-508:Fluid Dynamics iii) EMAT-509:Differential Geometry and Tensors DSE-2: (Choose only one) i) EMAT-510:Commutative Algebra ii) EMAT-511:Mechanics iii) EMAT-512:Dynamical Systems DSE-3: Optional paper-I (12 Credits)		20
Semester-II	CMAT-503: Analytic and Geometric Functions Theory CMAT-504: Algebraic Topology (8 credits)	DSE-4: Optional paper-II (4 credits)	RMAT-505: Research Methodology/Theory (2 credits) PMAT-506: Research (Thesis/Project/Field Work/Patent) (6 credits) VAC/AEC (2 credits)	22

COURSE DETAILS OF 2-YEAR PG COURSE IN MATHEMATICS

Semester	DSC	DSE	Dissertation/Academic Project/ Entrepreneurship /VAC/AEC	Total Credit
Semester-I	CMAT-401: Fundamentals of Topology CMAT-402: Field theory and Galois theory CMAT-403: Advanced Ordinary Differential Equation CMAT-404: Advanced Complex Analysis CMAT-405: Advanced Real Analysis CMAT-406: Advanced Linear Algebra (24 credits)			24
Semester-II	CMAT-407: Advanced Partial Differential Equation CMAT-408: Fuzzy Set Theory CMAT-409: Module Theory CMAT-410: Number Theory (16 credits)		VAC/AEC (2 credits)	18

Semester	DSC 4 credits	DSE 4 credits	Dissertation/A cademic Project/ Entrepreneursh ip/VAC/AEC	Total Credi t
Semester-III	CMAT-501: Functional Analysis CMAT-502: Measure and Integration (8 credits)	DSE-1: (Choose only one) i) EMAT- 507:Graph Theory ii) EMAT- 508:Fluid Dynamics iii) EMAT- 509:Different ial Geometry and Tensors DSE-2: (Choose only one) i) EMAT- 510:Commut ative Algebra ii) EMAT- 511:Mechani cs iii) EMAT- 512:Dynamic al Systems DSE-3: Optional paper-I (12 Credits)		20
Semester-IV	CMAT-503: Analytic and Geometric Functions Theory CMAT-504: Algebraic Topology (8 credits)	DSE-4: Optional paper-II (4 credits)	RMAT-505: Research Methodology/ Theory (2 credits) PMAT-506: Research (Thesis/Project /Field Work/Patent) (6 credits)	20

NOTE: The Dissertation/Research Project undertaken should be an original work and must not be a repetition of the work carried out during the 4th year of the U.G. programme.

Outcomes expected of Dissertation/Research project in the PGprogramme: The following outcomes must achieved by the end of semester.

- i. Identification of a research problem.
- ii. Review of relevant literature.
- iii. Formulation of research design (for empirical and scientific research).
- iv. Submission of the dissertation or research project report.
- v. Desirable research outputs include
 - a) Publication in a reputed journal, Scopus-indexed journal, or other journals of comparable quality.
 - b) Publication of a book or book chapter by a reputed publisher.
 - c) Presentation/publication in conference proceedings at national or international conferences.

DHANAMANJURI UNIVERSITY
2-YEAR POST GRADUATE (M.A/M.Sc) MATHEMATICS COURSE STRUCTURE

Total Marks: 2050

Total Credits: 82

Course Code	Course Type	Course Title	Internal Ass'ment Marks	End Sem Marks	Total Marks	Class Hours per Week	No. of Credits (L+T)
Semester-I			120	480	600	24	24
CMAT- 401	DSC	Fundamentals of Topology	20	80	100	4	4
CMAT- 402	DSC	Field Theory and Galois Theory	20	80	100	4	4
CMAT-403	DSC	Advanced Ordinary Differential Equation	20	80	100	4	4
CMAT-404	DSC	Advanced Complex Analysis	20	80	100	4	4
CMAT-405	DSC	Advanced Real Analysis	20	80	100	4	4
CMAT- 406	DSC	Advanced Linear Algebra	20	80	100	4	4
Semester-II			80	370	450	18	18
CMAT-407	DSC	Advanced Partial Differential Equation	20	80	100	4	4
CMAT-408	DSC	Fuzzy Set Theory	20	80	100	4	4
CMAT-409	DSC	Module Theory	20	80	100	4	4
CMAT-410	DSC	Number Theory	20	80	100	4	4
		VAC/AEC		50	50	2	2
Semester-III			100	400	500	20	20
CMAT-501	DSC	Functional Analysis	20	80	100	4	4
CMAT- 502	DSC	Measure and Integration	20	80	100	4	4
EMAT- 507 EMAT-508 EMAT-509	DSE (Choose Any One)	i) EMAT-507:Graph Theory ii) EMAT-508:Fluid Dynamics iii) EMAT-509:Differential Geometry and Tensors	20	80	100	4	4

EMAT- 510 EMAT-511 EMAT-512	DSE (Choose Any One)	i) EMAT- 510:Commutative Algebra ii) EMAT- 511:Mechanics iii) EMAT- 512:Dynamical System	20	80	100	4	4
Optional Paper-I EMAT-513 EMAT-514 EMAT-515 EMAT-516 EMAT-517 EMAT-518	DSE (Choose any One)	EMAT- 513:Operations Research-I EMAT-514:General Relativity and Cosmology-I EMAT-515: Cryptology-I EMAT-516: Operator Theory-I EMAT-517: Algebraic Coding Theory-I EMAT-518: Advanced Numerical Techniques-I	20	80	100	4	4
Semester-IV			70	430	500	20	20
CMAT- 503	DSC	Analytic and Geometric Functions Theory	20	80	100	4	4
CMAT- 504	DSC	Algebraic Topology	20	80	100	4	4
Optional Paper-II EMAT-519 EMAT-520 EMAT-521 EMAT-522 EMAT-523 EMAT-524	DSE Elective (Choose Any One)	EMAT- 519:Operations Research-II EMAT-520:General Relativity and Cosmology-II EMAT- 521:Cryptology-II EMAT-522:Operator Theory-II	20	80	100	4	4

		EMAT-523: Algebraic Coding Theory-II EMAT-524: Advanced Numerical Techniques-II					
RMAT-505		Research Methodology/Theory	10	40	50	2	2
PMAT-506		Research Project		150	150	6	6
							82

1-YEAR POST GRADUATE (M.A/M.Sc) MATHEMATICS COURSE STRUCTURE

Total Marks: 1050

Total Credits: 42

Semester-I			100	400	500	20	20
CMAT-501	DSC	Functional Analysis	20	80	100	4	4
CMAT- 502	DSC	Measure and Integration	20	80	100	4	4
EMAT- 507 EMAT-508 EMAT-509	DSE (Choose Any One)	i) EMAT-507:Graph Theory ii) EMAT-508:Fluid Dynamics iii) EMAT- 509:Differential Geometry and Tensors	20	80	100	4	4
EMAT- 510 EMAT-511 EMAT-512	DSE (Choose Any One)	i) EMAT- 510:Commutative Algebra ii) EMAT- 511:Mechanics iii) EMAT- 512:Dynamical System	20	80	100	4	4

Optional Paper-I EMAT-513 EMAT-514 EMAT-515 EMAT-516 EMAT-517 EMAT-518	DSE (Choose any One)	EMAT- 513:Operations Research-1 EMAT-514:General Relativity and Cosmology-1 EMAT-515: Cryptology-1 EMAT-516: Operator Theory-1 EMAT-517: Algebraic Coding Theory-1 EMAT-518: Advanced Numerical Techniques-1	20	80	100	4	4
Semester-II			70	480	550	22	22
CMAT- 503	DSC	Analytic and Geometric Functions Theory	20	80	100	4	4
CMAT- 504	DSC	Algebraic Topology	20	80	100	4	4
Optional Paper-II EMAT-519 EMAT-520 EMAT-521 EMAT-522 EMAT-523 EMAT-524	DSE Elective (Choose Any One)	EMAT- 519:Operations Research-II EMAT-520:General Relativity and Cosmology-II EMAT- 521:Cryptology-II EMAT-522:Operator Theory-II EMAT-523: Algebraic Coding Theory-II EMAT-524: Advanced Numerical Techniques-II	20	80	100	4	4
RMAT-505		Research Methodology/Theory	10	40	50	2	2

PMAT-506		Research Project		150	150	6	6
		VAC/AEC		50	50	2	2
							42

DISCIPLINE SPECIFIC COURSE (DSC): SEMESTER-I

CMAT-401 :(Semester-I)

[FUNDAMENTALS OF TOPOLOGY]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. To understand the fundamental concepts of topological spaces, subspaces, and continuous mappings.
2. To analyze structural properties of topological spaces such as connectedness, compactness, separation, and countability axioms.
3. To explore convergence through nets and filters and apply advanced theorems like Tychonoff's and Urysohn's metrization theorem.

Courses Outcomes: Students who successfully complete the course will be able to:

1. Define and construct topological spaces, subspaces, bases, and sub-bases, and describe operations such as closure, interior, and boundary.
2. Demonstrate understanding of continuous maps, homeomorphisms, and relative topology.
3. Construct and analyze product and quotient topological spaces.
4. Apply separation and countability axioms to classify and distinguish topological spaces.
5. Examine connectedness, compactness, and related theorems including Tychonoff's theorem and one-point compactification.
6. Use nets, filters, and ultrafilters to study convergence and explain results such as Urysohn's metrization theorem.

Course Contents:**Unit-I****(Lectures:21)/30 marks**

Topological spaces, bases and sub-bases for a topology, limit point, closure, interior, exterior, boundary of a set, dense and nowhere dense set, subspaces and relative topology, continuity and Homeomorphism.

Unit-II**(Lectures:21)/30 marks**

Product and quotient topological space, Countability axioms, separation axioms, connectedness, components, path connectedness, locally connected space, totally disconnected spaces, Urysohn's lemma, Tietze's extension theorem.

Unit-III**(Lectures:14)/20 marks**

Compactness and continuous functions, finite intersection property, Tychonoff's theorem, one-point compactification, Nets and filters, topology and convergence of nets, filters, ultra filters, Urysohn's metrization theorem.

Books Recommended:

1. James R Munkres; Topology, Pearson Education Asia, 2002
2. Schaum's- Theory and problems of General topology

References:

1. James R Munkres; Topology, A first Course, Prentice hall of India Pvt. Ltd., New Delhi 2000.
2. J Dugundji; Topology, Allyn and Bacon, 1966.
3. GF Simmons; Introduction to Topology and Modern Analysis, McGraw-Hill and Company, 1963.

CMAT-402: (SEMESTER-I)
[FIELD THEORY AND GALOIS THEORY]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives

1. Introduce advanced concepts of group theory, focusing on normal series, composition series, and structural theorems like the Jordan–Hölder theorem.
2. Develop a comprehensive understanding of field theory, including algebraic, transcendental, separable, and normal extensions.
3. Study the structure of perfect fields, finite fields, primitive elements, and algebraically closed fields, along with automorphisms of extensions.
4. Understand the fundamental concepts of Galois theory, including the Fundamental Theorem, and its applications to solving polynomial equations.

Course Learning Outcomes: The course will enable the students to:

1. Understand and construct normal and subnormal series in groups.
2. Define and analyze composition series and apply the Jordan–Hölder Theorem.
3. Distinguish between solvable and nilpotent groups and understand their hierarchical structure.
4. Apply key theorems and concepts in solving problems related to group structure and classification.
5. Understand and distinguish between various types of field extensions.
6. Identify and construct algebraic, transcendental, separable, and inseparable extensions.
7. Define and explore normal and perfect fields, and understand their relevance in algebra.
8. Examine finite fields and their structures, including primitive elements and algebraic closures.
9. Understand automorphisms in the context of field extensions and relate them to symmetry and structure.
10. Understand and construct Galois extensions and related concepts like fixed fields and automorphism groups.
11. Apply the Fundamental Theorem of Galois Theory to analyze relationships between fields and subgroups.
12. Determine solvability of polynomials by radicals.
13. Explain the insolvability of the General Equation of Degree 5 by Radicals.

Course Contents:

Unit-I

(Lectures-21)/30marks

Field Extensions, Algebraic Extensions, Splitting fields, Separable Extensions, Normal Extensions, Theorem of primitive element, Perfect Fields, Algebraically Closed Fields.

Unit-II

(Lectures-21)/30marks

The group of automorphisms of a field, Fixed fields, Galois Extensions, Fundamental Theorem of Galois Theory, Galois group of an extension, Galois group of a polynomial, Permutations of the roots of polynomial

Unit-III

(Lectures-14)/20marks

Finite Fields, Roots of unity, cyclotomic polynomials and extensions, Solution of Polynomial Equations by Radicals, Insolvability of the General Equation of Degree 5 by Radicals.

Books Recommended:

1. **PB Bhattacharya, SK Jain and SR Nagpaul;** Basic Abstract Algebra (2nd Edition) Cambridge University Press.

References:

1. **M Artin**; Algebra, Prentice Hall of India, 1991.
2. **PM Cohn**; Algebra, Vols. I, II & III, John Wiley and Sons, 1982, 1989, 1991.
3. **N Jacobson**; Basic Algebra, Vols. I & II, W.H. Freeman 1980.

CMAT-403: (SEMESTER -I)
[ADVANCED ORDINARY DIFFERENTIAL EQUATION]

Total Marks: 100(External -80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives: The main objectives of this course are to introduce the students to the exciting world of Differential Equations, Mathematical Modeling and their applications.

Course Outcomes: The course will enable the students to:

1. Formulate Differential Equations for various Mathematical models.
2. Solve first order non-linear differential equation and linear differential equations of higher order using various techniques.
3. Apply these techniques to solve and analyse various mathematical models.

Course Contents:**Unit-I:**

(Lectures-21)/30marks

Solution in series, Frobenius method, Initial value problem and the equivalent integral equation, Picard's method of successive approximation, Lipschitz condition, Well-posed problems, Picard's Existence, Uniqueness and Continuity theorems for the solution of IVPs of the first order, Existence, Uniqueness and Continuity for the solution of simultaneous differential equations of first order and ordinary differential equation of higher order.

Unit-II:

(Lectures-21)/30marks

Linear dependence and independence of solutions of linear differential equations, The Wronskian, Theorems on linearly independent solutions and linearly dependent set of functions, Homogeneous and non-homogeneous linear systems, Linear systems with constant coefficient and their solution by matrix method.

Unit-III:

(Lectures-14)/20marks

Oscillation theory, oscillatory and non-oscillatory solutions, Adjoint equation, Self-Adjoint linear homogeneous second order differential equation, Lagrange's Identity, Abel's formula, Sturm separation theorem, Sturm comparison theorem, Sturm Picone theorem, Sturm-Liouville systems, Orthogonal set of functions and Orthonormal set of functions, Eigenvalues and Eigenfunctions.

Recommended Books:

1. Earl A. Coddington; An Introduction to Ordinary Differential Equation, Prentice Hall of India, Pvt. Ltd., New Delhi.
2. TynMyint-U; Ordinary Differential Equations, North-Holland, New York

3. M.D. Raisinghania; Advanced Differential Equation, S. Chand and Company Ltd., New Delhi

References:

1. Edward L. Ince; Ordinary Differential Equations, Dover Publishing Inc.
2. W. Leighton; Ordinary Differential Equations; Long-Man's Publication.
3. J.C. Burkill; Ordinary Differential Equations, Oliver and Boyd.
4. G.F. Simmons; Ordinary differential equations with applications and historical notes, McGraw Hill.
5. S.L. Ross, Differential equation, Wiley India

CMAT-404: (SEMESTER -I)

ADVANCED COMPLEX ANALYSIS

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week), Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Understand transformations, analyticity, and Cauchy–Riemann equations.
2. Apply theorems of complex integration to evaluate contour integrals.
3. Develop series representations of functions and classify singularities.
4. Use residue theory and advanced theorems to solve problems.

Course Outcomes: After the completion of this course students will be able to:

1. Explain basic transformations, linear fractional maps, and cross ratios.
2. Test analyticity using Cauchy–Riemann equations and find harmonic conjugates.
3. Evaluate contour integrals using Cauchy's theorems and integral formula.
4. Apply Liouville's theorem, Fundamental Theorem of Algebra, and Maximum Modulus Theorem.
5. Expand functions in Laurent series and classify singularities.
6. Compute real and complex integrals using the residue theorem.
7. Apply Argument Principle, Rouché's, Hurwitz's, and Open Mapping Theorems.

Course Contents:

Unit-I: Bilinear Transformation and Analyticity

(Lecture-14)/20marks

Four basic transformations; linear fractional transformations; cross ratio; Cauchy-Riemann equations; necessary and sufficient conditions for differentiability and analyticity; harmonic functions; harmonic conjugates.

Unit-II: Fundamental Theorems

(Lecture-21)/30marks

Curves and contours; line integrals; contour integration; Cauchy's theorems; Cauchy's integral formula; Taylor's series expansions; Morera's theorem; Cauchy's inequalities; Liouville's theorem; the Fundamental Theorem of Algebra; uniqueness and identity theorems; Maximum Modulus Theorem; Schwarz's lemma.

Unit-III: Singularities and Mapping Theorems

(Lecture-21)/30marks

Laurent series expansions; multiplication and division methods for finding Laurent series; classification of singularities; Riemann's theorem on removable singularities; Casorati-Weierstrass theorem; residues; residue theorem; residues at poles; evaluation of real integrals using residues; argument principle; Rouché's theorem; Hurwitz's theorem; Open Mapping Theorem.

Books recommended:

1. S. Ponnusamy and H. Silverman (2006). *Complex variables with applications*. Birkhäuser.
2. J. W. Brown and R. V. Churchill (2004). *Complex variables and applications* (7th ed.), McGraw-Hill.

References:

1. H. A. Priestley (1990), *Introduction to complex analysis*. Clarendon Press.
2. S. Ponnusamy (2018) *Foundations of complex analysis* (2nd ed.), Narosa Publishing House.

CMAT-405 :(SEMESTER-I)

[ADVANCED REAL ANALYSIS]

Total Marks: 100 (External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives: The course will develop a deep and rigorous understanding of real line and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications to the real-world problems.

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

1. Understand Riemann-Stieltjes integrable functions and their properties.
2. Evaluate integration of vector-valued functions.

3. Learn the concept of rearrangement of terms of a series.
4. Apply Cauchy's criterion for uniform convergence, Weierstrass M-test, Abel's Test and Dirichlet's Test for uniform convergence of series of real-valued functions.
5. Understand the concept of differentiability of functions in higher dimensional space and their applications.

Course Contents:

Unit-I

(Lectures-21)/30marks

Functions of Several Variables: Linear Transformations; Derivatives in an Open Set R^n ; Chain Rule, Partial Derivatives, Interchange of the Order of Differentiation, Derivatives of Higher Order, Taylor's Theorem, Inverse Function Theorem, Implicit Function Theorem, Jacobians; Extremum Problems with Constraints, Lagrange's Multiplier Method, Differentiation of Integrals.

Unit-II:

(Lectures-21)/30marks

Lebesgue outer measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesgue measurability, Non-measurable sets, Integration of non-negative functions, The general integral, Integration of series, Riemann and Lebesgue integrals.

Unit-III:

(Lectures-14)/20marks

Differentiation and Integration, The four derivatives, Functions of bounded variations, Lebesgue differentiation theorem, Measures and outer measures, Extension of a measure, Uniqueness of extension, Completion of a measure, Measure spaces. Integration with respect to a measure.

References:

1. **Walter Rudin**; Principles of Mathematical analysis (3rd Edition) McGraw-Hill, Kogakusha, 1976, International student Edition.

References:

1. **TM Apostol**; Mathematical analysis, Narosa Publishing House, New Delhi, 1985.
2. **AW White**; Real Analysis an Introduction, Addison-Wesley Publishing Co., Inc., 1968.
3. **G de Barra**; Measure Theory and Integration, Wiley Eastern Ltd., 1981.
4. **PK Jain and VP Gupta**; Lebesgue Measure and Integration, New Age International Pvt. Ltd., New Delhi, 2000.

CMAT-406: (SEMESTER-I)
[ADVANCED LINEAR ALGEBRA]

Total Marks: 100(External -80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. To understand the fundamental concepts of vector spaces, subspaces, bases, dimensions, and quotient spaces.
2. To study linear transformations, their matrix representations, dual spaces, eigenvalues, eigenvectors, and canonical forms.
3. To apply inner product space theory and operator concepts to analyze orthogonality, adjoint operators, and spectral properties.

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

1. Solve systems of linear equations and apply the concepts of bases, dimensions, and quotient spaces in vector spaces.
2. Analyze and represent linear transformations and apply the Rank-Nullity Theorem.
3. Determine eigenvalues, eigenvectors, and use Jordan Canonical Form for classifying linear operators.
4. Apply dual space concepts, transpose, trace, determinant, and minimal polynomials in problem-solving.
5. Construct orthonormal bases using the Gram-Schmidt process and study orthogonality in inner product spaces.
6. Analyze different classes of operators (normal, unitary, self-adjoint) and apply the spectral theorem to vector spaces.

Course Contents:

Unit-I: Vector Spaces

(Lecturers 21)Marks: 30

Systems of linear equations, vector spaces, subspaces, bases and dimensions, change of bases and change of coordinates, sums and direct sums, spanning sets and independence, Quotient spaces

Unit-II: Linear Transformation and Dual Spaces

(Lecturers 21) Marks: 30

linear transformation, matrix representation of linear transformation, the rank and nullity theorem, dual spaces, second dual, transpose of linear transformations, trace and determinant, eigenvalues and eigenvectors, invariant subspaces, generalised eigenvectors, cyclic subspaces and annihilators, the minimal polynomial, the Jordan Canonical form

Unit-III: Inner Product Spaces and Operators on Vector Spaces (Lecturers 14) Marks: 20

Inner product spaces, orthonormal bases, Gram-Schmidt process, adjoint operators, normal, unitary and self-adjoint operators, Schur's theorem, spectral theorem for normal operators

Books recommended:

1. V.K. Khanna & S.K. Bhambri, A Course in Abstract Algebra, Vikas Publishing House, New Delhi.
2. K. Hoffman and R. Kunze, Linear Algebra, Prentice Hall of India, 1996.

References:

1. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). Linear Algebra (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.
2. S. Kumaresan: Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.

DISCIPLINE SPECIFIC COURSE (DSC): SEMESTER-II

CMAT-407:(Semester-II)

[ADVANCED PARTIAL DIFFERENTIAL EQUATION]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week), Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. To introduce the fundamental concepts and classification of partial differential equations (PDEs).
2. To develop the ability to formulate and solve first-order PDEs using different analytical methods.
3. To understand and apply methods for solving linear and nonlinear second-order PDEs with constant and variable coefficients.
4. To analyze and solve classical PDEs (wave, heat, and Laplace equations) with boundary conditions using separation of variables and integral transforms.

Course Learning Outcomes: After the completion of this course students will be able to:

1. Define and classify PDEs, and formulate mathematical models using PDEs.
2. Apply the method of characteristics, Charpit's method, and Jacobi's method to solve first-order PDEs.
3. Solve linear second-order PDEs with constant and variable coefficients using standard methods (variation of parameters, Monge's method).

4. Transform second-order PDEs into canonical forms and apply appropriate solution techniques.
5. Derive and solve the wave equation using D'Alembert's solution.
6. Solve diffusion (heat) equations and Laplace equations with given boundary conditions.
7. Apply separation of variables to solve boundary value problem.

Course Contents:

Unit-I:

(Lecturers 21)Marks: 30

Classification of Second Order PDE, Canonical Forms, Wave Equation, Solution of One-dimensional Wave Equation by Canonical Reduction, D'Alembert's Solution of the One-dimensional Wave Equation, Vibrating String – Variables Separable Solution, Forced Vibrations – Solution of Non-homogeneous Equation, Boundary and Initial Value Problem for Two-dimensional Wave Equations – Method of Eigenfunction, Uniqueness of the Solution for the Wave Equation, Duhamel's Principle, Solution of Wave Equation by Laplace Transform, Solution of Wave Equation by Fourier Transform.

Unit-II: :

(Lecturers 21)Marks: 30

Diffusion Equation, Boundary Conditions, Elementary Solutions of the Diffusion Equation, Separation of Variables Method, Maximum-Minimum Principle and Consequences, Solution of Diffusion Equation by Laplace Transform, Solution of Diffusion Equation by Fourier Transform.

Unit-III::

(Lecturers 14)Marks: 20

Laplace and Poisson Equations, Boundary Value Problems, The Spherical Mean, Mean Value Theorem for Harmonic Functions, Maximum-Minimum Principle and Consequences, Separation of Variables Method, Dirichlet Problem for a Rectangle, Neumann Problem for a Rectangle, Interior Dirichlet Problem for a Circle, Exterior Dirichlet Problem for Circle, Interior Neumann Problem for a Circle, Solution of Laplace Equation by Fourier Transform.

Recommended Books:

1. **K. Sankara Rao**, Introduction to Partial Differential Equations, PHI Pvt. Ltd. New Delhi.
2. **I.N. Sneddon**, Elements of Partial Differential Equations, McGraw Hill.

References:

1. **J. David Logan**, Partial Differential Equations, Springer International Edition.
2. **Stanley J. Farlow**, Partial Differential Equations for Scientist and Engineers, Dover.
3. **Lawrence C. Evans**, Partial Differential Equations, American Mathematical Society.
4. **A.R. Forsyth**, Differential Equation, A Treatise on Differential Equations, CBS.

CMAT-408:(SEMESTER-II)

[FUZZY SET THEORY]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Explain the fundamental concepts of fuzzy set theory, develop membership functions, and perform basic operations on fuzzy sets and numbers.
2. Apply fuzzy logic principles to decision-making processes, including fuzzification and defuzzification techniques.

Course Learning Outcomes: This course will enable the students to:

Course Outcomes:

- 1: Understand the basic concepts of Fuzzy sets
- 2: Understand the concepts of arithmetic operations on fuzzy numbers.
- 3: Understand the concepts Fuzzy relations.
- 4: Understand the concepts of Fuzzy logic.
- 5: Understand the concepts of uncertainty and crisp sets.

Course Contents:

Unit-I(Lecturers- 21)Marks: 30

Fuzzy Sets: Crisp Sets- an Overview, Fuzzy Sets-Definition and Examples, α -Cuts and its Properties, Representations of Fuzzy Sets, Extension Principles of Fuzzy Sets, Operations on Fuzzy Sets-Fuzzy Complements, Fuzzy Intersections, Fuzzy Unions, Combinations of Operations, Aggregation Operations.

Unit-II(Lecturers -21)Marks: 30

Fuzzy Arithmetic: Fuzzy Numbers, Arithmetic Operations on Intervals, Arithmetic Operations on Fuzzy Numbers.

Fuzzy Relations: Binary Fuzzy relations, Fuzzy Equivalence Relations, Fuzzy Compatibility Relations. Fuzzy Logic

Unit-III

(Lecturers-14)Marks: 20

Uncertainty-Based Information: Information and Uncertainty, Non Specificity of Crisp Sets – Non Specificity of Fuzzy Sets, Fuzziness of Fuzzy Sets, Uncertainty In Evidence Theory, Principles of Uncertainty. Decision making in fuzzy environment: Individual decision making, multi-person decision making, multicriteria decision making, multi stage decision making, fuzzy ranking methods, fuzzy linear programming.

Text book/ References

1. George J. Klir and Bo Yuan, Fuzzy Sets and Fuzzy Logic- Theory and Applications, Prentice Hall of India, 1997.
2. Timothy J. Ross, Fuzzy Logic with Engineering Applications, McGraw Hill, 1997.
3. H.J. Zimmermann, Fuzzy Sets and its Applications, Allied publishers, 1991.
4. RajjanShingal, Introduction to Fuzzy Logic: PHI Learning Private Limited, Delhi.
5. SK Pundir and R Pundir, Fuzzy Sets and their Applications, PragatiPrakashan.

CMAT-409: (SEMESTER-II) MODULE THEORY

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Develop a comprehensive understanding of module theory, including structure, homomorphisms, tensor products, and categorical perspectives.
2. Analyze algebraic structures using exact sequences, projective/injective modules, and chain conditions such as Noetherian and Artinian properties.
3. Apply structural theorems and canonical forms to classify modules over principal ideal domains and finite-dimensional algebraic systems.

Course Outcomes:

4. Understand and apply fundamental concepts of modules, including submodules, quotient modules, homomorphisms, tensor products, and categorical notions.
5. Analyze module structures using exact sequences, projective and injective modules, and apply key results such as Schur's Lemma and Hilbert Basis Theorem.
6. Examine algebraic systems under chain conditions, including Noetherian and Artinian modules and rings, and interpret their structural implications.
7. Apply advanced classification results such as Wedderburn-Artin theorem, Smith normal form, and canonical forms to study modules over PIDs and linear transformations.

Unit I (Lecture-21)/30marks Module, submodule, Quotient module, module homomorphism, finitely generated module, cyclic module, direct sum of modules, free module, torsion module, torsion free, category and functor, Tensor product of modules.

Unit II (Lecture-21)/30marks Exact sequence, split exact sequence, Projective module, injective module, simple module, semi simple module, Schur's lemma, Noetherian and Artinian modules and ring, Hilbert Basis theorem.

Unit III(Lecture-14)/20marks WedderburnArtin's theorem, Smith normal form over PID, Modules over PID, Rational canonical forms, Generalized Jordan canonical over any finite field.

Recommended Books:

8. I. S Luthar, I.B.S Passi, Algebra Vol. 3 Modules, Narosa Publishing House
9. M.F Atiyah and I.G MacDonald, Introduction to Commutative Algebra, CRC Press, Taylor & Francis, 2018.
10. N.S Gopala Krishnan, Commutative Algebra, University Press, 2016.
11. PB Bhattacharya, S.K Jain and S.R Nagpaul, Basic Abstract Algebra, Cambridge University Press, Indian Edition.

CMAT-410: (SEMESTER-II) NUMBER THEORY

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Objectives: This course is intended to provide a basic understanding of the properties and relationship of integers (number theoretic concepts) like divisibility, existence of primes, factorization of integer, congruences, primitive roots, residues and their applications in various fields and to gain solid foundation on the domain so that students can further explore how number theory connects to other branches of mathematics like algebra, geometry and cryptography and its applications in real world.

Course Learning Outcomes: This course will enable the students to learn:

1. Basic understanding of properties of integers and its number theoretic concepts like divisibility, gcd, fundamental theorems on arithmetic and number theoretic functions.
2. To find the order of an integer under congruence modulo, primitive roots for primes and Composite numbers and the core concepts like quadratic congruences, residues and Legendre symbols.
3. Express an integer in the form of squares of two or four integers and representation of a rational number as a continued fraction.

Unit-I:(Lecture-21)/30marks

Divisibility, g.c.d, Euclidean Algorithm, Fundamental theorem of Arithmetic, Congruences, Chinese Remainder Theorem, Fermat's Little Theorem, Wilson's Theorem, Euler's Theorem, Arithmetic functions $\Phi(n)$, $d(n)$, $\sigma(n)$, $\mu(n)$, Dirichlet product of arithmetic functions, Mobius Inversion formula.

Unit-II:(Lecture-21)/30marks

Primitive roots and indices, Quadratic residues, Legendre symbol, Euler's criterion, Gauss Lemma, Quadratic reciprocity Law, Jacobi symbol.

Unit-III:**(Lecture-14)/20marks**

Representation of an integer as sum of two and four squares, Continued fraction, Approximation of real by rational, Pell's equation.

References:

1. **David M Burton**, Elementary Number Theory, Tata McGraw Hill, 2007.
2. **GH Hardy and EM Wright**, An introduction to theory of Numbers, Oxford University Press, 2008.
3. **SG Telang** (edt. MG Nadkarni and JS Dani), Number Theory, Tata McGraw Hill, 2002.
4. **GA Jones and JM Jones**, Elementary Number Theory, Springer Verlag, London, 2005.
5. **Thomas Koshy**, Elementary number theory with applications, Harcourt science & Technology Co.

DISCIPLINE SPECIFIC COURSE (DSC): SEMESTER-III**CMAT-501: (SEMESTER-III)****[FUNCTIONAL ANALYSIS]**

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Grasp the fundamental concepts of Normed Linear Spaces and Banach Spaces, and work with their key properties
2. Understand the behavior of bounded linear transformations and key theorems like the Uniform Boundedness, Open Mapping, and Closed Graph theorems
3. Apply the Hahn-Banach theorem in various settings and understand the properties of reflexive spaces
4. Explore the structure of Inner Product Spaces and Hilbert Spaces, including their orthonormal properties and the Riesz Representation Theorem

Course Learning Outcomes: Upon completing this course, students will be able to:

5. Define and recognize normed linear spaces and Banach spaces, and provide examples of each.

6. State and apply the Riesz Lemma to understand the relationship between closed subspaces and compact sets.
7. Prove and apply the Uniform Boundedness, Open Mapping, and Closed Graph theorems to solve problems related to linear operators.
8. Utilize the Hahn-Banach theorem to extend linear functionals and characterize the dual spaces of various normed spaces.
9. Identify and differentiate between various types of operator convergence, including weak convergence.
10. Analyze the structure of an inner product space and a Hilbert space using concepts of orthogonality and orthonormal sets.
11. Apply the Riesz Representation Theorem to establish a connection between bounded linear functionals and elements of a Hilbert space.
12. Classify operators on Hilbert spaces (self-adjoint, normal, unitary, etc.) and understand their fundamental properties.

Course Contents:

Unit-I:(Lecture-21)/30marks

Normed Linear spaces, Banach spaces and examples. Quotient space of normed linear spaces, Equivalent Norms. Riesz Lemma, Basic properties of normed linear spaces and compactness. Weak convergence and bounded linear transformations, normed linear spaces of bounded linear transformations, Dual spaces with examples.

Unit-II:(Lecture-21)/30marks

Uniform boundedness theorem and some of its consequences. Open mapping and closed graph theorems. Hahn-Banach theorem for linear spaces, complex spaces and normed linear spaces. Reflexive spaces. Weak Sequences compactness. Compact operators. Solvability of linear equations in Banach spaces. The closed Range theorem.

Unit-III:(Lecture-14)/20marks

Inner product spaces. Hilbert spaces. Orthonormal spaces. Bessel's inequality. Complete orthonormal sets and Parseval's identity. Structure of Hilbert spaces. Projection theorem. Riesz representation theorem. Adjoint of an operator on Hilbert spaces. Reflexivity of Hilbert spaces. Self adjoint Operators, Positive, Projection, Normal and Unitary operators. Abstract variational boundary value problems.

References:

13. **HL Royden, Real Analysis**, Macmillan Pub Co. Inc. New York.
14. **C Goffman and G. Pedrick**, First Course in Functional Analysis, Prentice Hall of India
15. **E Kreyszie**, Introductory Functional Analysis with Application, John Wiley 7 Sons, NY
16. **RB Holmos**, Geometric Functional Analysis and its Applications, Springer-Verlag
17. **PK Jain, OP Ahuja and Khalil Ahmad**, Functional Analysis, New Age Int. & Wiley Eastern Ltd.

CMAT-502:(SEMESTER-III)

[MEASURE AND INTEGRATION]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Student will understand the general theory of measure and integration over abstract measure spaces.
2. Student will be able to introduce the idea of extension theorem and product measure.
3. Understand the theory that work in locally compact topological spaces.

Course Learning Outcomes: Students may be able to:

4. Understand signed measure and decomposition theorem.
5. Students should be able to compare the classical integration and integration with respect to a measure.
6. Apply Fubini's theorem to evaluate double integral.
7. Understand integration over locally compact spaces.

Course Contents:

Unit-I:

(Lecture-21)/30marks

Signed measure, Hahn decomposition theorem, Mutually singular measures, Absolutely continuous measures, Radon-Nikodym theorem, Lebesgue decomposition theorem, Riesz representation theorem.

Unit-II:

(Lecture-21)/30marks

Extension theorem (Caratheodory), Lebesgue-Stieltjes integral, Product measures, Fubini's theorem, Differentiation and Integration, Decomposition into absolutely continuous and singular parts.

Unit-III:

(Lecture-14)/20marks

Baire sets, Baire measure, Continuous functions with compact support, Regularity of measures on locally compact spaces, Integration of continuous functions with compact support, Riesz-Markoff theorem.

References:

8. **HL Royden**, Real Analysis, Macmillan Publishing Co. Inc. New York, 4th Edition.
9. **PK Jain and VP Gupta**, Lebesgue Measure and Integration, New Age International Pvt. Ltd.
10. **IK Rana**, Introduction to Measure and Integration, Narosa Publishing House, Delhi.
11. **Sterling K Berberian**, Measure and Integration, American Mathematical Society, Chelsea.
12. **G de Barra**, Measure Theory and Integration, New Age International.

DISCIPLINE SPECIFIC ELECTIVE(DSE): SEMESTER –III

EMAT-507:(SEMESTER-III)

[GRAPH THEORY]

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

The primary objective of this course is to introduce the concept of undirected graph, operation and connectedness of graph, different types of graphs, tree, center and centroid, independent cycles and co cycles, Connectivity and traversability, planarity and colorability,

Course Learning Outcomes:

This course will enable the students to:

1. Learn the basic concept and apply the connectedness of graph
2. Understand tree and its significance and applications in graph theory
3. Have the knowledge of point connectivity and line connectivity and their applications
4. Applications of Eulerian and Hamiltonian graph
5. Learn and apply the Kuratowski's theorem in planar graph
6. Learn and apply the point coloring and chromatic number

Unit-I

(Lecture-21)/30marks

Basic definitions of graphs and multigraphs; adjacency matrices, isomorphism, girth, decompositions, independent sets and cliques, graph complements, vertex coloring, chromatic number, important graph like cubes and the Petersen graph, Paths, cycles, and trails; Eulerian circuits, Vertex degrees and counting; large bipartite subgraphs, the handshake lemma, Havel-Hakimi Theorem, Directed graphs: weak connectivity, connectivity, strong components, Induction and other fundamental proof techniques.

Unit II

(Lecture-21)/30marks

Basics: equivalent characterizations of trees, forests,. Spanning trees and 2-switches
Distance and center, Optimization: Kruskal's Theorem and Dijkstra's Theorem , Trees and their properties, Binary trees, Spanning trees, Hamiltonian paths and Circuits, Partitioning, Representations of Graphs, adjacency matrix, incidence matrix, Path matrix, Circuit matrix.

Unit III

(Lecture-14)/20marks

Connectivity and travers ability, Connectivity and line connectivity, Menger's theorems, Eulerian graph, Hamiltonian graphs, Planar graphs, outer planar graphs, Kuratowski's theorem, dual graphs, chromatic number, five color theorem.

Reference:

1. F. Harary, Graph theory, Narosa Publishing House, New Delhi, 1988.
2. R. Balakrishnan and K. Renganathan, A textbook of Graph theory, Springer, 2000
3. B. Bollobas, Modern Graph Theory, Springer, 2002
4. G. Chartrand, L. Lesniak, Graphs & digraphs(fourth edition), Chapman & Hall/CRC, 2005.
5. R. J. Wilson, Introduction to Graph Theory (5th Edition), Prentice Hall, 2010

EMAT-508:(SEMESTER-III)**[FLUID DYNAMICS]**

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

1. Understand and apply the general theory of irrotational motion, including Kelvin's theorems, kinetic energy principles, and uniqueness results.
2. Analyze the mathematical and physical properties of vortices, vorticity, and vortex motion in ideal fluids.
3. Explore the effects of viscosity in fluid motion through stress-strain analysis, Stokes relation, Navier-Stokes equation, and energy dissipation.
4. Strengthen problem-solving and analytical skills by applying fluid dynamical theorems and equations to real-world physical models.

Course Outcomes: After the completion of this course students will be able to:

5. Define and describe irrotational motion, cyclic motion, and Kelvin's circulation theorem with applications.
6. Compute kinetic energy for finite and infinite liquid domains and apply Kelvin's minimum energy theorem to fluid systems.
7. Apply Green's theorem and uniqueness theorems to problems in velocity potential and fluid motion analysis.
8. Define vortex lines, vortex tubes, and vortex filaments; explain their fundamental properties and strength.
9. Analyze fluid motion due to multiple vortices, centers of vortices, two vortex filaments, and infinite rows of vortices.
10. Apply Helmholtz's velocity theorem and study special cases such as Karman's vortex street.
11. Explain viscosity, stress-strain relations, and derive Stokes relation; formulate and interpret the Navier-Stokes equation for viscous fluids.
12. Analyze energy dissipation, circulation in viscous fluids, and evaluate flow regimes using Reynolds number.

Course Contents:

Unit-I:

(Lecture-21)/30marks

General Theory of Irrotational motion: Irrotational motion, Kelvin's circular theorem, cyclic motion. Kinetic energy of finite liquid, Kinetic energy of infinite liquid, Kelvin's minimum energy theorem. Mean value of velocity potential over a spherical surface. Uniqueness theorem. Green's theorem.

Unit-II:(Lecture-21)/30marks

Vorticity: Vortex line, Vortex tube, Vortex filament, Properties of vortex filament, Strength of vortex, Rectilinear vortices, Motion due to m vortices, Centre of vortices, Two vortex filaments, Two infinite rows of vortices, Karman's vortex street, Helmholtz's velocity theorem.

Unit-III:(Lecture-14)/20marks

Viscosity: Coefficient of viscosity, Viscous fluid, Most general motion of a liquid element, Strain, Stress Analysis, Analysis of motion, Principal stress and Stokes relation, Navier-Stokes equation for a viscous fluid. Dissipation of energy due to viscosity, Circulation in a viscous fluid. Reynolds number.

References:

13. **GK Batchelor**, An Introduction to Fluid Mechanics, Cambridge University Press.
14. **AJ Chorin and JF Marsden**, A Mathematical Introduction to Fluid Dynamics, Springer.
15. **F Chorlton**, Textbook of Fluid Dynamics, CBS Publication, Delhi.
16. **LD Landau and F Lipschitz**, Fluid Mechanics, Pergamon Press.
17. **O'Neil & F. Chorlton**, Ideal and Incompressible Fluid Dynamics, Ellis Horwood Ltd.

EMAT-509:(SEMESTER-III)

[DIFFERENTIAL GEOMETRY AND TENSORS]

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

1. Develop a solid understanding of geodesics, curvature concepts, and fundamental theorems in the geometry of surfaces.
2. Acquire knowledge of tensor analysis, transformation laws, covariant differentiation, and the role of Christoffel symbols in curved spaces.
3. Explore advanced concepts of Riemannian geometry, including curvature tensors, Einstein space, and fundamental results such as Bianchi's identity and Schur's theorem.

Course Learning Outcomes: After the completion of this course students will be able to:

4. Derive and apply the differential equations of geodesics, compute geodesics on surfaces of revolution, and analyze geodesic curvature and torsion.
5. Apply Gauss-Bonnet theorem, Gauss's formulae, and Weingarten/Mainardi-Codazzi equations to study intrinsic and extrinsic geometry of surfaces.
6. Define tensors and their transformation laws, contraction, quotient law, reciprocal tensors, Kronecker delta, and metric tensors.
7. Perform covariant differentiation of tensors, use Ricci's theorem and intrinsic derivative, and analyze geodesic coordinates via Christoffel symbols.
8. Derive and analyze properties of the Riemann-Christoffel tensor, covariant curvature tensor, and Einstein tensor.
9. Apply Bianchi's identity, study Einstein space, and examine geometric structures such as flat space, isotropic points, and Schur's theorem.

Course Contents:

Unit-I:(Lecture-21)/30marks

Geodesics, Differential equation of a geodesic, Single differential equation of a geodesic, Geodesic on a surface of revolution, Geodesic curvature and torsion, Gauss-Bonnet theorem, Gauss's formulae, Gauss's characteristic equation, Weingarten equations, Mainardi-Coddazi equations, Fundamental existence theorem for surfaces.

Unit-II:(Lecture-21)/30marks

Tensor analysis, Tensor and their transformation laws, Contraction, Quotient law, Reciprocal tensors, Kronecker delta, symmetric and skew-symmetric tensors, metric tensors, Riemann space, Christoffel symbols and their transformation laws, covariant differentiation of tensors, Ricci's theorem, Intrinsic derivative. Geodesic co-ordinates.

Unit-III:(Lecture-14)/20marks

Riemann-Christoffel tensor and its properties, Covariant curvature tensor, Einstein space, Bianchi's identity, Einstein tensor, Flat space, Isotropic point, Schur's theorem.

References:

10. **TJ Wilmore**, An Introduction to Differential Geometry, Dover Publication.
11. **CE Weatherburn**, An Introduction to Riemann Geometry & Tensor, Cambridge University Press.
12. **Ruchard S Millman& George D Parker**, Elements of Differential Geometry, Pearson Publication.
13. **Brain F Doolin**, An Introduction to Differential Geometry for Engineers, Dover Pub. Inc.

EMAT-510:(SEMESTER-III)

[COMMUTATIVE ALGEBRA]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Develop a strong understanding of the structure of ideals, radicals, and modules, and apply key results such as Nakayama's Lemma and the Chinese Remainder Theorem.
2. Analyze localization techniques and rings of fractions, and understand primary decomposition along with its uniqueness properties.
3. Examine integral dependence and fundamental theorems such as Going Up, Going Down, and Hilbert's Nullstellensatz, with applications in algebraic structures.

Course Outcomes:

1. Explain and apply concepts of prime/maximal ideals, radicals, local rings, and finitely generated modules.
2. Construct and analyze rings of fractions and localization at prime ideals, including extension and contraction of ideals.
3. Demonstrate understanding of primary decomposition and prove the first and second uniqueness theorems.
4. Apply concepts of integral dependence, valuation rings, and major theorems like Going Up, Going Down, and Hilbert's Nullstellensatz.

Unit I (Lecture-21)/30marks

Prime and maximal ideals, Prime Avoidance lemma, Nil radical, Jacobson radical, Chinese Remainder theorem, extension and contraction of ideals, local ring, finitely generated module, Nakayama's lemma.

Unit II (Lecture-21)/30marks

Rings and modules of fraction, localisation at a prime ideal, extended and contracted of ideals in ring of fractions, primary decomposition, 1st and 2nd uniqueness theorems of primary decomposition.

Unit II:(Lecture-14)/20marks

Integral dependence, Going up theorem, Going down theorem, Integrally closed domain, Valuation ring, Hilbert Nullstellansatz Theorem.

Recommended Books:

1. M.F Atiyah and I.G MacDonald, Introduction to Commutative Algebra, CRC Press, Taylor & Francis, 2018.

2. N.S Gopala Krishnan, Commutative Algebra, University Press, 2016.
3. PB Bhattacharya, S.K Jain and S.R Nagpaul, Basic Abstract Algebra, Cambridge University Press, Indian Edition.
4. I. S Luthar, I.B.S Passi, Algebra Vol. 3 Modules, Narosa Publishing House

EMAT-511:(SEMESTER-III)

[MECHANICS]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Student will understand the fundamental principles of classical mechanics, including Newton's Law, Lagrangian and Hamiltonian mechanics, and conservation laws.
2. Student will be able to describe and analyse motion in various co-ordinates systems and reference frames.
3. Understand the concept of Gravitation.

Course Outcomes: Students may be able to:

1. Analyse and study Newtonian mechanics, Dynamics of rigid body, De Alembert's Principle, Lagrange's equations, Holonomic and Non-holonomic systems.
2. Understand the idea of Calculus of variations, Euler's equation, Hamilton's Principle, principle of least action.
3. Understand canonical transformation, Jacobi theory and about the Brackets.
4. Understand about gravitation, Attraction and potential, applications of Gauss's theorem.
5. Gain knowledge and skill in Physics.
6. Apply the knowledge and perform various experiments based on the knowledge of physics.

Course Contents:

Unit-I:

(Lecture-21)/30marks

Generalized co-ordinates, Holonomic and non-holonomic systems, Scleronomic and Rheonomic system, De Alembert's Principle, Lagrange's equation, Hamilton's Principle, Lagrange's Principle from Hamilton's Principle, Extension of Hamilton's Principle to non conservative and non holonomic systems.

Unit-II:**(Lecture-21)/30marks**

Calculus of variation, Shortest distance, Minimum surface of revolution, Geodesic, Fundamental lemma of calculus of variation. Euler's equation for one dependent function and its generalization to n independent functions, Hamilton's equation of motion, Conservation theorem and physical significance of Hamiltonian, Derivation of Hamilton's equation from variational principle, Principle of least action.

Unit-III:(Lecture-14)/20marks

Equation of canonical transformation, Integral invariance of Poincare, Lagrange and Poisson Brackets, Condition of canonical character of a transformation in terms of Lagrange Brackets and Poisson Brackets, Invariance of Lagrange and Poisson Brackets under canonical transformation, Constants of motion and symmetry properties, Gravitation, Attraction and Potential of rod, disc, spherical shell and sphere.

References:

1. **H Goldstein**, Classical Mechanics, Wesley Publication Massachusetts.
2. **F Grantmacher**, Lectures in Analytical Mechanics, MIR Publication.
3. **IM Gelfand and SV Fomin**, Calculus of Variation, Prentice Hall of India.
4. **SL Loney**, An Elementary Treatise on Statics, Kalyani Publishers, New Delhi.
5. **AS Ramsey**, Newtonian Gravitation, Cambridge University Press.
6. **TWB Kibble**, Classical Mechanics, Orient Longman, London.
7. **Gregory**, Classical Mechanics, Cambridge University Press.

EMAT-512: (SEMESTER-III)**[DYNAMICAL SYSTEMS]**

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives: The course objective is

1. To introduce students to the fundamentals of one-dimensional dynamical systems, topological dynamical systems and complex dynamical systems.
2. To give in depth knowledge of dynamical systems and its application.

Course Outcomes:

1. Understand different kinds of dynamical systems, orbit, phase space diagram.
2. Understand limit sets, topological transitivity, Chaos, topological entropy.
3. Understand dynamical behavior of complex functions.

UNIT I: One Dimensional Dynamical Systems (Lecture-21)/30marks

Examples of dynamical systems, one dimensional dynamical systems, orbit, periodic points, phase space diagrams.

UNIT II: Chaotic Dynamical Systems (Lecture-21)/30marks

Limit sets, recurrence, topological transitivity, topological mixing, sensitive dependence to initial condition, chaotic dynamical systems, equicontinuity, distality, proximality, topological entropy.

UNIT III: Complex Dynamics(Lecture-14)/20marks

Iteration of Mobious Transformations, Iteration of functions of the type $z^2 + c$, $z + \frac{1}{z}$, $2z - \frac{1}{z}$, Lipschitz condition and Mobius Map, fixed points of rational maps, Fatou and Julia Sets, classification of periodic points of rational maps,

References:

1. Robert L. Devaney, *An Introduction to Chaotic Dynamical Systems*, 2nd Ed, Addison-Wisley Publishing Company.
2. L. S. Block, W. A. Coppel, *Dynamics in one Dimension*, Springer-Verlag.
3. Jan De Vries, *Topological Dynamical Systems*, De Gruyter.
4. Boris Hasselblatt, Anatole Katok, *A First Course in Dynamics*, Cambridge University Press.
5. Alasn F. Beardon, *Iteration of Rational Functions: Complex Analytic Dynamical Systems*, Springer Verlag.

DISCIPLINE SPECIFIC ELECTIVE(DSE): SEMESTER –III (OPTIONAL PAPER-I)

EMAT-513:(SEMESTER-III) [OPERATIONS RESEARCH-I]

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Objectives:

1. Explain the fundamental concepts of Operations Research and formulate linear programming problems, applying the Simplex method and sensitivity analysis.
2. Solve integer and goal programming problems using advanced techniques such as the Branch and Bound and cutting plane algorithms.
3. Apply the principles of dynamic programming to complex decision problems.
4. Analyze and solve two-person zero-sum games using a variety of methods, including algebraic, graphical, and linear programming.

Course Outcomes: Upon completing this course, students will be able to:

5. Describe the methodology and scope of Operations Research and formulate a given problem as a linear programming model.
6. Solve linear programming problems using the Simplex method and interpret the results of duality and sensitivity analysis.
7. Apply the Dual Simplex method and Goal programming to solve specific types of linear programming problems.
8. Solve integer programming problems using the cutting plane algorithm and the Branch and Bound Technique.
9. Formulate and solve dynamic programming problems.
10. Determine a saddle point in two-person zero-sum games and solve games with mixed strategies using algebraic methods.
11. Utilize graphical methods and linear programming to find the optimal solution for two-person zero-sum games.

Course Contents:

Unit I:(Lecture-21)/30marks

Operations research and its scope, features of Operations research, Operations research Methodology, Structure of Mathematical model. Linear programming, Convex sets and their properties, Simplex method, Charnes method or Big M method, two phase Simplex method ,Duality in linear programming and Sensitivity analysis.

Unit II:(Lecture-21)/30marks

Integer programming, Gomory's all integer Cutting plane algorithm, Branch and Bound Technique, Applications of zero one integer programming, Dual Simplex method, Goal programming, Parametric linear programming.

Unit III:(Lecture-14)/20marks

Transportation problems, Transportation algorithm (Modi method), Assignment problems.,Game theory-Two person zero sum games, The maxima and minima principles, algorithm for determining a saddle point, Games with mixed strategies, Algebraic method for solving m by n games, Graphical solution, and solution by linear programming.

References:

12. **HA Taha**, Operations research: an introduction (Eighth edition), PHI New Delhi, 2006.
13. **F S Hiller and Gerald J**, Introduction to operations research, Leiberhan, McGraw Hills.
14. **PK Gupta and Manmohan**, Operations research: KantiSwarup, sultan Chand & Sons.

15. **JK Sharma**, Operations research: Theory and applications by, Trinity 2017.
16. **HS Kasana and KD Kumar**, Introductory operations research: Theory and Applications, Springer Verlag.

EMAT-514:(SEMESTER-III)
[GENERAL RELATIVITY AND COSMOLOGY-I]

Total Marks: 100(External-80, Internal-20)
 Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)
 Examination: 3 Hrs

Course Learning Objectives:

1. To provide the basic knowledge of tensor calculus needed for General relativity.
2. To provide a strong foundation in Einstein's field equations and their Newtonian approximation.
3. To study Schwarzschild solutions and their applications in explaining astronomical phenomena.
4. To enable students to connect special relativity, Newtonian gravity and General relativity in cosmological contexts.

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

5. Understand Transformation of co-ordinates, contravariant and covariant tensors, symmetric and skew symmetric tensor, kronecker delta symbol.
6. Perform tensor algebra and explain concept Riemannian geometry concepts: Metric, Parallel transport, Christoffel symbols, Curvature tensor and Bianchi identities and Einstein tensor.
7. Apply the principle of equivalence and general covariance in physical problems.
8. Construct and analyse energy-momentum tensor for perfect fluids.
9. Derive and analyse Einstein's field equation.
10. Interpret and calculate results from Schwarzschild solutions including planetary orbits, perihelion advance, bending of light and gravitational redshift.

Course Contents:

Unit-I:(Lecture-21)/30marks

Transformation of coordinates. Tensors, Algebra of tensors, Symmetric and Skew Symmetric tensors, Contraction of tensors and Quotient law. Riemannian metric. Parallel transport. Christoffel symbols. Covariant derivatives, Intrinsic derivatives and Geodesics. Riemann Christoffel symbols, Riemann curvature tensor and its symmetric properties. Bianchi Identities, Einstein tensor, Weyl curvature tensor.

Unit-II:(Lecture-21)/30marks

Review of the special theory of relativity and the Newtonian law of Gravitation. Principle of Equivalence and general covariance, Geodesic principle, Newtonian approximation of relativistic equation of motion. Einstein's field equations and Newtonian approximation.

Unit-III:(Lecture-14)/20marks

Schwarzschild external solution and its isotropic form. Planetary orbits and Analogues of Kepler's laws in general relativity. Advance of perihelion of a planet. Bending of light rays in a gravitational field. Variational red-shift of spectral lines. Radar echo delay. Energy momentum tensor of a perfect fluid. Schwarzschild external solution, Boundary conditions. Energy momentum tensor of a Electromagnetic field. Einstein-Maxwell equations. Riessner-Nordstrom solution.

References:

11. **H Stephani**, General Relativity, Ian Introduction to the theory of Gravitational field, Cambridge University Press.
12. **BF Schutz**, A first Course in General Relativity, Cambridge University Press.
13. **R Adlev, M Bazin and M Scjiffer**, Introduction to General Relativity, McGraw Hill Inc.
14. **S Weinberg**, Gravitation and Cosmology: Principles and Applications of General theory of Relativity, John Wiley & Sons Inc.
15. **RK Sachs and H Wu**, General Relativity for Mathematicians, Springer Verlag.
16. **JV Narlikar**, General Relativity and Cosmology, Macmillan and Co.
17. **JV Narlikar**, Introduction to Cosmology, Cambridge University Press.
18. **LD Landu and FM Lifshitz**, The Classical theory of fields, Pregmon Press.

EMAT-515:(SEMESTER-III)**[CRYPTOLOGY -I]**

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

1. Build a foundational understanding of algebra and number theory concepts essential for cryptography, including primality testing, modular arithmetic, and related theorems.
2. Develop knowledge of symmetric key encryption techniques, cryptographic hash functions, and probabilistic digital signatures.
3. Explore public-key cryptography with emphasis on RSA cryptosystem, key management, and security considerations against attacks.

Course Outcomes: After the completion of this course students will be able to:

4. Apply modular arithmetic, Chinese Remainder Theorem, Fermat's theorem, and Euler's theorem to cryptographic problems.
5. Implement primality testing methods such as Miller–Rabin and deterministic tests for cryptographic applications.
6. Analyze symmetric key encryption methods including stream ciphers, block ciphers, DES, and AES.
7. Evaluate modes of operation of hash functions, construct cryptographic hash functions, and apply probabilistic signatures and discrete logarithm principles.
8. Explain and apply the RSA cryptosystem: key generation, encryption, decryption, and signature verification processes.
9. Assess the security of RSA against factoring and various attacks, and determine appropriate key length for secure communication.

Course Contents:

Unit I:(Lecture-21)/30marks

Algebra & Number Theory: Integers & residues; Chinese Remainder Theorem, Miller Rabin Primality Test, Fermat's theorem, Euler's Theorem, Fast Deterministic Tests.

Unit II:(Lecture-21)/30marks

Symmetric Key Encryption: Stream Ciphers, Block Ciphers, Data Encryption Standard, Advanced Encryption Standard, Modes of Operation of Hash Functions; Construction of Hash Function, Probabilistic Signatures, and Discrete Logarithm.

Unit III:(Lecture-14)/20marks

Concept of Public-key Cryptography; the RSA Cryptosystem; Key Generation Scheme; Encryption, Decryption, Signature Verification, Key Length, Factoring Problem Security of RSA, Attacks.

References:

10. **William Stallings:** Cryptography & Network security (Principles & practice), Pearson Education, revised 3rd edition, 2003.
11. **Hans Delfs and Helmut Knebl:** Introduction to cryptography, (Principles & Applications), Springer verlag, revised 3rd Edition, 2002.
12. **David M Burton :** Elementary Number Theory, Tata McGraw Hill Educational Pvt. Ltd., New Delhi, Sevent Reprint, 2009.
13. Abraham Robinson: Numbers & Ideals; Yale University, Reprinted, 1965.

EMAT-516:(SEMESTER-III)

[OPERATOR THEORY-I]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

1. To make the students understand the fundamental concepts of spectral theory such as regular values, resolvent set, spectral values, spectrum of a linear operator.
2. To develop the skill of calculation of regular values and different spectral values by using many examples.
3. To impart ideas on Approximate point spectrum of a bounded linear operator and its properties including the relationship with spectrum of a bounded linear operator.
4. To learn about special properties of compact linear operator on normed spaces and their impact on spectral theory.
5. To make the student explore on the characteristics of different types of linear operators such as closed, densely defined, finite dimensional and adjoint linear operators.
6. To comprehend in differentiating in key classes of operators including Hermitian, Symmetric, Normal and Unitary operators.

Course Outcomes: After the completion of course the students will be able to:

7. Define and compute the spectrum, resolvent set and eigen values of a bounded linear operator.
8. Apply the spectral mapping theorem to find the spectrum of a polynomial of an operator.
9. Prove and utilize the key spectral properties of compact linear operator such as the existence of a finite countable spectrum.
10. Characterize the properties of a finite dimensional linear operator and determine the condition for the compactness of a product of operators.

11. Distinguish between closed, finite dimensional and densely defined linear operators and determine when an operator has a closer.
12. Reproduce many properties and observations between the adjoint operators of different operators.
13. Classify operators as Hermitian, Symmetric, Normal and Unitary operators and understand the relationship between these classes.
14. Solve problems involving the spectral properties of different types of operators on normed spaces.

Course Contents:

Unit-I: (Lecture-21)/30marks

Spectral theory of linear operators in normed spaces: Eigen values of an operator, spectrum, resolvent set, spectral properties of bounded linear operators, Approximate eigen values and its properties, Spectral mapping theorem for polynomials.

Unit-II: (Lecture-21)/30marks

Compact linear operators on normed spaces, spectral properties of compact linear operators, Finite dimensional linear operators, compactness of product of linear operators, ε -net, totally boundedness, separable.

Unit-III (Lecture-14)/20marks

Closed linear operators, Linear operators permitting closure (closer of an operator), Densely defined linear operators, Adjoint of a linear operator, Hermitian operator, Symmetric operator, Normal and Unitary operators.

References:

15. **E Kreyszig**, Introductory Functional Analysis with applications, John- Wiley & Sons.
16. **PR Halmos**, Introduction to Hilbert space and the Theory of Spectral Multiplicity, Second Edition, Chelsea Publishing Co. N.Y. 1957.
17. **N Dunford and JT Schwartz**, Linear operators-3 parts, Interscience Wiley, New York.
18. **G Bachman and L Narici**, Functional Analysis, Academic Press, New York, 1966.
19. **NI Akhiezer and IM Glazman**, Theory of Linear operators in Hilbert Spaces, Frederick Unger Pub. Co. N. Y. Vol. I (1961), Vol. II, 1963.

EMAT-517:(SEMESTER-III)
[ALGEBRAIC CODING THEORY-I]
Total Marks: 100(External-80, Internal-20)
Workload: 4 Lectures (per week), Credits: 4 Duration: 14 Weeks (56 Hrs.)
Examination: 3 Hrs.

Learning Objectives

1. Understand the principles of error detection and correction and the concept of group codes.
2. Apply matrix encoding techniques and construct generator and parity-check matrices.
3. Analyze polynomial codes and Hamming codes for encoding and decoding.
4. Understand finite fields and their role in coding theory.
5. Study linear codes, dual codes, and weight distribution.
6. Analyze BCH codes and methods of constructing new codes.
7. Understand cyclic codes and their algebraic structure.
8. Construct generator and check polynomials and perform decoding.
9. Study special cyclic codes like BCH, Reed–Solomon, and quadratic residue codes.

Course Outcomes (COs)

10. Construct and analyze linear codes using generator and parity-check matrices.
11. Apply Hamming codes for error detection and correction.
12. Solve problems related to encoding and decoding techniques.
13. Apply finite field concepts to construct and analyze linear codes.
14. Determine dual codes and evaluate weight distribution.
- 15.** Design and analyze BCH and related codes.
16. Construct and decode cyclic codes using polynomial methods.
17. Apply burst error correction techniques.
- 18.** Analyze and compare special cyclic codes.

Course Contents:

Unit-I:

(Lecture-14)/20marks

Group codes, error detection and error correction, matrix encoding techniques, polynomial codes, generator and parity check matrices, Hamming codes.

Unit-II:**(Lecture-21)/30marks**

Finite field and Bose-Chaudhuri-Hocquenghem (BCH) codes, Linear codes, dual of a linear code, Weight distribution of the dual code of a binary linear code, New codes obtained from a given codes.

Unit-III:**(Lecture-21)/30marks**

Cyclic codes, check polynomial, Generator polynomials, Generator and parity-check matrices, Decoding of cyclic codes, Burst error correcting codes, Some special cyclic codes- BCH codes, Reed-Solomon codes, Quadratic-residue codes.

References:

1. **E Berlekamp**, Algebraic Coding Theory, McGraw Hill, New York, 1968.
2. **L R Vermani, Chapmann and Hall**, Elements of Algebraic Number Theory, 1996.
3. **C Ling and C Xing**, Coding Theory: A First Course, Cambridge University Press, 2004.
4. **FJ Mac Williams and NJA Sloane**, Error-correcting codes, North Holland Publishing Company, 1977.
5. **WW Peterson and EJ Weldon, Jr.** Error-Correcting codes, MIT press, Cambridge, Massachusetts, 1972.

EMAT-518:(SEMESTER-III)**[ADVANCED NUMERICAL TECHNIQUES-I]**

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

1. To recall Numerical Analysis learnt in the previous Courses.
2. To gain knowledge about the insights of Numerical Analysis.
3. To develop the ability to apply numerical methods to problems.
4. To develop the ability to find numerical solutions to theoretically unsolvable problems.

Course Outcomes:

1. Should have command over Numerical Analysis.
2. Must be able to choose the right numerical method for physical problems.
3. Should be able to generalise other numerical Methods.

Unit-I:**(Lecture-21/30 marks)**

Solution of Equations: Newton-Raphson Method, General Iteration Method, Convergence of Iteration Methods, Gauss-Jordan Method, Gauss-Seidel Iteration Method; Interpolation: Newton's Divided Difference Interpolation, Newton's Forward and Backward Difference Interpolation, Spline Interpolation and Cubic Splines; Implementation in Mathematical Software.

Unit-II:**(Lecture-21/30 marks)**

Numerical Differentiation: Derivatives using Newton's Forward, Backward and Divided Difference Formula; Numerical Integration: Simpson's Rule, Romberg Method, Gauss-Legendre Rule, Double Integration by Trapezium and Simpson's Rule; Implementation in Mathematical Software.

Unit-III:**(Lecture-14/20 marks)**

Application in ODE: Runge-Kutta Fourth Order Method, Predictor-Corrector Method, Stability of Numerical Methods, Application in PDE: Finite Difference Methods for Heat Conduction and Wave Equation; Implementation in Mathematical Software.

Recommended Books:

- [1] S.R.K. Iyengar, R.K. Jain, Numerical Methods, New Age International Publishers
- [2] John H. Mathews, Numerical Methods for Mathematics, Science and Engineering, Prentice Hall of India.
- [3] D.V. Griffiths, I.M. Smith, Numerical Methods for Engineers, Oxford University Press

DISCIPLINE SPECIFIC COURSE (DSC): SEMESTER -IV**CMAT-503: (SEMESTER-IV)****ANALYTIC AND GEOMETRIC FUNCTIONS THEORY**

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Understand transformations, analyticity, and Cauchy–Riemann equations.
2. Apply theorems of complex integration to evaluate contour integrals.
3. Develop series representations of functions and classify singularities.
4. Use residue theory and advanced theorems to solve problems.

Course Outcomes: After the completion of this course students will be able to:

1. Explain basic transformations, linear fractional maps, and cross ratios.
2. Test analyticity using Cauchy–Riemann equations and find harmonic conjugates.
3. Evaluate contour integrals using Cauchy's theorems and integral formula.
4. Apply Liouville's theorem, Fundamental Theorem of Algebra, and Maximum Modulus Theorem.
5. Expand functions in Laurent series and classify singularities.
6. Compute real and complex integrals using the residue theorem.
7. Apply Argument Principle, Rouché's, Hurwitz's, and Open Mapping Theorems.

Course Contents:

Unit-I: Harmonic Functions

(Lecture-21)/30marks

Harmonic Functions: Comparison with analytic functions; Mean value property; Maximum Principle; Borel-Caratheodory. Poisson Integral formula for analytic and Harmonic functions, Harnack's inequality, Harnack's Principle.

Unit-II: Conformal Mapping and Infinite Product

(Lecture-21)/30marks

Conformal mappings, Normal families, Montel's theorem, group of automorphisms, Riemann Mapping theorem, infinite product, Weierstrass's product theorem, gamma function.

Unit-III: Meromorphic Functions and Variants of Schwarz Lemma

(Lecture-14)/20marks

Meromorphic functions, Mittag-Leffler's theorem, analytic continuations, Monodromy theorem, Euler's Product Formula, Schwarz-Pick Lemma, Lindelof version of Schwarz Lemma, Boundary Schwarz Lemma.

References:

1. S. Ponnusamy and H. Silverman (2006). *Complex variables with applications*. Birkhäuser.
2. S. Ponnusamy (2018) *Foundations of complex analysis* (2nd ed.), Narosa Publishing House.
3. Steven G. Krantz, *Geometric Function Theory*, Birkhauser.
4. Joseph Bak, Donald J. Newman, *Complex Analysis* (3rd Edition), Springer.
5. Edward B. Staff, Arthur David Snider, *Fundamentals of Complex Analysis Engineering, Science, and Mathematics*, Pearson.

CMAT-504:(SEMESTER-IV)

[ALGEBRAIC TOPOLOGY]

Total Marks: 100(External-80, Internal-20)

Workload: 4Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs

Course Learning Objectives:

1. Understand the fundamental concepts of topological group including key properties direct product, group action, orbit spaces.
2. Grasp the principles of homotopy, including how to classify continuous functions and spaces based on their homotopy type.
3. Explore the construction and properties of the fundamental group and its role as a powerful tool in algebraic topology.

4. Apply the tools of topology, such as the fundamental group, to prove significant theorems like the Fundamental Theorem of Algebra and Brouwer's fixed-point theorem.

Course Outcomes:

Upon completing this course, students will be able to:

1. Define and discuss topological group with their properties, such as being Hausdorff, compact, or connected.
2. Construct subgroup, product, and quotient topological group, and determine the continuity of functions between them.
3. Prove whether a given function is a homeomorphism and determine if a space is path-connected. Also discuss about group action and orbit spaces.
4. Define and classify spaces based on homotopy type and determine if a space is contractible.
5. Construct the fundamental group of a path-connected space and show that it is a well-defined group.
6. Analyze the effect of continuous functions on the fundamental group by constructing the induced homomorphism.
7. Identify and recognize simply connected topological spaces.
8. Formulate a proof for Brouwer's fixed-point theorem and the Fundamental Theorem of Algebra using topological concepts.

Course Contents:

Unit-I:

(Lecture-21)/30marks

Topological Group: Examples and basic properties, topological subgroups, topological quotient groups, homomorphism of a topological group, direct product, group action, orbit spaces.

Unit-II

(Lecture-21)/30marks

Homotopy: Instruction and definitions, properties of homotopic mappings, relative homotopy, contractible spaces, homotopy type, retractions, path-definition, path connected spaces, equivalent paths.

Unit-III:**(Lecture-14)/20marks**

Fundamental Group: Formation of a group, isomorphism of fundamental Groups, homomorphism of fundamental Groups, induced homomorphism, simply connected topological spaces, Brouwer's fixed point theorem, fundamental theorem of algebra.

References:

1. JR Munkres, Topology-A first Course, PHI
2. BK Lahiri, A First Course in Algebraic Topology, Narosa
3. D Wilkins, Course-421-Algebraic Topology, Lecture Notes, 2008-09 Sec. 1 & 2
4. A Hatcher, Algebraic Topology, CUP
5. EH Spainer, Algebraic Topology, McGraw Hill NY
6. Chatterjee, Ganguly and Ghosh, A Text Book of Topology, Asian.

**DISCIPLINE SPECIFIC ELECTIVE(DSE): SEMESTER –IV
(OPTIONAL PAPER-II)**

**EMAT-519:(SEMESTER-IV)
[OPERATIONS RESEARCH-II]**

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Analyze the properties of different types of non-linear functions and apply advanced methods like the Lagrangian and Kuhn-Tucker theory to solve optimization problems.
2. Solve quadratic programming problems using specific algorithms such as Beale's method and Wolfe's method.
3. Formulate and solve a variety of deterministic and probabilistic inventory control models to optimize inventory management.
4. Utilize simulation and network analysis techniques to solve complex problems, including shortest route and minimal spanning tree problems.

Course Outcomes: Upon completing this course, students will be able to:

1. Differentiate between convex, concave, and other non-linear functions and explain their relevance in optimization.
2. Apply the Kuhn-Tucker theory to find optimal solutions for non-linear programming problems with inequality constraints.
3. Solve quadratic programming problems using Beale's or Wolfe's method.
4. Calculate the Economic Order Quantity (EOQ) and other key metrics for deterministic inventory models with and without shortages.
5. Analyze and solve probabilistic inventory control models.
6. Utilize the Monte-Carlo simulation technique to model and analyze uncertain systems.
7. Apply algorithms to find the minimal spanning tree and the shortest route in a given network.

Course Contents:

Unit I:(Lecture-21)/30marks

Non-linear Programming, Convex function, Concave function, Pseudo convex function, Quasiconvex function, Quasiconcave function, Lagrangian method, Kuhn Tucker theory, Quadratic programming- Beale's method, Wolfe's method.

Unit II:(Lecture-21)/30marks

Deterministic Inventory Control Models, Economic lot size models, Deterministic models with shortages, Probabilistic Inventory Control models.

Monte-Carlo simulation, Network routing problems, Minimal spanning tree problem, Shortest route problems.

Unit III:(Lecture-14)/20marks

An overview of Crisp Sets, Basics of Fuzzy sets, Developing Membership Functions, Operations on Fuzzy sets, Fuzzy numbers and Fuzzy Arithmetic, Fuzzy logic, Defuzzification, Decision making in fuzzy Environment.

References:

1. **HA Taha**, Operations Research: An Introduction (Eighth edition) PHI Publications.
2. **FS Hiller and GJ Leiberman**, Introduction to Research, McGraw Hills Publication, International Edition, Industrial Engineering series, 1995.

3. **KantiSwarup, PK Gupta and Man Mohan**, Operation Research: Sultan Chand & Sons, New Delhi, 2008.
4. **JK Sharma**, Operations Research: Theory and applications by Trinity 2017.
5. **HS Kasana and KD Kumar**, Introduction to Operations Research: Theory and Applications Springer, 2011.

EMAT-520:(SEMESTER-IV)
[GENERAL RELATIVITY AND COSMOLOGY-II]

Total Marks: 100(External-80, Internal-20)
 Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)
 Examination: 3 Hrs.

Course Learning Objectives: The primary objectives of the course are to:

1. To introduce the foundation of modern cosmology through Einstein's General theory of Relativity.
2. To provide an understanding Mach's principle, Einstein's modified field equations.
3. To explain different cosmological models such as static cosmological models of Einstein, De-Sitter model, Friedmann models, Eddington-Lemaitre models and Steady state models.
4. To develop the ability to compare theoretical models with observation of the actual universe.

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

1. Explain and interpret Mach's principle and Einstein's modified field equations with cosmological term.
2. Derive and analyze Einstein's static model and de-Sitter universe, and evaluate their properties and comparison with actual universe..
3. Solve and discuss Friedmann equations and describe different universe models (open, closed, flat).
4. Calculate critical density, age of the universe, and horizons in cosmology.
5. Differentiate between matter-dominated, radiation-dominated, and steady-state cosmologies.
6. Apply the perfect cosmological principle and evaluate Eddington-Lemaitre model.

Course Contents:

Unit I: (Lecture-21)/30marks

Mach's principle, Einstein modified field equations with cosmological term. Static Cosmological model of Einstein and De-Sitter, their derivation, properties and comparison with the actual universe.

Unit II: (Lecture-21)/30marks

Hubble's law, Cosmological principles, Weyl's postulate. Derivation of RobertsonWalker metric. Hubble and deceleration parameters. Redshift. Redshift versus distance relation. Angular size versus redshift relation and source counts in Robertson-Walker space time.

Unit III: (Lecture-14)/20marks

Friedmann models, Fundamental equations of dynamical cosmology. Critical density. Closed and open Universe. Age of the Universe. Matter dominated era of the universe. Einsteinde-Sitter model. Particle and event horizons. Eddington-Lamaitre models with I-term. Perfect cosmological principle. Steady state cosmology.

References:

1. **H Stephani**, General Relativity: An Introduction to the theory of gravitational field, Cambridge University Press.
2. **AS Eddington**, Mathematical Theory of Relativity, Cambridge University Press.
3. **JV Narlikar**, General Relativity and Cosmology, Macmillan and Co. India Ltd.
4. **R Adlev, M Bazin& M Schiffer**, Introduction to general relativity, McGraw Hill Inc.
5. **BF Shutz**, a first course in general relativity, Cambridge University Press.
6. **S Weinberg**, Gravitation and Cosmology: Principles and applications of the general theory of relativity, Hohn Wiley & Sons. Inc.
7. **JV Narlikar**, Introduction to Cosmology, Cambridge University Press.
8. **RK Sachs and H Wu**, General Relativity for Mathematicians, Springer Verlag.
9. **LD Landu and EM Lifshitz**, The Classical Theory of Fields, Pergamon Press.
10. **JL Synge**, Relativity: The general theory, North Holland Pub. Company.

EMAT-521:(SEMESTER-IV)**[CRYPTOLOGY-II]**

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Understand cryptographic protocols for key exchange, authentication, and secure communication, along with classical and modern cryptosystems.
2. Develop knowledge of elliptic curve cryptography, its efficiency, mathematical foundations, and its comparison with RSA in terms of security and performance.

3. Explore probabilistic methods and information-theoretic principles underlying modern cryptography, with applications to internet security and secure transactions.

Course Outcomes: After the completion of this course students will be able to:

1. Explain and implement cryptographic protocols for key exchange and authentication, including Diffie–Hellman key agreement and mutual authentication schemes.
2. Analyze and apply cryptosystems such as the Rabin Cipher, PGP (Phil Zimmermann), and McEliece Cryptosystem in secure communication.
3. Perform computations with elliptic curves, including point addition, and analyze algorithmic efficiency in elliptic curve cryptography.
4. Evaluate elliptic curve–based cryptosystems (Koblitz curves, Pollard’s Rho attacks, ECC2K-130) and compare ECC with RSA in terms of strength and efficiency.
5. Apply probability theory and information-theoretic concepts such as random variables, weak law of large numbers, and distance measures to cryptographic analysis.
6. Examine applications of information theory in IP security, web security, and secure electronic transactions.

Course Contents:

Unit I:

(Lecture-21)/30marks

Cryptographic Protocols; Key-exchange and Authentication, Diffie-Hellman Key Agreement, Key Exchange and Mutual Authentication; The Rabin Cipher, Phil Zimmermann on PGP, McEliece Cryptosystem.

Unit II:(Lecture-21)/30marks

Elliptic Curve Cryptography; Simplified Elliptic Curve Cryptography, Efficiency of Algorithms, Addition on Elliptic Curves, Koblitz Curves, Integer Factorization and Discrete Logarithm Problems, NIST Primes, Pollard’s Rho Attacks, ECC2K-130 & Iteration Function, ECC Vs RSA.

Unit III: (Lecture-14)/20marks

Probabilities & Information Theory; Finite Probability Spaces and Random Variables, The Weak Law of Large Numbers, Distance Measures, IP Security, Web Security, Secure E-Transactions.

References:

1. **William Stallings:** Cryptography & Network security (Principles & practice), Pearson Education, revised 3rd edition [2003].
2. **Hans Delfs, Helmut Knebl:** Introduction to cryptography; (Principles & Applications), Springer Verlag, revised 3rd Edition, 2002.
3. **Stinson Douglass:** Cryptography: Theory and Practice, CRC Press [1995].
4. **Darrel Hankerson,** Alfred Menezes, Scott Vanstone, Guide to Elliptic Curve Cryptography, Springer-Verlag, New York (2004).
5. **Vandenay S,** A Classical Introduction to Cryptography (Applications for Communications Security); Springer (India) Pvt. Ltd. Akash Deep Building, Barakhamba Road, New Delhi (2009).

EMAT-522:(SEMESTER-IV)

[OPERATOR THEORY-II]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. Grasp the fundamental concepts of spectral measures and spectral integrals and their role in operator theory.
2. Derive many observations when spectrum is regular and develop many relationships of the spectrum of the spectral measure.
3. Analyze the spectral properties of bounded self adjoint linear operators on a Hilbert space.
4. Establish many properties on the sum and product of two positive operators .
5. Explore the theory of unbounded linear operators focusing on their adjoint, spectra, and spectral theorem.
6. Understand and apply unitary operator to find the Cayley's transformation of unbounded self adjoint operator.
7. Comprehend the idea of multiplicative operator for deriving many useful observations.

Course Outcomes: After completion of course the students will be able to:

1. Define and construct spectral measures and spectral integrals, and use them to represent operators.

2. Recognize regular spectral measure and develop many observations on the spectral measure of the spectrum of the spectral measures and its complements.
3. Analyze the spectral properties of bounded self adjoint linear operators, including the positivity and projection properties of their spectra.
4. Compute the Hilbert-adjoint of unbounded linear operator and determine its resolvent set and spectrum.
5. Apply Cayley's transformation to establish a connection between unbounded self adjoint operators and unitary operators.
6. Formulate and prove the spectral theorems for unitary and self adjoint unbounded linear operators.
7. Provide examples on unbounded operators such as multiplication and differentiation operators, and analyze their spectral properties.

Course Contents:

Unit-I:(Lecture-21)/30marks

Spectral measure, Spectral Integrals, Regular spectral measures, Real and Complex measures Complex spectral Integrals, Description of the spectral subspaces, and characterization of Spectral subspaces. The Spectral theorem for bounded Normal operators.

Unit-II:(Lecture-21)/30marks

Spectral properties of bounded self-adjoint linear operators, Positive operators, Projection operators, product of projections, Monotone sequence theorem for bounded self adjoint operators on a complex Hilbert space.

Unit-III:(Lecture-14)/20marks

Unbounded linear operators and their Hilbert-Adjoint operators, Characterization of resolvent of an unbounded self-adjoint operator, Spectrum of a self-adjoint unbounded linear operator, Spectral theorem for unitary and self-adjoint linear operators, Cayley's transformation of an unbounded self- adjoint operator, Multiplication operators and Differentiation operators.

References:

1. **E Kreyszig**, Introductory Functional Analysis with applications, John-Wiley & Sons, New York.

2. **PR Halmos**, Introduction to Hilbert Space and the Theory of Spectral Multiplicity, Second Edition, Chelsea Publishing Co. N.Y. 1957.
3. **N Dunford and JT Schwartz**, Linear operators 3 parts, Inter-science Wiley, New York, 1958-71.
4. **G Bachman and L Narici**, Functional Analysis, Academic Press, New York, 1966.
5. **NL Akhiezer and IM Glazman**, Theory of Linear Operators in Hilbert Spaces, Frederick Unger Pub. Co. N. Y. Vol. I (1961), Vol. II (1963).
6. **PR Halmos**, A Hilbert Problem Book, D. Van Nostrand Company Inc., 1967.

EMAT-523: (SEMESTER-IV)

[ALGEBRAIC CODING THEORY-III]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Learning Objectives

1. To understand various bounds in coding theory and their significance in code efficiency.
2. To study classical bounds such as Hamming, Singleton, Plotkin, and Gilbert–Varshamov bounds.
3. To analyze perfect codes, q-ary Hamming codes, Golay codes, and the role of nonlinear codes.
4. To understand factorization of polynomials over finite fields.
5. To study Berlekamp's algorithm for efficient polynomial factorization.
6. To explore quadratic residue codes, MDS codes, and automorphism groups of codes.
7. To introduce quaternary linear codes over $\mathbb{F}_4$ and their generator matrices.
8. To study Gray maps and binary images of $\mathbb{F}_4$ -codes.
9. To understand $\mathbb{F}_4$ -linearity and nonlinearity of binary codes.

Course Outcomes

1. Students will be able to derive and compare different coding bounds.
2. Students will analyze and identify perfect codes and important code families.
3. Students will evaluate code optimality using bounds like Griesmer and Singleton bounds.
4. Students will be able to factor polynomials using Berlekamp's algorithm.
5. Students will construct and analyze quadratic residue and MDS codes.

6. Students will examine weight distribution and symmetry (automorphism groups) of codes.
7. Students will construct and analyze q -linear codes and their properties.
8. Students will apply the Gray map to obtain binary representations.
9. Students will distinguish between q -linear and nonlinear binary codes.

Course Contents:

Unit-I:

(Lecture-21)/30marks

Bounds in coding theory: lower bounds, sphere-covering bound, Gilbert-Varshamov bound, Hamming bound and perfect codes, q -ary Hamming codes, Golay codes, Singleton bound and MDS codes, Plotkin bound, non-linear codes, Griesmer bound.

Unit-II:

(Lecture-21)/30marks

Factorization of polynomials, Berlekamp's algorithm for factorization of polynomials, Quadratic residue codes, Idempotents of quadratic residue codes, Maximum distance separable (MDS) codes, Weight distribution of MDS codes, Automorphism group of a code.

Unit-III:

(Lecture-14)/20marks

Quaternary linear codes and their generator matrices, weight enumerators, Gray map and binary images of q -codes, q -linearity and q -nonlinearity of some binary linear codes.

References:

1. **E Berlekamp**, Algebraic Coding Theory, McGraw Hill, New York, 1968.
2. **L R Vermani, Chapmann and Hall**, Elements of Algebraic Number Theory, 1996.
3. **C Ling and C Xing**, Coding Theory: A First Course, Cambridge University Press, 2004.
4. **Z X Wan**, Quaternary Codes, World Scientific, Series on Applied Mathematics Volume 8, 1997.
5. **FJ Mac Williams and NJA Sloane**, Error-correcting codes, North Holland Publishing Company, 1977.
6. **WW Peterson and EJ Weldon, Jr.** Error-Correcting codes, MIT press, Cambridge, Massachusetts, 1972.

EMAT-524:(SEMESTER-IV)

[ADVANCED NUMERICAL TECHNIQUES-III]

Total Marks: 100(External-80, Internal-20)

Workload: 4 Lectures (per week) ,Credits: 4 Duration: 14 Weeks (56 Hrs.)

Examination: 3 Hrs.

Course Learning Objectives:

1. To recall Numerical Analysis learnt in the previous Courses.
2. To gain knowledge about the insights of Numerical Analysis.
3. To develop the ability to apply numerical methods to problems.
4. To develop the ability to find numerical solutions to theoretically unsolvable problems.

Course Outcomes:

1. Should have command over Numerical Analysis.
2. Must be able to choose the right numerical method for physical problems.
3. Should be able to generalise other numerical Methods.

Unit-I:(Lecture-21/30 marks)

Numerical Solution to ODE(IVP): Runge-Kutta Methods, Accuracy of One-step Method, Reduction of high order Equations, Solution of simultaneous first order Equation; Boundary Value Problem(BVP): Weighted Residual Methods, Collocation, Least squares, Galerkin, Implementation in Mathematical Software.

Unit-II:

(Lecture-21/30 marks)

Numerical Solution to PDE: Finite Difference Scheme for Hyperbolic Equations, Finite Difference Scheme for Parabolic Equations, Crank-Nicholson Method, Finite Difference Scheme for Elliptic Equations, Error Analysis ,Implementation in Mathematical Software.

Unit-III:

(Lecture-14/20 marks)

Eigen Values and Eigen Vectors: Homogeneous System, The Power Method, Jacobi's Method, Eigen Values of Symmetric Matrices; Polynomial Approximation: Pade Approximation, Implementation in Mathematical Software.

Recommended Books:

- [1] D.V. Griffiths, I.M. Smith, Numerical Methods for Engineers, Oxford University Press
- [2] John H. Mathews, Numerical Methods for Mathematics, Science and Engineering, Prentice Hall of India.
- [3] S.R.K. Iyengar, R.K. Jain, Numerical Methods, New Age International Publishers

RMAT-505:(SEMESTER-IV)

[RESEARCH METHODOLOGY]

Total Marks: 50(External-40, Internal-10)

Workload: 2 Lectures (per week) ,Credits: 2 Duration: 14 Weeks (28 Hrs.)

Examination: 2 Hrs.

Course Learning Objectives:

1. To understand the principles of learning and writing mathematics effectively, including the process of mathematical research.
2. To develop skills in structuring, presenting, and revising mathematical arguments, solutions, and research reports.
3. To explore digital mathematical resources, evaluate journal metrics, and practice ethical standards in research and publication.

Course Outcomes: The course will enable the students to:

1. Explain the goals and principles of mathematical writing and apply them to problem-solving and proof-writing.
2. Avoid common errors in mathematical exposition and improve clarity through revision.
3. Identify a mathematical research problem, conduct a literature survey, and apply appropriate research criteria.
4. Structure and format a mathematical research article and project report according to academic standards.
5. Utilize web-based mathematical resources and critically analyze journal metrics for evaluating research.
6. Demonstrate awareness of research ethics, including plagiarism issues, and use plagiarism detection tools responsibly.

Course Contents:

Unit-I: Foundations of Scientific and Mathematics Research: (Lecturers 14)/Marks: 20

Knowledge and its kinds: perception, reasoning, intuition, and testimony; empirical knowledge, rational knowledge, and intuitive knowledge. Distinction between scientific knowledge and mathematical knowledge. Overview of scientific research: meaning, scope, objectives, and characteristics. Types of research: fundamental, applied, and action research. Introduction to mathematical research: identifying a research topic, conducting a literature survey, and applying research criteria. Principles of mathematical writing: goals, general guidelines, and strategies for avoiding errors. Writing mathematical solutions and proofs; the revision process.

Unit-II: Mathematical Typesetting and Digital Resources: (Lecturers 21)/Marks: 30

Structure and format of a mathematical research article (with illustrative examples) and research project/report writing. Process of publishing research. Presenting mathematics effectively: preparing and delivering a mathematical talk; oral presentation techniques.

Exploring mathematical web resources: MAA, AMS, SIAM, arXiv, and ResearchGate. Journal metrics: Impact Factor (JCR), MCQ, SNIP, SJR, Google Scholar Metrics; limitations and challenges of metrics. Reviews and databases: MathSciNet, zbMATH, Web of Science, Scopus. Research ethics, plagiarism awareness, use of plagiarism detection tools such as URKUND/Ouriginal and Turnitin.

Essential Readings

1. <https://egyankosh.ac.in/bitstream/123456789/8270/1/Unit-5.pdf>
2. https://www.researchgate.net/publication/364352262_Knowledge_and_its_Types
3. **Locharoenrat, Kitsakorn.** *Research Methodologies for Beginners*. 1st ed., Pan Stanford Publishing, 2017. ISBN 978-981-4745-390.
4. Nicholas J. Higham, *Handbook of Writing for the Mathematical Sciences*, SIAM, 1998.
5. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). *How to Write Mathematics*, American Mathematical Society.
6. Bindner, Donald, & Erickson Martin (2011). *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*. CRC Press, Taylor & Francis Group.
7. Committee on Publication Ethics- COPE (<https://publicationethics.org/>)
8. Evaluating Journals using journal metrics;
(<https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874>)
9. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (<https://www.d.umn.edu/~jgallian/goodPPTalk.pdf>). MATH HORIZONS.
10. Lamport, Leslie (2008). *LaTeX, a Document Preparation System*, Pearson. Locharoenrat, Kitsakorn (2017). *Research Methodologies for Beginners*, Pan Stanford. Publishing Pte. Ltd., Singapore.
11. Tantau, Till, Wright, Joseph, & Miletić, Vedran (2023). *The BEAMER class, Use Guide for Version 3.69*. TeX User Group.
(<https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf>)
12. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4).

PMAT-506:(SEMESTER-IV) [RESEARCH PROJECT]

Total Marks: 150

Workload: 6 Lectures (per week) ,Credits: 6 Duration: 14 Weeks (84 Hrs.)

Examination: Dissertation (100), Oral Presentation (30), Questioning/ Viva Voce (20).

Course Learning Objectives:

Contents:

Dissertation/Research Project Report: 100 marks

Research problem identification, Literature Review, methodology, mathematical formulation, interpretation, analysis and formatting of results.

Oral Presentation:

30 marks

Communication Skill, slide organization, time management and clarity of explanation and visual presentation.

Questioning/ Viva Voce:

20 marks

Understanding of the research work, Domain Knowledge, critical thinking and justification and defense of research findings and methodology.