



Mahatma Gandhi University
Purba Medinipur-721628, West Bengal

Syllabus

M.Sc. in Mathematics

PG Curricular Structure for 2 Year PG Programmes (3+2)

Based on NEP 2020

Faculty of Science
(School of Physical Sciences)

Department of Mathematics
MAHATMA GANDHI UNIVERSITY
Purba Medinipur, 721628
West Bengal, India

[w.e.f. Academic Session 2026-2027]

PREAMBLE:

The **Master of Science (M.Sc.) in Mathematics** programme of **Mahatma Gandhi University** has been formulated in accordance with the provisions of the **National Education Policy (NEP) 2020** and the **University Grants Commission (UGC) Curriculum and Credit Framework for Postgraduate Programmes (CCFPG-2024)**. The programme seeks to provide students with advanced knowledge of mathematical sciences through a balanced integration of theoretical foundations, analytical reasoning, computational techniques, and research-oriented learning. It is designed to cultivate intellectual competence, scientific temper, ethical values, and professional excellence, thereby preparing graduates to address the challenges of higher education, research, industry, and society.

The curriculum encompasses a broad spectrum of contemporary areas in both **Pure and Applied Mathematics**, including **Algebra, Analysis, Differential Equations, Topology, Numerical Analysis, Mechanics, Probability, Stochastic Processes, Graph Theory, Number Theory, Fuzzy Mathematics, Soft Computing, Biomathematics** and other emerging domains. The programme provides a rigorous academic foundation while offering a range of discipline-specific elective courses, enabling students to pursue specialized areas of study in accordance with their academic interests and professional aspirations. Opportunities for learning through **MOOC** courses further enhance academic flexibility and encourage multidisciplinary engagement.

A distinguishing feature of the programme is its flexible academic structure, which offers learners the option to pursue one of three curricular pathways during the second year, namely **Course Work, Course Work with Research, and Research**. This flexibility enables students to choose an academic pathway commensurate with their aptitude, career objectives, and research interests. The research-oriented pathways incorporate supervised dissertation and research projects that promote independent inquiry, critical analysis, mathematical modelling, scientific writing, research ethics, and effective dissemination of research outcomes.

In consonance with the holistic vision of **NEP 2020**, the curriculum integrates **Skill Enhancement Courses (SEC), Value Added Courses (VAC), Indian Knowledge System (IKS), Research Methodology, Society Engagement, Field Visits**, and computational training through **MATLAB and Python**. These components are intended to strengthen analytical and computational competencies, promote experiential and interdisciplinary learning, encourage social responsibility, and equip students with the professional skills required for the effective application of mathematical knowledge in diverse contexts.

The programme is structured to develop higher-order cognitive abilities, logical reasoning, quantitative aptitude, and research competence while fostering innovation, creativity, and lifelong learning. It also prepares students for doctoral studies and advanced research, as well as for national-level competitive examinations such as **CSIR-UGC NET, GATE, and SET**. Furthermore, the curriculum equips graduates with the knowledge and professional competencies required for careers in higher education, scientific research, data science, artificial intelligence, operations research, finance, actuarial science, information technology, and other interdisciplinary and emerging fields.

Upon successful completion of the programme, graduates shall possess advanced disciplinary knowledge, computational proficiency, research capability, and the ability to formulate, analyse, and solve complex mathematical problems through logical and scientific approaches. The programme aspires to produce competent mathematicians, researchers, educators, and professionals who can make meaningful contributions to the advancement of mathematical sciences and to the broader socio-economic and technological development of the nation.

Programme Educational Objectives (PEOs):

The Master of Science (M.Sc.) in Mathematics programme is designed to prepare its graduates to achieve the following educational objectives within a few years of programme completion:

PEO1: Advanced Knowledge and Professional Competence:

Apply advanced mathematical knowledge, analytical reasoning, and computational techniques to solve complex theoretical and practical problems in mathematics and allied disciplines.

PEO2: Research and Innovation:

Pursue research, innovation, and higher studies by demonstrating competence in independent inquiry, critical analysis, scientific communication, and ethical research practices.

PEO3: Professional Excellence:

Establish successful careers in higher education, scientific research, industry, government organizations, financial institutions, information technology, data science, and other interdisciplinary fields requiring mathematical expertise.

PEO4: Lifelong Learning:

Engage in lifelong learning and continuous professional development by adapting to emerging developments in mathematics, computational sciences, and interdisciplinary research.

PEO5: Ethical and Social Responsibility: Demonstrate professional ethics, leadership, teamwork, social responsibility, and an appreciation of Indian Knowledge Systems (IKS) while contributing to the advancement of science and society.

PEO6: Leadership and Entrepreneurship:

Demonstrate leadership, innovation, and entrepreneurial abilities by applying mathematical knowledge and computational skills to address contemporary challenges and create sustainable solutions.

Programme Outcomes (POs):

Upon successful completion of the programme, the students shall be able to:

PO1: Comprehensive Mathematical Knowledge:

demonstrate a comprehensive understanding of advanced mathematical concepts, theories, and techniques, and apply them to analyse and solve complex problems in mathematics and related disciplines.

PO2: Problem Solving and Mathematical Modelling:

apply mathematical reasoning, abstraction, modelling techniques, and computational methods to formulate, analyse, and solve complex mathematical and real-world problems.

PO3: Critical Thinking and Analytical Reasoning:

demonstrate critical thinking, analytical ability, logical reasoning, and problem-solving skills for addressing complex mathematical challenges and pursuing advanced studies and professional development.

PO4: Computational Proficiency:

demonstrate proficiency in modern computational tools, programming languages, and mathematical software such as Python and MATLAB for mathematical modelling, numerical computation, simulation, visualization, and interdisciplinary applications.

PO5: Research Skills:

demonstrate competence in mathematical research through independent inquiry, literature review, problem identification, data collection where appropriate, analysis, interpretation, and dissemination of research findings while adhering to research ethics and academic integrity.

PO6: Communication Skills:

communicate mathematical ideas, research findings, and technical information effectively through oral presentations, seminars, scientific writing, dissertations, proposals, reports, and collaborative interactions with both specialist and non-specialist audiences.

PO7: Interdisciplinary Integration:

apply mathematical knowledge and quantitative techniques to interdisciplinary domains by integrating mathematics with computer science, engineering, physical sciences, biological sciences, finance, data science, and other emerging areas.

PO8: Teamwork and Collaboration:

demonstrate the ability to work effectively both independently and collaboratively in academic, professional, and research environments while exhibiting leadership, responsibility, and mutual respect.

PO9: Professional Ethics and Indian Knowledge Systems:

demonstrate professional ethics, academic integrity, social responsibility, and an appreciation of Indian Knowledge Systems (IKS) and their contribution to the development of mathematical thought and scientific knowledge.

PO10: Lifelong Learning:

engage in lifelong learning through continuous acquisition of knowledge and skills, enabling adaptation to emerging developments in mathematics, computational sciences, and interdisciplinary research.

PO11: Employability and Entrepreneurship:

demonstrate professional competence, employability, and entrepreneurial abilities by applying mathematical knowledge and analytical skills in higher education, research, industry, innovation, government organizations, and other professional sectors.

Programme Specific Outcomes (PSOs):

Upon successful completion of the Master of Science (M.Sc.) in Mathematics programme, the students shall be able to:

PSO 1: Advanced Mathematical Knowledge:

demonstrate comprehensive and advanced knowledge of pure and applied mathematics, including **Algebra, Analysis, Topology, Differential Equations, Numerical Analysis, Mechanics, Probability, Graph Theory, Number Theory, Stochastic Processes, Fuzzy Mathematics, Soft Computing**, and other specialized areas.

PSO 2: Analytical and Problem-Solving Skills:

apply logical reasoning, abstract thinking, mathematical modelling, and computational techniques to formulate, analyse, and solve complex mathematical and interdisciplinary problems.

PSO 3: Computational Competence:

utilize modern computational tools, programming languages, and mathematical software such as **MATLAB** and **Python** for numerical computation, simulation, data analysis, visualization, and mathematical modelling.

PSO 4: Research and Innovation:

design and undertake independent research by identifying research problems, reviewing literature, selecting appropriate methodologies, analysing results, and communicating research findings through dissertations, seminars, technical reports, and publications while adhering to research ethics.

PSO 5: Interdisciplinary Applications:

apply mathematical principles and quantitative techniques to interdisciplinary domains such as data science, artificial intelligence, operations research, finance, actuarial science, computer science, engineering, biological sciences, and other emerging fields.

PSO 6: Professional and Ethical Competence:

demonstrate professional ethics, academic integrity, effective communication, teamwork, leadership qualities, and social responsibility while contributing to the advancement of mathematical sciences and sustainable development.

PSO 7: Lifelong Learning:

pursue higher studies, engage in lifelong learning, adapt to emerging developments in mathematical sciences, and continuously enhance professional knowledge and skills to meet evolving societal and technological needs.

PSO 8: Career Readiness:

acquire the knowledge, research competence, and professional skills required for careers in higher education, scientific research, industry, government organizations, financial institutions, information technology and for qualifying national-level competitive examinations such as **CSIR-UGC NET, SET, and GATE**.

Post Graduate Attributes (PGAs):

Upon successful completion of the Master of Science (M.Sc.) in Mathematics programme, the students shall possess the following attributes:

PGA1: Advanced Mathematical Foundation:

Graduates shall possess a comprehensive foundation in advanced mathematical concepts and theories, including **Algebra, Analysis, Topology, Differential Equations, Graph Theory, Numerical Analysis** and related areas, enabling them to pursue higher studies, research, and professional applications.

PGA2: Specialized Knowledge:

Graduates shall acquire advanced knowledge in specialized areas of mathematics through discipline-specific elective courses, enabling them to develop expertise aligned with their academic interests, research aptitude, and career aspirations.

PGA3: Advanced Disciplinary Competence:

Graduates shall demonstrate a thorough understanding of contemporary mathematical theories, methods, and computational techniques required for analysing, modelling, and solving complex mathematical and interdisciplinary problems.

PGA4: Research Competence:

Graduates shall demonstrate the ability to undertake independent research through problem identification, literature review, formulation of research objectives, selection of appropriate methodologies, analysis and interpretation of results, dissertation writing, and dissemination of research findings while adhering to research ethics and academic integrity.

PGA5: Scientific Communication:

Graduates shall communicate mathematical ideas and research outcomes effectively through seminars, technical presentations, dissertations, research articles, reports, and scientific discussions with both specialist and non-specialist audiences.

PGA6: Computational Proficiency:

Graduates shall demonstrate proficiency in modern computational tools and programming environments such as **MATLAB** and **Python** for mathematical computation, numerical analysis, simulation, visualization, modelling, and interdisciplinary applications.

PGA7: Professional Ethics and Indian Knowledge Systems:

Graduates shall uphold professional ethics, academic integrity, environmental consciousness, and social responsibility while appreciating the significance of **Indian Knowledge Systems (IKS)** and their contribution to the development of mathematical sciences and scientific thought.

PGA8: Lifelong Learning and Professional Development:

Graduates shall exhibit intellectual curiosity, adaptability, and a commitment to lifelong learning through continuous updating of knowledge and skills, enabling them to respond effectively to emerging developments in mathematics, computational sciences, and interdisciplinary research.

PGA9: Employability, Leadership and Collaboration:

Graduates shall demonstrate leadership qualities, teamwork, innovation, and professional competence required for careers in higher education, research, industry, government organizations, entrepreneurship, and other interdisciplinary professional domains.



1st Year of PG Curricular Structure for 2 Year PG Programmes (3+2)

Semester	Course Type	Course Code & Level	Name of the Course	Credits (L-T-P)	IA	End Sem. Exam	Full Marks
I	Major/Core Course	PG2 MATH 1011 (400-499)	Abstract Algebra	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 1012 (400-499)	Measure Theory and Integration	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 1013 (400-499)	Classical Mechanics	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 1014 (400-499)	Ordinary Differential Equations	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 1015 (400-499)	Stochastic Process	2 (1-1-0)	05	20	25
	Minor Course	PG2 MATH 1021 (300-399)	Mathematical Reasoning **	4 (3-1-0)	10	40	50
	Skill Enhancement Course	PG2 MATH 1051 (400-499)	Programming in MATLAB	2 (0-0-2)	----	25	25
1st Semester of PG				24			300
II	Major/Core Course	PG2 MATH 2011 (400-499)	Complex Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 2012 (400-499)	Partial Differential Equations	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 2013 (400-499)	Linear Algebra	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 2014 (400-499)	Topology	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 2015 (400-499)	Research Methodology	2 (1-1-0)	05	20	25
	Minor Course	PG2 MATH 2021 (300-399)	Discrete Mathematics **	4 (3-1-0)	10	40	50
	Skill Enhancement Course	PG2 MATH 2051 (400-499)	Programming in Python	2 (0-0-2)	---	25	25
2nd Semester of PG				24			300
Total: 1st Year of PG				48			600

** Students from other disciplines should take this course.

Mathematics students should choose a minor course offered by another department or opt for a course through a MOOC platform.

2nd Year of PG Curricular Structure for 2 Year PG Programmes (3+2)

Structure 1: Course Work

SEM	Course Type	Course Code & Level	Name of the Course	Credits (L-T-P)	IA	End Sem. Exam	Full Marks
III	Major/Core Course	PG2 MATH 3011 (500-599)	Functional Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3012 (500-599)	Advanced Numerical Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3013 (500-599)	Continuum Mechanics	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3014 (500-599)	Discipline Specific Elective-I (Any One)	4 (3-1-0)	10	40	50
			A: Operations Research-I B: Fluid Mechanics –I C: Advanced Algebra-I D: Advanced Topology-I E: Advanced Functional Analysis-I F: MOOC Course				
	Major/Core Course	PG2 MATH 3015 (500-599)	Discipline Specific Elective-II (Any One)	4 (3-1-0)	10	40	50
			A: Operations Research-II B: Fluid Mechanics –II C: Universal Algebra D: Advanced Topology-II E: Advanced Functional Analysis-II F: MOOC Course				
	VAC Course	PG2 MATH 3016 (500-599)	Indian Knowledge System	2 (1-1-0)	05	20	25
	Community Service	PG2 MATH 3041 (500-599)	Community Engagement	2 (0-0-2)	---	25	25
	Compulsory 2-Credit Course		Mahatma Gandhi: Life & Philosophy	The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA			
3rd Semester of PG				24			300
IV	Major/Core Course	PG2 MATH 4011 (500-599)	Fuzzy Mathematics and Soft Computing	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 4012 (500-599)	Mathematical Methods	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 4013 (500-599)	Biomathematics	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 4014 (500-599)	Discipline Specific Elective-III (Any One)	4 (3-1-0)	10	40	50
			A: Operations Research-III B: Fluid Mechanics –III C: Advanced Algebra-II D: Algebraic Topology-I E: Operator Algebra- I F: MOOC Course				
	Major/Core Course	PG2 MATH 4015 (500-599)	Discipline Specific Elective-IV (Any One)	4 (3-1-0)	10	40	50
			A: Operations Research-IV B: Fluid Mechanics –IV C: Category Theory D Algebraic Topology-II E: Operator Algebra- II F: MOOC Course				
	Research Thesis/ Project	PG2 MATH 4032 (500-599)	Dissertation & Field Visit	4 (0-0-4)	----	50	50
4th Semester of PG				24			300
Total: 2nd Year of PG				48			600

Structure 2: Course Work + Research

SEM	Course Type	Course Code & Level	Name of the Course	Credits (L-T-P)	IA	End Sem. Exam	Full Marks
III	Major/Core Course	PG2 MATH 3011 (500-599)	Functional Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3012 (500-599)	Advanced Numerical Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3013 (500-599)	Continuum Mechanics	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3014 (500-599)	Discipline Specific Elective-I (Any One) A: Operations Research-I B: Fluid Mechanics –I C: Advanced Algebra-I D: Advanced Topology-I E: Advanced Functional Analysis-I F: MOOC Course	4 (3-1-0)	10	40	50
	Major/Core Course	PG2 MATH 3015 (500-599)	Discipline Specific Elective-II (Any One) A: Operations Research-II B: Fluid Mechanics –II C: Universal Algebra D: Advanced Topology-II E: Advanced Functional Analysis-II F: MOOC Course	4 (3-1-0)	10	40	50
	VAC Course	PG2 MATH 3016 (500-599)	Indian Knowledge System	2 (1-1-0)	05	20	25
	Community Service	PG2 MATH 3041 (500-599)	Community Engagement	2 (0-0-2)	---	25	25
	Compulsory 2-Credit Course		Mahatma Gandhi: Life & Philosophy	The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA			
3rd Semester of PG				24			300
IV	Research Thesis/ Project	PG2 MATH 4031 (500-599)	Research Thesis/Project	24 (0-0-24)	----	300	300
4th Semester of PG				24			300
Total: 2nd Year of PG				48			600

***Compulsory Course: The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA

##Students satisfying the following criteria will be eligible to undertake this course in fourth semester (**Structure 2: Course work + Research**):

- (i) Minimum CGPA of 7.5 in PG (Upto Semester III)
- (ii) Minimum attendance of 80% in PG (Upto Semester III)

The final decision will be taken by the Department subject to availability and feasibility of the courses.

Structure 3: Research

SEM	Course Type	Course Code & Level	Name of the Course	Credits (L-T-P)	IA	End Sem. Exam	Full Marks
III	VAC Course	PG2 MATH 3016 (500-599)	Indian Knowledge System	2 (1-1-0)	05	20	25
	Research Thesis/Project	PG2 MATH 3031 (500-599)	Research Thesis/Project	20 (0-0-20)	----	250	250
	Community Service	PG2 MATH 3041 (500-599)	Community Engagement	2 (0-0-2)	---	25	25
	Compulsory 2-Credit Course		Mahatma Gandhi: Life & Philosophy	The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA			
3rd Semester of PG				24			300
IV	Research Thesis/Project	PG2 MATH 4031 (500-599)	Research Thesis/Project	24 (0-0-24)	----	300	300
4th Semester of PG				24			300
Total: 2nd Year of PG				48			600

****¹Compulsory Course:** The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA

##Students satisfying the following criteria shall be eligible to undertake this course (**Structure 3: Research**):

- (i) Minimum CGPA of 7.5 in PG (Upto Semester II)
- (ii) Minimum attendance of 80% in PG (Upto Semester II)

The final decision will be taken by the Department subject to availability and feasibility of the courses.

Details of the Courses

Semester-I

PG2 MATH 1011: Abstract Algebra

Full Marks: 50

Course Objectives:

1. To give students a foundation for all future mathematics courses.
2. To explain the fundamentals of algebraic problem-solving methods.
3. To explore the Algebraic structures, Groups, Rings, Ideals, Fields, Homomorphisms etc.
4. To make students aware of the applicability of abstract mathematics in real world problems.

Course Learning Outcomes:

After completion of this course, students will be able to

1. utilize the class equation and Sylow theorems to solve different related problems.
2. identify and analyse different types of algebraic structures such as Solvable groups, Simple groups, Alternate groups to understand and use the fundamental results in Algebra.
3. know in detail about polynomial rings, fundamental properties of finite field extensions and classification of Finite Fields.
4. acquaint with the basic concepts of Galois Theory such as the concepts of normal extensions, fixed field, the fundamental theorem of Galois theory etc.

Syllabus:

Automorphisms and inner automorphisms, conjugacy class equation and consequences, group actions, applications of group actions and generalized Cayley theorem, simple groups, p-groups, Cauchy's theorem, Converse of Lagrange's theorem for finite abelian groups, Sylow's theorems and their applications, classifications of finite groups of order up to 15, normal and subnormal series, composition series, solvable groups and nilpotent groups, Jordan-Hölder theorem and its applications.

Prime and maximal ideals, field of quotient, polynomial rings, divisibility theory in integral domain, Euclidean Domain, Principal Ideal Domain, irreducible and prime element, Unique Factorization Domain, Eisenstein's irreducibility criterion.

Field extension, Algebraic and transcendental extensions, finite extension, algebraically closed field, splitting field, separable extension, impossibility of some constructions by straightedge and compass, finite fields and their properties, normal extension, Galois group of automorphisms, Galois theory, solution of polynomial equations by radicals, insolubility of the general equation of degree 5 (or more) by radicals.

References:

1. David S. Dummit, Richard M. Foote, Abstract Algebra, 3rd edition, John Wiley & Sons, 2003.
2. J. B. Fraleigh, A first course in Abstract algebra, 7th edition, Addison-Wesley, 2003.
3. Joseph A Gallian, Contemporary Abstract Algebra, Cengage Learning India Pvt. Ltd., 2019.
4. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra, Second Edition, Cambridge.
5. T. W. Hungerford, Abstract Algebra, An Introduction, 3rd edition, Brooks/Cole Cengage Learning.
6. D. S. Malik, J. N. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGraw Hill.
7. Herstein, I. N., Topics in Abstract Algebra, Wiley Eastern Limited. Hungerford, T.W., Algebra, Springer.
8. Goldhaber, J.K., Ehrlich, G., Algebra, The Macmillan Company, Collier-Macmillan Limited, London.
9. Jacobson, N., Basic Algebra, I & II, Hindusthan Publishing Corporation, India.
10. Rotman, J.J., The Theory of Groups: An Introduction, Allyn and Bacon, Inc., Boston.

Course Objectives:

1. To familiarize with functions of bounded variations, measure theory etc.
2. To understand the relation between function of bounded variation and absolutely continuous functions, outer measure and general measure, Riemann integral and Riemann-Stieltjes integral, etc.
3. To use Lebesgue monotone and dominated convergence theorems and Fatous' Lemma
4. To explain the situation where the above concepts are applied in other branch of mathematics and higher studies.
5. To extend the concept of outer measure in an abstract space and almost everywhere property of functions and its application

Course Learning Outcomes:

After successful completion of the course the student would be able to

1. verify whether a given subset of $\mathbb{R}$ is measurable or to examine whether a real valued function is a function of bounded variation, absolutely continuous, measurable, Riemann-Stieltjes integrable etc.
2. understand the requirement and the concept of the Bounded variation, measurable sets, measurable function along with its properties
3. demonstrate understanding of the statement and proofs of the different theorems and their applications.
4. determine questions related to different kinds of convergence, convergence in measure and convergence almost everywhere
5. apply the fundamental concepts of measure theory for further study in a range of other fields, e.g. Stochastic calculus, Quantum Theory and Harmonic analysis.

Syllabus:

Functions of Bounded Variation: Definitions, basic properties and geometrical meaning of functions of bounded variation, Differentiation of a function of bounded variation, Representation of an absolutely continuous function by an integral, Total variation, Jordan's theorem.

The Riemann-Stieltjes Integral: The definition of Riemann-Stieltjes integral, Linear properties, Reduction to a Riemann integral, Reduction of a Riemann-Stieltjes integral to a finite sum, Euler's summation formula, Upper and lower integrals, Riemann's condition, Sufficient conditions for the existence of Riemann-Stieltjes integrals.

Lebesgue Measure: Measurable Sets, Concept of Lebesgue function, Inner and outer measure. It's simple properties. Set of measure zero. Cantor set, Borel set and their measurability, non-measurable sets, Lebesgue measure, Measure space.

Measurable function: Definition and it's simple properties, Borel measurable functions, sequence of measurable functions, Statement of Lusin's theorem, Egoroff's theorem. Simple functions and it's properties.

Lebesgue integral on a measurable set: Definition, Basic simple properties, Lebesgue integral of a bounded function over a set of finite measure. Simple properties. Integral of nonnegative measurable functions, General Lebesgue integral. Bounded convergence theorem for a sequence of Lebesgue integrable function, Fatou's lemma. Classical Lebesgue dominated convergence theorem. Monotone convergence theorem, Relation between Lebesgue integral and Riemann integral.

References:

1. W. Rudin., Principal of mathematical Analysis, McGraw-Hill Publishing Company, 2006.
2. Robert G. Bartle., The elements of Real Analysis, Wiley, New York, 1964.
3. T. M. Apostol., Mathematical Analysis, 2nd edition, Narosa Book Distributors Pvt Ltd-New Delhi, 1996.
4. Ghorpade & Limyae., A Course in Multivariable Calculus and Analysis, 2nd edition, Springer, 2009.
5. Ajit Kumar, S. Kumaresan. A Basic Course in Real Analysis, 1st edition, CRC press, 2014.
6. G. De Barra., Introduction to Measure Theory, 3rd edition, Van Nostrand Reinhold Company Ltd, 1974.
7. Inder K. Rana., An Introduction to Measure and Integration, 2nd edition, Narosa, 2007.

Course Objectives:

1. To develop a thorough understanding of constrained motion, generalized coordinates, Lagrangian and Hamiltonian formulations of classical mechanics.
2. To apply variational principles and the calculus of variations to derive equations of motion and solve physical problems.
3. To understand canonical transformations, Poisson brackets, Hamilton–Jacobi theory, and the dynamics of rigid bodies.
4. To acquire knowledge of the fundamentals of special relativity and its applications in classical mechanics.

Course Learning Outcomes:

After completion of this course, students will be able to

1. acquire a deep knowledge of different types of principles of motion.
2. apply the equations of motion to solve analytically the problems of motion
3. apply the Hamilton's principle for deriving the equations of motion of a system
4. analyze constrained dynamical systems using generalized coordinates, D'Alembert's principle, Lagrange's equations, and conservation laws.
5. apply Hamiltonian mechanics, variational principles, Noether's theorem, and the calculus of variations to formulate and solve problems in classical mechanics.
6. solve advanced problems involving canonical transformations, Poisson brackets, Hamilton–Jacobi equations, and the motion of rigid bodies.
7. explain and apply the principles of special relativity, including Lorentz transformations and relativistic dynamics, to analyze physical systems.

Syllabus:

Constrained Motion: Constraints and its classification, Constraint forces, Dynamical system, Generalized coordinates, Classification of dynamical system, Degrees of freedom, D'Alembert's Principle, Lagrange's equation of motion of first kind, Principle of virtual work. Plane pendulum and spherical pendulum. Cyclic co-ordinates. Coriolis force.

Lagrangian Mechanics and Hamiltonian Mechanics: Lagrange's equation of motion, Lagrange's equation of motion for a nonholonomic dynamical system, Velocity dependent potential, Dissipative forces, Rayleigh's dissipation function, Physical interpretation of the dissipative function. Generalised momenta and energy, Ignorable coordinates, Noether's theorem, Symmetry and conservation laws, Routhian process for the ignorance of coordinates; Hamiltonian of a dynamical system, Infinitesimal transformations, Space-time transformations. Conservation theorem for angular momentum, Condition of Invariance, Legendre dual transformations, Hamiltonian of a system; Hamilton's equations of motion, Applications of Hamiltonian mechanics.

Variational Principles and Calculus of Variations: Variation of a functional, Hamilton's principle, Establishment of Hamilton's principle from D'Alembert's principle, Deduction of Lagrange's equations of motion from Hamilton's principle, Deduction of Hamilton's equations of motion from Hamilton's principle, Extended Hamilton's principle, Deduction of Lagrange's equations of motion for non-conservative dynamical system, Principle of least action, Brachistochrone problem, Euler-Lagrange equation, Applications of Euler-Lagrange equation, Isoperimetric problems.

Canonical Transformations and Brackets: Aspects of canonical transformation, generating function, Principal forms of generating function, Condition for canonicity, Contact transformation. Liouville's theorem, Poisson brackets, Poisson theorem, Hamilton's equations of motion in terms of Poisson's brackets, Lagrange brackets, Properties of Poisson brackets, Constants of the motion, Hamilton-Jacobi equation.

Motion of a Rigid Body: Rotating coordinate system, Motion of a system of particles, Euler angles, Linear and angular momentum of a rigid body, Kinetic energy of a rigid body, Equation of motion of a

rigid body, Euler's equations of motion of a rigid body about a fixed point and Euler's equations of motion of a rigid body about a fixed axis, Motion of a top, Steady motion of a top, Stability of top motion.

Special theory of relativity in Classical Mechanics: Postulates of special relativity, Applications of Classical Mechanics in Special Theory of Relativity: Lorentz transformation, Applications of Lorentz transformation, Velocity and acceleration in relativistic mechanics, Force and energy in relativistic mechanics.

Texts / References:

1. H. Goldstein, *Classical Mechanics*, Addison-Wesley, Cambridge, 1950.
2. A. S. Gupta, *Calculus of Variations with Applications*, Prentice-Hall of India, New Delhi, 2005.
3. B. D. Gupta and S. Prakash, *Classical Mechanics*, KedarNath Ram Nath, Meerut, 1985.
4. T.W.B. Kibble, *Classical Mechanics*, Orient Longman, London, 1985.
5. N. C. Rana and P. S. Joag, *Classical Mechanics*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004.
6. V. B. Bhatia, *Classical Mechanics with Introduction to Nonlinear Oscillation and Chaos*, Narosa Publishing House, 1997.
7. E. T. Whittaker, *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies*, Cambridge University Press, 1993.
8. A. K. Raychaudhuri, *Classical Mechanics-A Course of Lectures*, Oxford University Press, Calcutta, 1983.
9. M. R. Spiegel, *Theoretical Mechanics*, Schaum Series, New York, 1967.
10. K. R. Symon, *Mechanics*, Addison-Wesley Publ. Co., Inc., Massachusetts, 1971.
11. R. G. Takwale and S. Puranik, *Introduction to Classical Mechanics*, Tata McGraw-Hill Publ. Co. Ltd., New Delhi, 1980.

PG2 MATH 1014: Ordinary Differential Equations

Full Marks:50

Course Objectives:

1. To provide knowledge of ordinary differential equations required for practicing scientific problems
2. To identify ordinary and singular points of ordinary differential equations
3. To acquire knowledge about greens functions and applications to boundary value problem
4. To find series solutions of Hermite equation, Legendre equation and Bessel's equation

Course Learning Outcomes:

After completion of this course, students will be able to

1. understand the properties of eigenvalues and eigen functions that will be useful in studying Mathematical physics
2. apply ideas of phase plane analysis and stability in dynamical systems or mathematical biology
3. utilize the concept of special functions in continuum mechanics or theoretical physics
4. solve and analyse differential equations arising in different real-life problems

Syllabus:

First-order Ordinary Differential Equations: Existence and uniqueness theorems, Continuous dependence on initial conditions, simple illustrations, Maximal interval of existence of solution, Maximal Gronwall's inequality, Peano's and Picard's theorems (statements only). Linear systems, General theory of homogenous and non-homogeneous linear ODEs.

Second Order Linear Ordinary Differential Equations: Ordinary and singular points, regular singular points, Fuch's theorem (Statement only), series solution about an ordinary point with examples, Regular singularity, series solution about regular singular point with examples, Frobenius Method, Special functions.

Boundary Value Problems: Construction of two-point boundary value problems, Green's functions, construction of Green's functions for both homogeneous and nonhomogeneous boundary conditions, application to Boundary Value Problems, eigenvalues, eigenfunctions and their applications.

Special Functions: Legendre polynomial, Legendre functions of first kind and second kind, Laplace integral, Generating function, Rodrigue's formula, Recurrence relations, orthogonal properties of Legendre polynomials, Series solution of Bessel equation, Bessel function, Generating function, Recurrence relations, Integral representations of Bessel's functions, asymptotic expansion of Bessel functions, Hermite polynomials, Recurrence relations, Properties.

References:

1. E. A. Coddington and Levinson – *Theory of Ordinary Differential Equations* [TMH].
2. R.P. Agarwal & R. C. Gupta – *Essentials of Ordinary Differential Equations* [MGH]
3. G.F. Simmons: *Differential Equations*, TMH Edition, New Delhi, 1974.
4. S.L. Ross: *Differential Equations* (3rd edition), John Wiley & Sons, New York, 1984.
5. J. C. Burkill – *The Theory of Ordinary Differential Equations* [Oliver & Boyd, London].
6. G. Birkhoff & G. Rota - *Ordinary Differential Equation* [Ginn].
7. E. D. Rainville – *Special Functions* [Macmillan].
8. I. Stackgold- *Green's Functions and Boundary Value Problems*. 3rd edition (Wiley, 2011).
9. I. N. Sneddon - *Special Functions of mathematical Physics & Chemistry* [Oliver & Boyd, London].
10. N. N. Lebedev - *Special Functions and Their Applications* [PH].

PG2 MATH 1015: Stochastic Process

Full Marks: 25

Course Objectives:

1. To introduce the fundamental concepts, classifications, and properties of stochastic processes and Markov chains.
2. To develop an understanding of recurrent, transient, branching, birth–death, and random-walk processes.
3. To study continuous-time Markov processes and Poisson processes.
4. To develop skills in analyzing stochastic models such as Gambler's Ruin and related applications.
5. To introduce multivariate statistical techniques including correlation analysis, PCA, discriminant analysis, and cluster analysis.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. understand and classify stochastic processes and Markov chains.
2. analyze recurrent, transient, null and positive recurrent states.
3. apply random walk, Gambler's Ruin, branching and birth–death models.
4. analyze continuous-time Markov processes and Poisson processes.
5. apply multivariate statistical techniques such as PCA, discriminant and cluster analysis.

Syllabus:

Stochastic Process: Concept and classification, Definition of a chain, Markov property, Markov chain with finite and countable state space, Classification of states, Recurrent and Transient states, Null recurrent and Positive recurrent states, Mean Ergodic Theorem, Random walk and Gambler's ruin chain, Branching chain, Birth – and – Death chain, Probability of ultimate ruin in a Gambler's ruin chain, Expected duration

of a Gambler's ruin chain, Markov processes in continuous time, Birth and Death process, Pure Birth process, Poisson process.

Partial and multiple correlation coefficients, Principal component analysis, Discriminant analysis, Cluster analysis, Advanced theory of linear estimation.

References:

1. Samuel Karlin and Howard E. Taylor, A First Course in Stochastic Process, Academic Press.
2. Hoel, Port and Stone, Introduction to Stochastic Process, Waveland Press.
3. K. L. Chung: Elementary Probability Theory and Stochastic Process
4. A.M. Goon, M.K. Gupta & B. Dasgupta, Fundamentals of Statistics, Vol. 1 & 2, Calcutta: The World Press Private Ltd., 1968.
5. J. Medhi, Stochastic Process, New Age International Publisher, 2ed, 1984.
6. S. K. Srinivasan and K.M. Mehata: Stochastic Process
7. Suddhendu Biswas, G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011

PG2 MATH 1021: Mathematical Reasoning

Full Marks: 50

Course Objectives:

1. Develop a fundamental understanding of sets, functions, relations, cardinality, countability, and mathematical induction.
2. Develop students' mathematical reasoning and aptitude through problem-solving involving series, codes, relationships, ratios, percentages, averages, profit and loss, time and distance, and interest.
3. Develop the ability to understand and evaluate logical arguments, including deductive and inductive reasoning, propositions, fallacies, analogies, and Venn diagrams.
4. Introduce students to Indian logic and the Pramanas, including perception, inference, comparison, verbal testimony, implication, and non-apprehension.
5. Develop skills in data collection, classification, graphical representation, and interpretation of quantitative and qualitative data.

Course Learning Outcomes:

After completing the course, students will be able to:

1. explain and apply the fundamental concepts of sets, functions, relations, cardinality, countability, and mathematical induction.
2. solve problems using appropriate mathematical reasoning and aptitude techniques, including series, ratios, percentages, averages, profit and loss, and time-distance calculations.
3. analyze and evaluate deductive and inductive arguments using appropriate logical principles, Venn diagrams, and concepts of fallacies.
4. explain and apply the basic concepts of Indian logic and different Pramanas, including inference and its associated fallacies.
5. organize, represent, analyze, and interpret quantitative and qualitative data using tables, charts, graphs, and other suitable methods.

Syllabus:

Basics of set theory:

Sets, functions, relations, countability, cardinality. Mathematical induction, Principle of inclusion and exclusion.

Mathematical reasoning and aptitude:

Types of reasoning. Number series, Letter series, Codes and Relationships. Mathematical Aptitude (Fraction, Time & Distance, Ratio, Proportion and Percentage, Profit and Loss, Interest and Discounting, Averages etc.).

Logical Reasoning:

Understanding the structure of arguments: argument forms, structure of categorical propositions, Mood and Figure, Formal and Informal fallacies, Uses of language, Connotations and denotations of terms, Classical square of opposition. Evaluating and distinguishing deductive and inductive reasoning. Analogies.

Venn diagram: Simple and multiple use for establishing validity of arguments.

Indian Logic: Means of knowledge.

Pramanas: Pratyaksha (Perception), Anumana (Inference), Upamana (Comparison), Shabda (Verbal testimony), Arthapatti (Implication) and Anupalabdhi (Non-apprehension).

Structure and kinds of Anumana (inference), Vyapti (invariable relation), Hetvabhasas (fallacies of inference).

Data interpretation:

Sources, acquisition and classification of data. Quantitative and qualitative data.

Graphical representation (Bar-chart, Histograms, Pie-chart, Table-chart and Line-chart) and mapping of data. Data interpretation. Data and governance.

Texts / References:

1. Seymour Lipschutz: Schaum's Outline of Set Theory and Related Topics
2. Kenneth H. Rosen: Discrete Mathematics and Its Applications
3. Irving M. Copi, Carl Cohen & Kenneth McMahon: Introduction to Logic
4. C. D. Sharma: A Critical Survey of Indian Philosophy
5. B. K. Matilal: Logic, Language and Reality: Indian Philosophy and Contemporary Issues
6. KVS Madaan: UGC NET Paper 1: Teaching and Research Aptitude

PG2 MATH 1041: Programming in MATLAB

Full Marks: 25

Course Objectives:

1. To understand the basic structure of MATLAB programming language
2. To learn the use of arrays, functions and matrix manipulation
3. To acquire skills of plotting graphs using MATLAB
4. To acquire problem solving skills of various mathematical problems

Course Learning Outcomes:

After completion of this course, students will be able to

1. demonstrate proficiency in MATLAB programming by using variables, data types, arrays, matrices, control statements, scripts, and functions.
2. perform matrix operations, solve systems of linear equations, compute eigenvalues, singular values, and apply built-in MATLAB functions for numerical linear algebra.
3. generate and customize two-dimensional graphical plots, visualize mathematical data, annotate figures, and export publication-quality graphs.
4. develop efficient MATLAB programs using user-defined functions, vectorization techniques, and pre-allocation for solving mathematical and engineering problems.

Syllabus:

Programming in MATLAB: The MATLAB workspace, data types, variables, assignment statements, arrays, sets, matrices, string, time, date, cell arrays and structures, introduction to M – file scripts, input and output functions, conditional control statements, loop control statements, break, continue and return statements.

Working with matrix: Generating matrix, Concatenation, Deleting rows and columns. Symmetric matrix, matrix multiplication, Test the matrix for singularity, magic matrix. Matrix analysis using function: norm, normest, rank, det, trace, null, orth, rref, subspace, inv, expm, logm, sqrtm, funm.

Array: Addition, Subtraction, Element-by-element multiplication, Element-by-element division, Element-by-element left division, Element-by-element power. Multi-dimensional Arrays, Cell Arrays, Characters and Text in array.

Graph Plotting: Plotting Process, creating a Graph, Graph Components, Figure Tools, Arranging Graphs Within a Figure, choosing a Type of Graph to Plot, Editing Plots, Plotting Two Variables with Plotting Tools, Changing the Appearance of Lines and Markers, Adding More Data to the Graph, Changing the Type of Graph, Modifying the Graph Data Source, Annotating Graphs for Presentation, Exporting the Graph.

Using Basic Plotting Functions: Creating a Plot, Plotting Multiple Data Sets in One Graph, Specifying Line Styles and Colors, Plotting Lines and Markers, Graphing Imaginary and Complex Data, Adding Plots to an Existing Graph, Figure Windows, Displaying Multiple Plots in One Figure, Controlling the Axes, Adding Axis Labels and Titles, Saving Figures.

Programming: Conditional Control – if, else, switch, Loop Control – for, while, continue, break, Error Control – try, catch, Program Termination – return.

Scripts and Functions: Scripts, Functions, Types of Functions, Global Variables, Passing String Arguments to Functions, The eval Function, Function Handles, Function Functions, Vectorization, Pre allocation.

Linear Algebra: Systems of Linear Equations, Inverses and Determinants, Factorizations, Powers and Exponentials, Eigen values, Singular Values.

Polynomials: Polynomial functions in the MATLAB® environment, Representing Polynomials, Evaluating Polynomials, Roots, Derivatives, Convolution, Partial Fraction Expansions, Polynomial Curve Fitting, Characteristic Polynomials.

Texts / References:

1. Gilat A. MATLAB: an Introduction with Applications. New York: Wiley; 2008.
 2. Palm III WJ. Introduction to MATLAB for Engineers. New York: McGraw-Hill; 2011.
 3. Chapman SJ. MATLAB programming with applications for engineers. Cengage Learning; 2012.
 4. Lopez C. MATLAB programming for numerical analysis. Apress; 2014.
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PG2 MATH 2011: Complex Analysis

Full Marks: 50

Course Objectives:

1. To study the topology of the complex plane.
2. To get knowledge of complex integrations, maximum modulus principle and basic idea of analytic continuation.
3. To understand the behaviour of critical points
4. To study the zeros of analytic functions and the related theorems
5. To understand spaces of continuous functions, analytic functions and meromorphic functions.

Course Learning Outcomes:

After completion of this course, students will be able to

1. visualize the complex plane and the extended complex plane
2. identify the zeros and critical points of different analytic functions
3. integrate complex valued functions along a curve and find the Laurent series of certain functions.
4. apply Schwarz's lemma in the geometry of unit disc.
5. apply Hurwitz's theorem, Rouché's theorem, Open Mapping theorem, Inverse and Implicit Function theorems, Riemann mapping theorem.

Syllabus:

Analytic functions, Zeroes of Analytic functions, Cauchy-Goursat Theorem, Homotopy version of Cauchy's theorem, Morera's theorem, uniqueness and maximum principle and its applications.

Singularity and its classification, singularity at infinity, behaviour of function near isolated singularity, Riemann's theorem, limit points of zeroes and poles, Casorati – Weierstrass's theorem, multivalued functions – branch point, idea of winding number, Analytic continuation, Monodromy theorem.

Residue at a finite point, Residue at Infinity, the residue theorem, integral over the real axis, improper integrals and principal values, integrands with branch points, Principle of the argument, Rouché's theorem, open mapping theorem, deformation of contours, Schwarz's lemma.

Conformal mapping, bilinear transformation, harmonic functions and mappings, the Schwarz – Christoffel transformation, Hurwitz polynomials and positive functions, Inverse mappings and univalent functions, Global mapping theorems, the Riemann mapping theorem.

Convergence of sequences, convergence of series, Formulas of Parseval, Schwarz and Poisson, Asymptotic series.

References:

1. Complex Analysis, T W Gamelin, Springer.
2. Real and Complex Analysis, W. Rudin, Mc Graw Hill Private Ltd.
3. Complex Analysis: The Geometric Viewpoint, S G Krantz, JSTOR
4. Complex Variable and Applications, J. W. Brown and R. V. Churchill, 8th Edition, McGraw Hill.
5. Foundations of Complex Analysis, S. Ponnusamy, Narosa, 1995.
6. Complex Variables, N. Levinson and R. M. Redheffer, McGraw Hill Education (India) Private Limited, 2015

Course Objectives:

1. To learn analytical methods for solving PDEs, including Charpit's method, Jacobi's method, the method of characteristics, and separation of variables.
2. To understand the analytic methods for solving hyperbolic, elliptic and parabolic type partial differential equations
3. To study the mathematical theory of elliptic, parabolic, and hyperbolic equations, including existence, uniqueness, and stability of solutions.
4. To understand boundary value and initial value problems associated with Laplace, Poisson, heat, and wave equations.
5. To apply PDE techniques to solve mathematical models arising in physics, engineering, and other applied sciences.

Course Learning Outcomes:

After completion of this course, students will be able to

1. classify first-order and second-order partial differential equations and solve them using appropriate analytical methods.
2. apply Charpit's method, Jacobi's method, the method of characteristics, and Cauchy's method to obtain solutions of first-order PDEs.
3. analyze elliptic, parabolic, and hyperbolic equations, including well-posedness, existence, uniqueness, and stability of solutions.
4. solve classical boundary value and initial value problems involving Laplace, Poisson, heat, and wave equations using separation of variables, Green's functions, and other analytical techniques.
5. interpret the physical significance of PDE models and apply them to problems in heat conduction, wave propagation, and potential theory.
6. demonstrate the ability to formulate and solve advanced mathematical problems from allied branches of science and engineering.

Syllabus:

First Order Partial Differential Equations: First order PDE, characteristics of a linear first order PDE, Charpit's method, Jacobi's method, Integral surfaces, Method of characteristics, Monge cone, Characteristic strip, Cauchy's problem. Semi-linear and quasi-linear equations in two-independent variables, general solution, complete integral and singular solution of PDE, solution of PDE by Cauchy's method of characteristics, Charpit's method, second order linear PDE, Adjoint and self-adjoint equations, Reduction of equations in two independent variables to canonical forms, Classifications, well – posed and ill – posed problems.

Second Order Partial Differential Equations: Cauchy problem for linear partial differential equations: Basic concepts; Properties of linear PDE of order M in m variables; Cauchy problem; Solution criteria for second order PDE in two variables; Riemann method for solving Cauchy problem for linear hyperbolic PDE. Occurrence of elliptic equation, Fundamental solution of Laplace's equations in two variables, Poisson Equations, Origin and physical descriptions of Laplace and Poisson equations, maximum and minimum principles, uniqueness of solutions, Harmonic function, Characterization of harmonic function by their mean value property, Existence, Uniqueness and Continuous dependence of solutions, Method of separation of variables for the solutions of Laplace's equations, Dirichlet's and Neumann's problems, Existence, uniqueness and stability of solutions of Dirichlet's, Neumann's and Robin problems, Dirichlet principle; Green's function for Dirichlet's problem of Laplace equation – properties, Poisson's general solution, Method of images, Method of conformal mapping (two-dimensional) Occurrence of Hyperbolic equation, Equation of vibration of a string, Existence,

Uniqueness and continuous dependence of the solution on the initial conditions, D'Alembert's solution for the vibration of an infinite string, Domain of dependence, Method of separation of variables, higher dimensional wave equations, Occurrence of parabolic equation, Heat equation - Heat conduction problem for an infinite rod – Heat conduction in a finite rod - existence and uniqueness of the solution.

References:

1. I. N. Sneddon, *Elements of Partial Differential Equations*, Dover, 2006.
2. T. Amarnath, *An Elementary Course in Partial Differential Equations*, 2nd edition, Jones and Bartlett, 2011.
3. L. C. Evans, *Partial Differential Equations*, 2nd edition, American Mathematical Society, 2010.
4. P. Phoolan Prasad & R. Ravindran, *Partial Differential Equations*, Wiley, 1984.

PG2 MATH 2013: Linear Algebra

Full Marks: 50

Course Objectives

1. To develop a rigorous understanding of advanced concepts in linear algebra, including linear transformations, dual spaces, and matrix representations.
2. To study canonical forms, invariant subspaces, eigenvalue problems, and matrix decompositions.
3. To analyse inner product spaces, orthogonal and unitary operators, and spectral theory.
4. To understand quadratic forms, bilinear forms, and generalized inverses of matrices.
5. To apply advanced linear algebra techniques to solve theoretical and computational problems in mathematics and related disciplines.
6. To develop the understanding of concepts through examples, counter examples and problems.
7. To orient the students with tools and techniques of Linear Algebra.
8. To develop a skill to solve problems.

Course Learning Outcomes:

After completion of the course the learners should be able to

1. explain and apply the concepts of dual spaces, dual bases, linear functionals, and linear transformations.
2. check whether given matrix or transformation is diagonalizable or not.
3. determine characteristic and minimal polynomials, compute canonical forms, and analyse invariant subspaces of linear operators.
4. determine the orthogonal basis in an inner product space.
5. solve problems involving inner product spaces, orthogonal projections, adjoint operators, normal operators, and spectral theorems.
6. analyse and classify quadratic forms and bilinear forms, and study groups preserving bilinear forms.
7. compute generalized inverses, including the Moore–Penrose inverse, and apply them to solve matrix equations and related problems.
8. demonstrate the ability to use advanced linear algebra concepts in mathematical modelling, research, and interdisciplinary applications.

Syllabus:

Linear functional, dual space, dual basis, double dual and related results, transpose of a linear transformation and matrix representation of the transpose of a linear transformation.

Characteristic and minimal polynomial, similarity of linear operators, invariant sub-spaces, primary decomposition theorem, diagonalizable form, triangular form, idempotent operator, nilpotent operator, Simultaneous diagonalization, Simultaneous triangulation, generalized eigenvectors, Jordan blocks and Jordan canonical form, rational canonical form.

Linear transformations on inner product spaces, adjoint of a linear operator, matrix representation of the adjoint, normal and self-adjoint operators, unitary and orthogonal operators and their matrices, orthogonal projections, spectral theorems and consequences.

Quadratic forms, Reduction and classifications of quadratic forms, Bilinear forms, Symmetric and skew-symmetric bilinear forms, Groups preserving bilinear forms.

Generalized inverse of a matrix, Pseudo inverse, Moore-Penrose inverse and related results.

References:

1. Kenneth Hoffman and Ray Kunze, Linear Algebra, Prentice-Hall International, 2010.
2. P. Lax, Linear Algebra, John Wiley & Sons, 1997.
3. H. E. Rose, Linear Algebra, Birkhauser, 2002.
4. S. Lang, Algebra, 3rd Edition, Springer (India), 2004.
5. Roger A. Horn, Charles R. Johnson., Matrix Analysis, 2nd edition, CUP, 2013.
6. Sheldon Axler., Linear Algebra Done Right, 3rd edition, Springer, 2015.
7. N. Jacobson., Basic algebra I, 2nd edition, Dover Publications, 2012.
8. N. Jacobson., Basic algebra II, 2nd edition, Dover Publications, 2012.
9. T. S. Blyth., Module Theory: An approach to Linear Algebra., Clarendon Press, Oxford, 1977.
10. S. Roman, Advanced Linear Algebra, 3rd edition, Springer, 2007. 11. J. H. Kwak and S. Hong, Linear Algebra, 2nd edition, Birkhauser, 2006.

PG2 MATH 2014: Topology

Full Marks: 50

Course Objectives:

1. To introduce basic concepts of point set topology, derived concepts, basis and sub-basis for a topology and order topology.
2. To explain the idea of continuity, topological equivalence and define homeomorphisms.
3. To study the notions of connectedness, path connectedness, local connectedness, local path connectedness, convergence, compactness of spaces.
4. To familiarize with the concept of countability and separation axioms etc.

Course Learning Outcomes:

After successful completion of the course the student would be able to

1. demonstrate knowledge and understanding of concepts such as open and closed sets, interior, closure and boundary.
2. check whether a collection of subsets is a basis for a given topological space or not, and determine the topology generated by a given basis.
3. understand separation axioms and find their differences.

Syllabus:

Topological spaces and Continuous Functions: Topology on a set, Examples of Topologies (Topological Spaces): Discrete Topology, Indiscrete Topology, Finite Complement Topology, Countable Complement Topology, Topologies on the Real Line, Finer and Coarser Topologies, Basis and Sub basis for a topology, Product topology on $X \times Y$, Subspace Topology, Metric topology, Order Topology. Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set, Kuratowski closure operator and the generated topology.

Continuous Functions, Rules for Constructing Continuous Functions: Inclusion Map, Composition, by restricting the domain, by restricting/expanding the range, Pasting Lemma, Open maps, Closed maps and Homeomorphisms. Product Topology: Sub basis for product Topology defined by Projection Maps, Box Topology, Quotient Topology, Metric Topology.

Connectedness and Compactness: Connected and Path connected spaces, Connected subspaces of the real line, Components and local connectedness, Compact spaces, Heine-Borel Theorem, Local-compactness, Tychonoff's Theorem on compact spaces.

Separation Axioms: 1st and 2nd countable spaces, Hausdorff spaces, Regularity, Complete irregularity, normality, Hausdorff spaces, Regularity, Complete Regularity, Normality, Urysohn Lemma, Tychonoff embedding and Urysohn Metrization Theorem, Tietze Extension Theorem (Statement Only).

References:

1. J. R. Munkres, Topology, 2nd Ed., Pearson Education (India), 2000.
2. M. A. Armstrong, Basic Topology, Springer (India), 1983.
3. K. D. Joshi, Introduction to General Topology, New Age International Private Limited, New Delhi, 2014.
4. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York, 1963.
5. W. J. Thron – Topological Structures.
6. K. D. Joshi – Introduction to General Topology.
7. J. L. Kelly – General Topology.
8. G. F. Simmons – Introduction to Topology & Modern Analysis

PG2 MATH 2015: Research Methodology

Full Marks: 25

Course Objectives:

1. To introduce the fundamental concepts, characteristics, and types of research, and to distinguish between research methods and methodology.
2. To develop the ability to identify and formulate research problems, review literature critically, and frame appropriate research questions and hypotheses.
3. To equip students with knowledge of research design, data collection methods, sampling techniques, and proposal writing skills.
4. To cultivate ethical awareness in research by emphasizing research integrity, academic honesty, and responsible conduct in data handling and publication.
5. To familiarize students with research metrics, publication ethics, and modern tools for evaluating the quality and impact of research.

Course Learning Outcomes:

After completion of this course, students will be able to

1. understand the fundamental concepts of research, including types of research, research problems, hypothesis formulation, and the research process.
2. apply research design principles, data collection methods, and sampling techniques to conduct effective and systematic research.
3. develop skills to review literature, write research proposals, and integrate research findings into coherent reports or projects.
4. demonstrate knowledge of research ethics, publication ethics, privacy and confidentiality, and evaluate research impact using appropriate metrics.

Syllabus:

Basics of Research: Definition, importance, and characteristics of research, types of research – basic, applied, qualitative, quantitative, descriptive, analytical, experimental.

Research Problem and Literature Review: Research questions and objectives; survey of literature – importance, sources, and research gaps.

Hypothesis and Research Process: Meaning, role and types of hypotheses, research process

Research Design and Plan: Meaning, significance, and types of research design; developing a research plan

Data and Data Collection: Primary and secondary data; sources of data; methods of data collection

Sampling Methods: Concept of sampling and its different methods

Reviewing and Proposal Writing: Importance of reviewing, objectives, methodology, findings; How to write a research proposal.

Introduction to Ethics: Definition, nature, and scope of ethics; different branches of ethics; importance of ethics in research and academic life.

Research Ethics: Responsibilities of researchers towards fellow researchers, public, and academic community; concept of academic integrity.

Ethical Judgments and Scientific Misconduct: Ethical judgments in research: scientific misconduct – falsification, fabrication, plagiarism; redundant, duplicate, and overlapping publications; selective reporting; misrepresentation of data.

Privacy and Confidentiality: Concepts of privacy, confidentiality, anonymity in research; ethical handling of sensitive data.

Publication Ethics: Definition and importance of publication ethics; publication misconduct; conflict of interest; authorship issues; responsibilities of editors, reviewers, and publishers.

Research Metrics: Concept of research metrics; impact factor, h-index, g-index, i10-index; its roles in research.

References:

1. Kothari, C. R., & Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
2. S. G. Krantz, *A Primer of Mathematical Writing*, Second Edition, American Mathematical Society, 2017.
3. N. J. Higham, *Handbook of Writing for the Mathematical Sciences*, Society for Industrial and Applied Mathematics, 1998.
4. Kumar, R. (2019). *Research Methodology: A Step-by-Step Guide for Beginners* (5th ed.). Sage Publications.
5. Resnik, D. B. (2020). *The Ethics of Research with Human Subjects: Protecting People*, Advancing Science, Promoting Trust. Springer.
6. Shamoo, A. E., & Resnik, D. B. (2015). *Responsible Conduct of Research* (3rd ed.). Oxford University Press.
7. Beauchamp, T. L., & Childress, J. F. (2019). *Principles of Biomedical Ethics* (8th ed.). Oxford University Press.

PG2 MATH 2021: Discrete Mathematics

Full Marks: 50

Course Objectives:

1. Introduce the fundamental concepts and principles of Boolean algebra and their representation.

2. Develop an understanding of propositional logic, logical connectives, truth tables, logical equivalences, normal forms, and inference.
3. Develop knowledge of predicate logic, including predicates, variables, quantifiers, interpretations, and normal forms.
4. Introduce partial order relations and lattices, including chains and antichains.
5. Develop a foundation in graph theory, including paths, walks, connected graphs, cycles, circuits, bipartite graphs, trees, and rooted trees.

Course Learning Outcomes:

After completing the course, students will be able to:

1. apply the principles and basic theorems of Boolean algebra to represent and simplify Boolean expressions.
2. construct and analyze propositional logic using truth tables, logical equivalences, CNF, DNF, tautologies, contradictions, and inference.
3. formulate and analyze statements using predicate logic, quantifiers, predicates, variables, interpretations, and logical equivalences.
4. explain and analyze partial order relations and lattices, including chains and antichains.
5. apply fundamental concepts of graph theory to analyze walks, paths, connected graphs, regular and bipartite graphs, cycles, circuits, trees, and rooted trees.

Syllabus:

Unit 1: Boolean algebra: introduction, basic definitions, duality, basic theorems. Boolean algebra and lattice, representation theorem, sum-of-product form for sets, sum-of-products forms for Boolean algebra.

Unit 2: Propositional logic: Definition of a proposition, atomic/simple propositions, and compound propositions, Logical Connectives, Truth Tables, Conditional Statements, Well-Formed Formulae (WFF), Logical Equivalences & Laws, Conjunctive Normal Form (CNF) and Disjunctive Normal Form (DNF), tautology, contradiction, Inference and Arguments.

Unit 3: Predicate logic: Limitations of Propositional Logic; Basic Components: Constants, variables, functions, and predicates (relations); Atomic and Compound Statements: Translating English sentences into formal logical expressions; Quantifiers and Syntax: Universal Quantifier, Existential Quantifier, Nested Quantifiers, Free and Bound Variables; Semantics and Interpretations; Equivalences and Normal Forms.

Unit 4: Partial order relations and lattices: Chains and antichains.

Unit 5: Graph Theory: Definition, walks, paths, connected graphs, regular and bipartite graphs, cycles and circuits. Tree and rooted tree.

Texts / References:

1. Rosen, K. H. (2007) Discrete Mathematics and its Applications, McGraw-Hill.
2. Deo, N. (2017) Graph theory with applications to engineering and computer science. Courier Dover Publications.
3. Wilson, R. J. & Watkins, J. J. (1990) Graphs: an introductory approach: a first course in discrete mathematics. John Wiley & Sons Inc.

PG2 MATH 2041: Programming in Python

Full Marks: 25

Course Objectives:

1. To understand the fundamentals of Python programming, including installation, syntax, variables, operators, and program structure.
2. To develop the ability to use Python data types and control structures to solve computational and mathematical problems.

3. To learn to write modular Python programs using functions, modules, packages, file handling, and exception handling techniques.
4. To acquire knowledge of object-oriented programming concepts and apply Python programming skills to mathematical modelling and scientific computing.

Course Learning Outcomes:

On completion of the course, students will be able to

1. demonstrate proficiency in Python syntax, data types, operators, and control statements for developing basic programs.
2. design and implement Python programs using functions, modules, packages, and appropriate data structures to solve mathematical and computational problems.
3. apply file handling and exception handling techniques to develop reliable and efficient Python applications.
4. implement object-oriented programming concepts, including classes, objects, inheritance, and constructors, to develop structured and reusable Python programs suitable for scientific and mathematical applications.

Syllabus:

Introduction to Python: Installation and Working with python, Python variables, Basic operations, precedence, comments, understanding Python blocks.

Python Data Types: Numeric data types, string data types, its operations, lists, list slicing, tuples, sets, dictionaries.

Program Flow Control: Conditional blocks using if, else, and elif, for loops, for loops using ranges, string, list and dictionaries, while loops, loop manipulation using pass, continue, break and else, Programming using conditional and loops block.

Functions, Modules and Packages: Python codes using function, python projects into modules, importing own modules as well as external modules, understanding Packages, Lamda function, Programming using functions, modules, and external packages.

Python File Operations: Files and File Paths, File Reading, File Writing, Saving Variables with the shelve Module, Saving Variables with the print. format () Function, Programming using File operations.

Exception Handling: Avoiding code break using exception handling, Safe guarding file operation using exception handling, Handling and helping developer with error code, Programming using exception handling

Object Oriented Programming: Concept of Class, objects and instances, Constructor, class attributes, destructors, inheritance, Programming using class concepts.

References:

1. Ramalho, Luciano. Fluent Python: Clear, concise, and effective programming. " O'Reilly Media, Inc.", 2015.
2. Lutz, Mark. Learning python: Powerful object-oriented programming. " O'Reilly Media, Inc.", 2013
3. Summerfield, Mark. Programming in Python 3: a complete introduction to the Python language. Addison-Wesley Professional, 2010.
4. Fhrer, Claus, Jan Erik Solem, and Olivier Verdier. Computing with Python. Pearson Education, 2013.

PG2 MATH 3011: Functional Analysis

Full Marks: 50

Course Objectives

1. To develop a rigorous understanding of normed linear spaces, Banach spaces, inner product spaces, and Hilbert spaces and their fundamental properties.
2. To introduce the concepts of bounded linear operators and linear functionals and develop the ability to analyze their properties.
3. To familiarize students with fundamental results of functional analysis, including the Hahn–Banach Theorem, Uniform Boundedness Principle, Open Mapping Theorem, and Closed Graph Theorem.
4. To develop an understanding of dual spaces, quotient spaces, orthogonality, projections, and approximation in normed and inner product spaces.
5. To introduce the theory of operators on Hilbert spaces, including adjoint, self-adjoint, normal, unitary, and positive operators.
6. To develop students' ability to apply abstract functional-analytic concepts to mathematical problems and proofs.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. analyze normed and Banach spaces: Define and distinguish normed linear spaces and Banach spaces, establish their basic properties, and work with equivalent norms, finite-dimensional spaces, and quotient spaces.
2. apply fundamental theorems: Apply the Riesz Lemma, best approximation property, Hahn–Banach Theorem, Uniform Boundedness Principle, Open Mapping Theorem, and Closed Graph Theorem to appropriate problems.
3. understand Hilbert spaces: Explain the structure and properties of inner product and Hilbert spaces and apply the Cauchy–Schwarz inequality, parallelogram law, orthogonality, and projection concepts.
4. work with orthonormal systems: Construct and analyze orthonormal and complete orthonormal systems and apply Bessel's inequality and Parseval's identity to problems in Hilbert spaces.
5. classify special operators: Identify and establish basic properties of self-adjoint, normal, unitary, and positive operators and apply related results to elementary problems in functional analysis.

Syllabus:

Normed Linear Space (NLS), Banach Space and its basic properties, Equivalent norms, Finite dimensional NLS, Heine – Borel Theorem, Riesz Lemma and best approximation property, Quotient space of normed linear space and its completeness, bounded linear operators and its basic properties, Space of bounded linear operators, uniform boundedness principle and some applications, Open Mapping Theorem, Closed Graph Theorem, Linear functional, Hahn-Banach Theorem, Dual Space, Inner Product Space (IPS), Hilbert Space, orthonormal basis, Complete orthonormal basis, Cauchy-Schwarz inequality, Parallelogram law, Bessel's inequality, Parseval's identity, Orthogonal complement and Projection Theorem, Inner product is a continuous operator, Relation between IPS and NLS, Strong and weak convergence of sequence of operators, Reflexivity of Hilbert Space, Riesz Representation Theorem for bounded linear functional on a Hilbert Space, Adjoint of an operator on a Hilbert Space, Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related simple theorems.

References:

1. B.V. Limaye, Functional Analysis, 2nd Edition, New Age International Private Limited New Delhi, 2014.
2. J. B. Conway, A Course in Functional Analysis, 2nd Edition, Springer-Verlag New York, 1985.

3. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1989.
4. A. Taylor and D. Lay, Introduction to Functional Analysis, Wiley, New York, 1980

PG2 MATH 3012: Advanced Numerical Analysis

Full Marks: 50

Course Objectives:

1. To enhance the problem-solving skills using numerical methods.
2. To handle large system of equations, non-linearity and that are often impossible to solve analytically
3. To solve ordinary and partial differential equations by numerical methods

Course Learning Outcomes:

After completion of this course, students will be able to

1. apply advanced interpolation, approximation, curve fitting, numerical integration, and polynomial root-finding techniques to solve mathematical and scientific problems.
2. analyze and solve systems of linear and nonlinear algebraic equations using direct and iterative numerical methods, and evaluate their convergence, stability, and computational efficiency.
3. implement numerical methods for ordinary differential equations and boundary value problems, including Runge–Kutta, predictor-corrector, shooting, finite difference, and finite element methods.
4. develop and analyze numerical schemes for solving partial differential equations using finite difference methods, including explicit, implicit, and Crank–Nicolson methods, while assessing their stability, consistency, and convergence.

Syllabus:

Cubic spline interpolation, Lagrange's bivariate interpolation, Approximation of function, Chebyshev polynomial: Minimax property, Curve fitting by least square method, Use of orthogonal polynomials, Economization of power series.

Numerical integration: Newton-Cotes formulae-open type, Gaussian quadrature: Gauss-Legendre, Gauss Chebyshev, Integration by Monte Carlo method.

Roots of polynomial equation: Bairstow method.

System of linear equations: Pivoting, Matrix inverse, LU decomposition method, Tri-diagonal system of equations, Ill-conditioned linear systems, Relaxation method.

System of non-linear equations, Fixed point method, Newton methods, Convergence, Rate of convergence.

Eigen value problem, Power method, Jacobi's method.

Ordinary differential equation: Runge-Kutta method for linear ODEs and second order IVP, Predictor corrector method: Milne's method, Stability, second order BVP: Shooting method, finite difference method, finite element method.

Partial differential equation: Finite difference scheme, Explicit and implicit methods of Hyperbolic and Parabolic equations, Crank-Nicolson method, Elliptic equation, Stability, Consistency and convergence.

References:

1. A. Gupta and S.C. Bose, Introduction to Numerical Analysis, Academic Publishers, Calcutta, 1989.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, 1984.
3. E.V. Krishnamurthy and S.K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
4. J.H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, 2nd ed. Prentice Hall, Inc., N.J., U.S.A., 1992.
5. E.A. Volkov, Numerical Methods, Mir Publishers, Moscow, 1986.

Course Objectives:

1. To develop a systematic understanding of deformation, strain, and stress in continuous media.
2. To introduce the mathematical formulation of conservation laws for mass, momentum, and energy.
3. To study the fundamental concepts and governing equations of classical elasticity.
4. To develop an understanding of fluid media, including path lines, streamlines, and bounding surfaces.
5. To introduce the mathematical theory of water waves, including progressive and stationary waves.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. formulate and interpret finite and infinitesimal strain tensors, principal strains, and strain invariants.
2. analyze stress tensors, stress transformations, principal stresses, and equilibrium conditions.
3. apply conservation laws and derive the fundamental equations of continuum mechanics.
4. formulate and analyze constitutive relations and field equations for isotropic elastic media.
5. analyze basic water-wave problems, including wave energy, particle paths, and group velocity.

Syllabus:

Theory of strain: Configuration of a continuous medium, Continuum hypothesis, Material & Spatial description, Deformation Gradients, Strain measures, Finite strain tensors. Small deformation theory, infinitesimal strain tensor. Relative displacement, Rotation tensor. Interpretation of linear strain tensors. Stretch ratio. Finite strain interpretation. Principal strains. Strain invariant. Cubical dilatation. Saint Venant's Compatibility equation for strain.

Theory of Stress: Body force. Surface forces. Cauchy's stress principle. Stress vector. State of stress at a point. Stress tensor. Stress vector–stress tensor relationship. Stress equation of equilibrium, Stress tensor symmetry, Stress quadric of Cauchy. Stress transformation laws, Principal stress. Stress invariant. Stress ellipsoid, extremum normal stress and shearing stress.

Conservation Laws: Reynold's Transport Theorem, Conservation of mass, Equation of continuity, Principle of conservation of momentum, Cauchy's first equation of motion, Cauchy's second equation of motion, Conservation of energy, First law of Thermodynamics.

Elasticity: Ideal materials, Classical elasticity, Generalized Hooke's Law, Isotropic materials, Constitutive equation (stress-strain relations) for isotropic elastic solid, Strain-energy function, Beltrami-Michell compatibility equations for stresses, Field equations of linear elasticity, Fundamental boundary value problems of elasticity and uniqueness of their solutions (Statement only), Saint-Venant's principle. Hook's law, Strain energy function, Isotropic media, Waves in isotropic elastic media, Navier's equations of motion.

Fluid media: Path lines, stream lines and streak lines, Bounding surface, Lagrange's criterion for bounding surface.

Water Waves: General features, Condition at the free surface, Cisotti's equation, Complex potential, energy and path of particles for progressive waves and stationary waves, group velocity.

References:

1. Mechanics of Continua: A. C. Eringen, Wiley, 1967.
2. Mathematical Theory of Continuum Mechanics: R. N. Chatterjee (Narosa Publishing House, New Delhi, 1999).
3. Continuum Mechanics: T. J. Chung, Prentice Hall.
4. Continuum Mechanics: Schaum's out line of Theory and Problems of Continuum Mechanics:
5. Gedrg R. Mase, Mc Graw Hill.
6. Continuum Mechanics: D. S. Chandra Sekharaiah and L. Debnath, Academic Press.
7. Continuum Mechanics: A.J.M. Spencer, Long man.
8. Mathematical theory of Elasticity: I. S. Sokolnikoff, Tata Mc Grow Hill Co.

Course Objectives:

1. To develop an understanding of advanced linear programming and simplex-based optimization techniques.
2. To introduce decomposition, parametric, and post-optimality analysis of large-scale optimization problems.
3. To study convexity, integer programming, and algorithms for solving integer optimization problems.
4. To develop knowledge of classical and quadratic programming techniques.
5. To introduce modern unconstrained optimization methods such as gradient, Newton, conjugate-gradient, and quasi-Newton methods.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. solve linear programming problems using revised and dual simplex methods.
2. perform parametric and post-optimality analysis of optimization problems.
3. apply convexity concepts and integer programming techniques.
4. solve quadratic and constrained optimization problems.
5. apply gradient, Newton, conjugate-gradient and quasi-Newton methods.

Syllabus:

Revised simplex method (with and without artificial variable). Modified dual simplex.

Large Scale Linear Programming: Decomposition Principle of Dantzig and Wolf.

Parametric and post-optimal analysis: Change in the objective function. Change in the requirement vector, Addition and deletion of variables, Addition and deletion of constraints., Parametric analysis of cost and requirement vector.

Convex and concave functions: Basic properties and some fundamental theorems of convex/concave functions, Differentiable convex and concave functions.

Integer Programming: Gomory's cutting plane algorithm, Gomory's mixed integer programming algorithm, Branch and bound algorithm.

Classical optimization techniques: Single variable optimization, multivariate optimization (with no constraint, with equality constraints and with equality-inequality constraints).

Quadratic Programming: Wolfe's modified simplex method, Beale's method, convex programming.

Unconstrained optimization: Gradient methods, Steepest descent method, conjugate gradient method, Newton's method, Quasi-Newton's method, Davidon-Fletcher-Powell method.

Texts / References:

1. Edwin K. P. Chang & S. Zak. An Introduction to Optimization. John Wiley & Sons Inc., 2004.
2. S. S. Rao. Engineering optimization: theory and practice. John Wiley & Sons, 2009.
3. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
4. Belegundu, Ashok D., and Tirupathi R. Chandrupatla. Optimization concepts and applications in engineering. Cambridge University Press, 2011.
5. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.

PG2 MATH 3014B: Fluid Mechanics –I**Full Marks: 50****Course Objectives:**

1. To introduce the fundamental concepts, assumptions, and classifications of fluid mechanics.
2. To develop an understanding of inviscid and irrotational fluid motion.
3. To study velocity potential, circulation, stream functions, and complex potential methods.
4. To introduce vortex motion and the fundamental theorems governing vorticity.

5. To develop the mathematical formulation of viscous incompressible flows and their applications.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. classify fluid motion and formulate basic equations governing inviscid fluid flow.
2. apply Euler's equation, Bernoulli's equation, and Helmholtz's equation to appropriate fluid-flow problems.
3. analyze two-dimensional and three-dimensional irrotational flows using velocity potential, stream function, and complex potential.
4. analyze vortex motion and apply Helmholtz's theorems and related results.
5. formulate and apply the Navier–Stokes equations to standard viscous flows such as Poiseuille and Couette flows.

Syllabus:

Basic concepts of fluid: Continuum hypothesis, Fluid and its classification, Newton's law of viscosity, Classification of fluid motion.

Inviscid fluid: Inviscid incompressible fluid, Constitutive equation, Euler's equation of motion & its vector invariant form, Bernoulli's equation and applications to some special cases, Helmholtz's equation for vorticity, impulsive generation of motion and some properties, Boundary Conditions.

Irrotational motion of fluid: Irrotational motion, Velocity potential, Circulation, Kelvin's circulation theorem, Irrotational motion in simply connected and multiply connected regions, Kelvin's theorem of minimum kinetic energy, Acyclic irrotational motion and some properties (Using Green's theorem), Stream function, Complex potential, Two dimensional motion, Source, sink and doublets for two dimensional flows, Complex potentials for simple source, sink and doublet, Circle theorem, Uniform flow past a circle, Image of a source with respect to a plane boundary, image of a source outside a circle, image of a doublet outside a circle, Motion of translation and rotation of circular cylinder in an infinite liquid, Blasius theorem, Kutta-Joukowski's theorem, Axi-symmetric motion, Stokes' stream function, Three-dimensional motion, Source, sink, doublet for three dimensional flows.

Vortex motion: Vortex lines, vortex filaments and vortex surface, Helmholtz's theorems for vorticity, rectilinear vortices, Vortex pair and doublets, Image of a vortex with respect to a circle.

Flow of viscous incompressible fluid: Viscous incompressible fluid, Navier Stokes' Equations of motion, Boundary conditions, Reynolds number and its significance, Poiseuille flow, Couette flow, Flow through parallel plates, Flow through pipes of circular and elliptic cross sections, Vorticity transport equation, Energy dissipation due to viscosity.

References:

1. Ramsay, A.S., Hydrodynamics (Bell).
2. Kundu, P.K. & Cohen, I.M., Fluid Mechanics, 4th edition(Academic Press, 2008).
3. Lamb, H., Hydrodynamics (Cambridge)
4. Landau, L.D., Lifchiz, E.M., Fluid Mechanics (Pergamon), 1959
5. Milne-Thomson, I.M., Theoretical Hydrodynamics
6. Chorlton, F., Textbook of Fluid Dynamics, Van Nostrand Reinhold Co., London, 1990.

PG2 MATH 3014C: Advanced Algebra -I

Full Marks: 50

Course Objectives:

1. To develop a deeper understanding of modules, submodules, quotient modules, and module homomorphisms.

2. To introduce exact sequences, tensor products, projective, injective, and flat modules.
3. To study ideals, radicals, localization, and rings of fractions.
4. To understand Noetherian and Artinian rings and their fundamental properties.
5. To introduce primary decomposition and major structural results in commutative algebra.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. analyze modules and establish relationships through homomorphisms, isomorphisms, and exact sequences.
2. construct and apply tensor products and distinguish projective, injective, and flat modules.
3. work with radicals, localization, and extensions and contractions of ideals.
4. identify and apply the properties of Noetherian and Artinian rings.
5. apply the Hilbert Basis Theorem, Cohen's theorem, and primary decomposition in appropriate algebraic settings.

Syllabus:

Module, Submodule, Quotient module, Homomorphism and isomorphism of modules, Exact sequences, short and split exact sequences, tensor product of modules, definition and existence, universal mapping property, further properties of the tensor product of modules, projective modules, injective modules, flat Modules, direct sum of projective modules, direct product of injective modules. Nilradical and Jacobson radical, Chinese remainder theorem, extension and contraction of ideals, rings and modules of fractions, local ring, characterizations of local ring, localization, Extended and contracted ideals in rings of fractions, Noetherian rings, Artinian rings, Hilbert Basis Theorem, Cohen's Theorem, Primary Decomposition in Noetherian Rings.

References:

1. Dummit, D.S. and Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.
2. Atiyah, M., MacDonald, I.G., Introduction to Commutative Algebra, Addison-Wesley, 1969.
3. Lang, S., Algebra, Addison-Wesley, 1993.
4. Lam, T.Y., A First Course in Non-Commutative Rings, Springer Verlag.
5. Hungerford, T.W., Algebra, Springer.
6. Jacobson, N., Basic Algebra, II, Hindustan Publishing Corporation, India.
7. Gopalakrishnan, N. S., Commutative Algebra, 2nd edition, Orient Blackswan, 2015.
8. Balwant Singh, Basic Commutative Algebra, World Scientific Publishing Co Pte Ltd,

PG2 MATH 3014D: Advanced Topology –I

Full Marks: 50

Course Objectives:

1. To introduce nets, filters, directed sets, and their role in general topology.
2. To develop convergence-based characterizations of topological properties.
3. To study arbitrary product spaces and their compactness, connectedness, separation, and countability properties.
4. To introduce major compactification techniques, including one-point and Stone-Čech compactification.
5. To develop an understanding of metrization, paracompactness, and related embedding theorems.

Course Learning Outcomes:

On successful completion of the course students will be able to

1. use nets, subnets, filters, and ultrafilters to study convergence and compactness.
2. characterize important topological properties using nets and filters.
3. analyze product spaces and apply Tychonoff's and embedding theorems.
4. explain and distinguish different compactification constructions.
5. apply Urysohn's and Tietze's theorems and understand the role of paracompactness in metrization.

Syllabus:

Nets and Filters: Directed sets, Nets and its convergence, Cluster point of a net, Subnets, Characterization of topological properties in terms of convergence of nets, Filter, Filter associated with nets and nets associated with filters, Base and subbase of a filter, Filters in Topology, Ultra filter and its properties, ultra filter and compactness.

Product space: Product of an arbitrary family of topological spaces, Productive properties of compactness and connectedness, separation and countability axioms, Embedding Lemma and Tychonoff embedding theorem.

Compactification: One-point compactification, Stone-Cech compactification, Hausdorff compactification.

Separation and Metrization: Urysohn's lemma and Tietze Extension Theorem, Pseudometric spaces, Equicontinuity, Urysohn's embedding theorem, Urysohn's Metrization theorem, Paracompactness.

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
4. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1955.
5. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
6. Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York.

PG2 MATH 3014E: Advanced Functional Analysis –I Full Marks: 50

Course Objectives:

1. To develop an understanding of topological vector spaces and their fundamental structures.
2. To study locally convex spaces, seminorms, Minkowski functionals, and normability.
3. To introduce fundamental functional-analytic theorems in topological vector spaces.
4. To develop an understanding of weak and weak* topologies and compact convex sets.
5. To introduce barreled and bornological spaces and their characterizations.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. identify and analyze topological vector spaces using local bases and separation properties.
2. work with seminorms, locally convex structures, quotient spaces, and criteria for normability.
3. apply the Banach–Steinhaus, Open Mapping, Closed Graph, and Hahn–Banach theorems.
4. distinguish weak and weak* topologies and apply the Banach–Alaoglu theorem.
5. characterize barreled and bornological locally convex spaces.

Syllabus:

Topological vector spaces: Definition and different examples of Topological vector space, Local base and its properties, Separation properties, Symmetric sets, Balanced sets, absorbing sets, convex sets, Bounded sets in topological vector space.

Linear operators over topological vector space: Definition and properties, locally compact topological vector spaces and its dimension, Metrization of topological vector space, Boundedness and continuity of linear operator.

Local convexity and seminorms: Locally convex topological vector spaces, Semi-norms, Minkowski functional, Generating family of semi norms in locally convex topological vector spaces, Criterion for norm ability, Quotient spaces

Fundamental theorems on topological vector space: Equicontinuity, The Banach-Steinhaus theorem and its consequences, the open mapping theorem, the closed graph theorem, The Hahn-Banach Theorem and its consequences.

Weak topologies: The weak and weak* topology of a topological vector space, convergence, closure, Compact convex sets, The Banach-Alaoglu theorem and its applications in separable and locally convex topological vector space.

Barreled spaces and Bornological spaces: Definition and several examples, Criterion for locally convex topological vector spaces to be (i) Barreled and (ii) Bornological.

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Kelly J. L. & Namioka I., Linear Topological spaces, Springer-Verlag, New York, Heidelberg, Berlin.
3. Schaffer, A.A., Topological Vector Spaces, Springer, 2nd Edn., 1991
4. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
5. Diestel, Application of Geometry of Banach Spaces
6. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985
7. Simmons, G. F., Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963

PG2 MATH 3014F: MOOC Course

Full Marks: 50

The course will be selected based on its availability on the MOOC platform and must be compatible with the Mathematics curriculum. The chosen MOOC should carry 4 credits. The University will conduct the examination and evaluation in accordance with the guidelines prescribed for the respective MOOC.

PG2 MATH 3015A: Operational Research-II

Full Marks: 50

Course Objectives:

1. To develop mathematical models for inventory, replacement, and maintenance decision problems.
2. To introduce queueing models and techniques for analyzing the performance of service systems.
3. To study sequencing models and methods for obtaining optimal job schedules.
4. To develop an understanding of simulation, Monte Carlo methods, and their applications in operational systems.
5. To introduce game theory, bi-matrix games, and Nash equilibrium with optimization-based solution approaches.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. formulate and solve inventory, replacement and maintenance problems.
2. analyze queueing systems and their operating characteristics.
3. solve sequencing problems involving multiple jobs and machines.
4. apply simulation and Monte Carlo techniques to operational problems.
5. analyze basic game-theory models and Nash equilibrium.

Syllabus:

Inventory control: Deterministic Inventory control including price breaks and multi-item inventory models with constraints. Probabilistic inventory control (with and without lead time), Dynamic inventory models. Basic concept of Supply chain management and two echelon supply chain model.

Replacement and Maintenance Models: Introduction, Failure Mechanism of items, Replacement of items deteriorated with time, Replacement policy for equipment when value of money changes with constant rate during the period, Replacement of items that fail completely— individual replacement policy and group replacement policy, other replacement problems — staffing problem, equipment renewal problem.

Queueing Theory: Basic features of queueing systems, operating characteristics of a queueing system, arrival and departure (birth & death) distributions, inter-arrival and service times distributions, transient, steady state conditions in queueing process. Poisson queueing models- $M/M/1$, $M/M/C$ for finite and infinite queue length. Machine-Maintenance problem (steady state), power supply model, non-Poisson queueing models- $M/E_k/1$, $M/G/1$, mixed queueing model $M/D/1$, cost models in queueing system.

Sequencing: Sequencing problems, Solution of sequencing problems, Processing of n jobs through two machines, Processing of n jobs through three machines, Optimal solutions, Processing of two jobs through m machines, Graphical method of solution, Processing of n jobs through m machines.

Simulation: Introduction, Steps of simulation process, Advantages and disadvantages of simulation, Stochastic simulation and random numbers— Monte Carlo simulation, Random number generation, Simulation of inventory problems, Simulation of queueing problems, Role of computers in simulation, Applications of simulations.

Theory of Games: Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming).

Texts / References:

1. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
2. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.
3. Sharma J.K. Operations Research: theory and application, Macmillan Publishers, 2006.
4. Hillier, F.S., 2012. Introduction to operations research. Tata McGraw-Hill Education.

PG2 MATH 3015B: Fluid Mechanics –II

Full Marks: 50

Course Objectives

1. To develop an advanced understanding of viscous fluid dynamics and the Navier–Stokes equations.
2. To study slow and creeping flows and their classical solutions.
3. To introduce boundary-layer theory and Prandtl's assumptions.
4. To study analytical solutions of important boundary-layer flows.
5. To develop an understanding of integral methods for solving boundary-layer equations.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. formulate and analyze viscous-flow problems using the Navier–Stokes equations and dimensionless parameters.
2. analyze creeping flow and apply Stokes' and Oseen's solutions to slow flows.
3. formulate boundary-layer equations and identify important boundary-layer parameters and separation phenomena.
4. analyze Blasius boundary-layer flow and other self-similar boundary-layer solutions.
5. apply the Kármán integral equation and Kármán–Pohlhausen method to estimate boundary-layer characteristics.

Syllabus:

Viscous fluid dynamics: Continuum hypothesis, Fluid, Fluid viscosity, Newton's law of viscosity, Classification of fluids, Flow and its classification, Stokes' hypothesis, Stokes' law of friction, Navier-Stokes' equations and its dimensionless form, Reynolds number and its significance, Flow due to suddenly accelerated plane wall, Flow due to harmonic oscillation of plane wall, Flow around orthogonal stagnation-point and oblique stagnation-point, von-Karman flow near a rotating disk.

Slow motion: Creeping motion and its examples, Steady flow past a fixed sphere (Stokes' flow), Steady motion between parallel planes, Stokes' solution for slow steady parallel flow past a sphere, Stokes' paradox, Oseen's improvement over Stokes' solution, Oseen's solution for steady parallel flow past a sphere.

Boundary layer theory: Concept and properties of boundary layer flows, Prandtl's assumptions and validity, Boundary layer equations, Boundary layer parameters, Boundary layer separation.

Solutions of some boundary layer flows: Blasius boundary layer flows, Concept of self similar flows, Blasius similar equation and series solution, Boundary layer flow in a convergent channel, Flow past a wedge, Planar jet flows .

Integral method for boundary layer equations: Basic concept of integral method, Karman's integral equation, Karman-Pohlhausen method and its applications for estimating boundary layer parameters.

References:

1. J. L. Bansal, Viscous Fluid Dynamics, , 2nd edition (Oxford and IBH Publishing Co, 1977).
2. D. J. Tritton, Physical Fluid Dynamics. 2nd edition (Oxford Science Publications, 1988).
3. S.W. Yuan. Foundations of Fluid Mechanics. (PHI, 1970).
4. P. K. Kundu, Fluid Mechanics. (Academic Press, 1990).
5. G. K. Batchelor, An introduction to Fluid Dynamics. (Cambridge University press, 1967).
6. Thompson, P. A., Compressible fluid dynamics.
7. Shapiro, A. H., Compressible fluid flow.
8. Lipman, B., Aspects of subsonic and transonic flows.
9. Niyogi, P., Inviscid gas dynamics, Mcmillan, 1975 (India)
10. Oswatitsch, K., Gas dynamics

PG2 MATH 3015C: Universal Algebra

Full Marks: 50

Course Objectives:

1. To introduce the fundamental concepts and structures of universal algebra.
2. To study subalgebras, congruences, quotient algebras, and homomorphisms.
3. To develop an understanding of free algebras, direct and subdirect products, and varieties.
4. To study Birkhoff's theorems and related structural results.
5. To introduce group representations, group rings, and selected representation-theoretic results.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. identify and analyze universal algebras, subalgebras, congruences, and quotient structures.
2. apply the isomorphism theorems and analyze homomorphisms and kernels.
3. construct and work with free algebras, products, and subdirectly irreducible algebras.
4. use identities, term algebras, varieties, and Birkhoff's theorem in structural analysis.
5. explain basic group representations, group rings, and apply results such as Maschke's theorem.

Syllabus:

Universal algebra, examples, subalgebra, sub universe, congruences and quotient algebra. homomorphisms of universal algebra, kernel of a homomorphism. First Isomorphism Theorem, Second Isomorphism Theorem, Third Isomorphism Theorem. semigroup of endomorphisms of a universal algebra. Birkhoff's theorem. Special faithful representation of universal algebras into semigroups, Theorem of Cohn-Rebane.

Free algebra. direct and subdirect product of universal algebras. Sub directly irreducible universal algebras.

Class operators. Turski's theorem, identities. Term algebra, universal mapping property, k -free universal Algebra, variety, Birkhoff's theorem on variety, Macev's conditions.

Group representations, group-rings, Maschke's theorem, character of a representation, regular representations, orthogonality relations, Burnside two-prime theorem.

References:

1. Stanley Burries and H. P. Sankappanavan; Universal Algebra; Springer-Verlag.
2. Curtis, C.W., Reiner, I., Representation Theory of Finite Groups and Associated Algebras, Wiley Inter science, NY.
3. Benjamin Steinberg, Representation Theory of Finite groups, An Introductory Approach, Springer, 2012.

PG2 MATH 3015D: Advanced Topology –II

Full Marks: 50

Course Objectives:

1. To study advanced metrization and topological embedding theorems.
2. To introduce uniform spaces and their associated uniform topologies.
3. To develop the theory of completeness, Cauchy nets, Cauchy filters, and completion.
4. To introduce proximity spaces and their compactification theory.
5. To study topological groups and their algebraic-topological structures.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. apply major metrization and embedding theorems to suitable topological spaces.
2. construct and analyze uniformities, uniform topologies, and uniformly continuous mappings.
3. characterize completeness using Cauchy nets and filters and understand completion results.
4. analyze proximity spaces, their products, and associated compactifications.
5. work with topological groups, continuous homomorphisms, quotient groups, and uniform structures.

Syllabus:

Metrizability Topological imbedding, Imbedding theorem of a regular space with countable base, NagataSmirnov Metrization theorem.

Uniform spaces: Uniformity and its uniform topology, neighbourhoods, bases and subbases, uniform continuity, product uniformities, uniform isomorphism, relativization and products. Characterization of metrizability, uniformity of pseudometric spaces, uniformity generated by a family of pseudometrics, Uniformizability and complete regularity, the gauge of uniformity, Completeness, Cauchy net, Cauchy filter, complete spaces, extension of mappings, completion-existence and uniqueness, Compactness and uniformity, diagonal uniformities, uniformity via uniform covers.

Proximity Spaces: Topology induced by a proximity, subspaces and products of proximity spaces, elementary proximity, p -continuity and p -isomorphism, Compactification of proximity spaces-clusters and ultrafilters, Smirnov's theorem.

Topological Group: Definition, Example, Homeomorphism of translation mapping, Neighbourhood systems of identity, separation axioms, uniform structures, subgroups, quotient groups, continuous and open homomorphism, Isomorphism.

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Joshi, K.D., Introduction to General Topology, New age International Publishers, 1983.
4. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
5. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1955.
6. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
7. Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York.
8. Hossain, T, Introduction to topological groups, Dover Publications, Inc. Mineola, New York.

PG2 MATH 3015E: Advanced Functional Analysis –II Full Marks: 50

Course Objectives:

1. To develop the theory of strictly convex and uniformly convex Banach spaces.
2. To study approximation theory in normed linear spaces and function spaces.
3. To introduce convexity in topological vector spaces and separation results.
4. To develop the theory of Banach algebras and spectral theory.
5. To introduce Gelfand theory and representation of Banach algebras.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. distinguish strictly convex and uniformly convex spaces and apply relevant inequalities and theorems.
2. analyze best approximation and uniqueness problems in normed linear spaces.
3. apply separation theorems, extreme-point theory, and the Krein–Milman theorem.
4. determine and analyze spectra, resolvents, spectral radius, and spectral mappings in Banach algebras.
5. explain maximal ideal spaces, Gelfand transforms, and fundamental results of Gelfand theory.

Syllabus:

Strictly convex and Uniformly convex space: Definition and several examples of strictly convex and uniformly convex Banach space. Clarkson's renorming lemma, Uniform Convexity of a Hilbert Space. Milman-Pettit theorem, Clarkson's inequalities, Reflexivity of a uniformly convex Banach space, Uniqueness of extension of functional on normed linear space.

Approximation theory: Weierstrass approximation theorem in $C[a,b]$, Stone- Weierstrass theorem in $C(X, \mathbb{R})$ and $C(X, \mathbb{C})$ where X is a compact Hausdorff space, Representation theorem for bounded linear functional on $C[a,b]$, l_p ($1 \leq p < \infty$) and $L_p[a,b]$, ($1 \leq p < \infty$). Approximation Theory in Normed Linear space, Best approximation, Uniqueness Criterion.

Convexity in topological vector space: Convex Hull and representation Theorem, Extreme points, Hyperplanes, Separation of convex sets by Hyperplanes, Krein-Milman Theorem on extreme points.

Banach Algebra: Analytic vector valued functions, normed and Banach algebra, Identity element, Gelfand Mazur Theorem, Analytic property of resolvent Operator, Compactness of Spectrum, the resolvent operator, Spectral radius and Spectral mapping Theorem for polynomials, Topological divisors of zero.

The Gelfand theory: Ideals, Maximal Ideals, Quotient space, Maximal ideal space, Gelfand topology, Gelfand mapping, Gelfand Theory on representation of Banach Algebra, involutions in Banach algebra, The Gelfand Neumark Theorem.

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co. Ltd., New Delhi, 1973
2. Simmons, G. F., Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963
3. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
4. Kelly J. L. & Namioka I., Linear Topological spaces, Springer-Verlag, New York, Heidelberg, Berlin.
5. Schaffer, A. A., Topological Vector Spaces, Springer, 2nd Ed., 1991
6. Diestel, Application of Geometry of Banach Spaces
7. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985.

PG2 MATH 3015F: MOOC Course

Full Marks: 50

The course will be selected based on its availability on the MOOC platform and must be compatible with the Mathematics curriculum. The chosen MOOC should carry 4 credits. The University will conduct the examination and evaluation in accordance with the guidelines prescribed for the respective MOOC.

PG2 MATH 3016: Indian Knowledge System

Full Marks :25

Course Objectives

1. To understand the historical development of Indian mathematics and its contributions to number systems, algorithms, and mathematical thought.
2. To explore the contributions of ancient Indian scholars to geometry, arithmetic, algebra, and computational methods.
3. To appreciate the mathematical achievements of medieval and modern Indian mathematicians and their influence on contemporary mathematics.
4. To develop an understanding of the significance of the Indian Knowledge System in the evolution of mathematics and its relevance in modern scientific studies.

Course Learning Outcomes:

After completion of this course, students will be able to

1. explain the origin and evolution of Indian number systems, decimal place-value notation, zero, and traditional algorithms, and assess their global impact.
2. analyze the contributions of ancient Indian mathematics to geometry, arithmetic, algebra, trigonometry, and computational techniques described in classical texts.
3. evaluate the mathematical contributions of eminent Indian mathematicians such as Brahmagupta, Bhāskara II, Madhava, Aryabhata, and Srinivasa Ramanujan, and relate them to modern mathematical developments.
4. demonstrate an appreciation of the historical, cultural, and scientific significance of the Indian Knowledge System and its continuing influence on mathematics and related disciplines.

Syllabus:

Foundation of Number Systems and Algorithms: Historical overview of Indian mathematics, Influence of Indian mathematics on the world, the evolution of the decimal place-value system and the mathematical and philosophical concept of zero, Unique Indian approaches to representing large numbers, including the Bhūta Saṃkhya (word-numerical) and Kaṭapayādi systems, Binary systems found in the Chandah Sāstra of Pingala.

Contributions to Geometry: Vedas and Sulbasutras as sources of mathematical knowledge, Geometry in ancient Indian mathematics, Arithmetic operations and algebraic methods in ancient Indian mathematics, Trigonometry in ancient India, Geometric principles used in the construction of altars and fire rituals (Vedic altars), Geometric proofs and applications prior to Pythagoras (such as the Bodhayana theorem), Methods for squaring a circle, circling a square, and approximations of the square root and π (Pi), The development of sine and cosine tables (Jyā and Kojyā) and cyclic quadrilaterals.

Arithmetic and Algebra: Brahmagupta and his contributions to algebra and number theory, Bhaskara II and his contributions to calculus, Madhava and his contributions to infinite series and calculus, Solutions to indeterminate equations, including the Kuṭṭaka (pulverizer) and Cakravāla methods, Computational techniques from traditional texts such as the Aryabhatiya, Brahmasphuta siddhanta, and Lilavati.

Indian Mathematics in the Medieval and Modern Period: Development of Indian mathematics during the medieval period, Modern developments in Indian mathematics, including Ramanujan's contributions to number theory, Influence of Indian mathematics on modern mathematics

References:

1. "The Crest of the Peacock: Non-European Roots of Mathematics" by George Gheverghese Joseph (1991), Princeton University Press
2. "A Concise History of Mathematics in India" by Bibhutibhushan Datta and Avadesh Narayan Singh (1995), New Delhi: Motilal Banarsidass.
3. Geometry in ancient India by Saraswati Amma (1999, 2nd Ed.), Motilal Banarsidass.
4. The mathematics of India: concepts, methods, connections, sources and studies in the history of mathematics and physical sciences by P.P. Divakaran (2018), Hindustan Book Agency.
5. Mathematics in India by Kim Plofker (2009), Princeton University Press.
6. Erik Gregersen, The Britannica Guide to The History of Mathematics, Britannica.
7. Eleanor Robson, Jacqueline Stedall, The Oxford Handbook of THE HISTORY OF MATHEMATICS, Oxford.

PG2 MATH 3041: Community Engagement

Full Marks:25

Community engagement will be arranged according to the decision of the Department in every year.

Compulsory 2-credit Course:

Mahatma Gandhi: Life & Philosophy

The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA

PG2 MATH 4011: Fuzzy Mathematics and Soft Computing Full Marks:50

Course Objectives:

1. To introduce the fundamental concepts, operations, relations, and arithmetic of fuzzy sets and fuzzy numbers.
2. To develop an understanding of fuzzy measures, possibility, necessity, defuzzification, and fuzzy decision-making.
3. To introduce soft-computing paradigms and their applications in problem solving.
4. To study artificial neural networks and genetic algorithms as computational intelligence techniques.
5. To develop an understanding of fuzzy logic, inference, controllers, and their practical applications.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. understand fuzzy sets, fuzzy relations, fuzzy numbers and fuzzy measures.
2. apply fuzzy arithmetic, ranking and defuzzification techniques.
3. solve decision-making and fuzzy linear-programming problems.
4. understand and apply artificial neural networks and genetic algorithms.
5. develop basic fuzzy-logic models and controllers.

Syllabus:

Fuzzy Sets and Basic Operations:

Basic concepts and definition of fuzzy sets, Membership functions, Types of fuzzy sets, Basic fuzzy set operations and their properties, Basic terminologies of fuzzy sets

Fuzzy Numbers and Fuzzy Arithmetic:

Fuzzy numbers and their representation, α -cuts of fuzzy numbers, Interval arithmetic, Arithmetic operations on fuzzy numbers, Zadeh's Fuzzy Extension Principle, Applications for the Fuzzy Extension Principle

Fuzzy Relations and Fuzzy Measures:

Basic concept of fuzzy relations, Crisp relations and fuzzy relations, Binary fuzzy relations, Operations on fuzzy relations, Composition of fuzzy relations, Fuzzy equivalence and compatibility relations, Basic concept of fuzzy measures, Possibility, necessity, and credibility measures

Fuzzy Decision Making:

Basic concept of decision making in a fuzzy environment, Individual decision making, Multicriteria decision making, Defuzzification techniques, Fuzzy ranking methods, Simple numerical problems on fuzzy decision making

Fuzzy Linear Programming:

Basic concept of fuzzy linear programming, Linear programming with fuzzy resources, Linear programming with fuzzy objective functions, Basic formulation and solution of fuzzy linear programming problems, Introduction to fuzzy multi-objective linear programming

Fuzzy Logic:

Fuzzy relations, rules, propositions, implications and inferences, Fuzzy logic controller design, and some applications of Fuzzy logic.

Introduction to Soft Computing:

Evolution of Computing: Soft Computing Constituents, "Soft" versus "Hard" computing, Characteristics of Soft computing, Some applications of soft computing techniques.

Artificial Neural Network:

Biological neurons and their working, Simulation of biological neurons to problem solving, Different ANNs architectures, learning rules and various activation functions, Basic models of ANN, single layer perceptron, and Applications of ANNs to solve some real-life problems.

Heuristic search approach:

Introduction: Single objective continuous optimization problems (SOCOP), Heuristic search approach: Population generation, Fitness evaluation, Probabilistic selection (Roulette wheel selection procedure), Neighbour solution, Perturbation techniques, and population update.

Genetic Algorithm: Basic GA architecture for SOCOPs: Population generation, evaluation, selection, crossover, mutation, population update, and Illustration.

Particle Swarm Optimization: Basic PSO architecture for SOCOPs: Population generation, evaluation, perturbation, population update, and Illustration.

References:

1. Klir, G.J. and Yuan, B. (1995) Fuzzy sets and fuzzy logic, Prentice-Hall of India, New Delhi.
2. Dubois, D. J. (1980) Fuzzy sets and systems: theory and applications, Academic press.
3. Bector, C.R. and Chandra, S. (2005) Fuzzy mathematical programming and fuzzy matrix games, Berlin: Springer.
4. Zimmermann, H. J. (1991) Fuzzy set theory and its Applications, Allied Publishers Ltd, New Delhi.
5. Sivanandam, S.N. and Deepa, S.N., 2007. PRINCIPLES OF SOFT COMPUTING, John Wiley & Sons
6. Jang, J.S.R., Sun, C.T. and Mizutani, E., 1997. Neuro-fuzzy and soft computing; a computational approach to learning and machine intelligence. Prentice Hall, Upper Saddle River NJ (1997).
7. Ogly Aliev, R.A. and Aliev, R.R., 2001. Soft computing and its applications, World Scientific.
8. Karray, F.O. and De Silva, C.W., 2004. Soft computing and intelligent systems design: theory, tools, and applications. Pearson Education.

PG2 MATH 4012: Mathematical Methods

Full Marks: 50

Course Objectives:

1. To develop a clear understanding of integral, wavelet, integral equation, and operator equation methods.
2. To introduce analytical techniques for solving differential and integral equations.
3. To develop knowledge of Fourier and wavelet transforms and their applications.
4. To familiarize students with Hilbert spaces, operators, and spectral theory.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. apply Laplace and Fourier transforms to solve differential equations and related problems.
2. analyze time-frequency signals using wavelet and short-time Fourier transforms.
3. solve Fredholm, Volterra, and Abel integral equations using appropriate methods.
4. apply Hilbert space and operator theory to formulate and solve operator equations.
5. use transform, integral equation, and operator methods in applications such as signal and image processing.

Syllabus:

Integral Transforms: Laplace Transform, Properties of Laplace transform, Inversion by analytic method and Bromwich path, Convolution theorem, Lerch's theorem, Applications to differential equations. Fourier Transform and its properties, Inversion formula, Convolution theorem, Parseval's relation, Applications.

Wavelet Transforms: Time-frequency analysis, multi-resolution analysis, Spline wavelets, scaling function, Short-time Fourier transforms, Wavelet series, orthogonal wavelets, Applications to signal and image processing.

Integral Equations: Reduction of differential equations to integral equations, Existence and uniqueness, Types of Integral equations - Fredholm and Volterra, Solution processes - successive substitutions, successive approximations, degenerate kernel, resolvent Kernel, symmetric kernel, singular integral equation and Abel's integral equation.

Operator Equations: Hilbert space, Fourier expansion, Reisz Fisher theorem, adjoint, self-adjoint, Eigen value problems, Spectral theorem for compact self – adjoint operations, integral equations with Hilbert – Schmidt kernel, solubility of operator equations.

References:

1. I. N. Sneddon: Fourier Transforms, McGraw - Hill.
2. S. G. Mikhlin: Integral Equations, Pergamon Press
3. P. P. G. Dyke, An Introduction to Laplace Transform and Fourier Series, Springer 2005.

4. R.P. Kanwal: Linear Integral Equations; Theory & Techniques, Academic Press, New York, 1971.
5. W. V. Lovitt, Linear Integral Equations, Dover Publications, 1950.
6. R.V. Churchill: Operational Methods

PG2 MATH 4013: Biomathematics

Full Marks:50

Course Objectives:

1. To develop mathematical models for single-species population growth and harvesting.
2. To study mathematical models of predator–prey, competing, and multiple-species populations.
3. To introduce mathematical modelling of simple, general, and recurrent epidemic processes.
4. To develop an understanding of economic and mathematical models for renewable-resource harvesting.
5. To study fisheries models and optimal harvesting policies using mathematical optimization techniques.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. formulate and analyze mathematical models of single-species populations.
2. analyze predator–prey, competition and multi-species population models.
3. develop and interpret mathematical models of epidemics.
4. apply mathematical and economic models to renewable-resource harvesting.
5. analyze fisheries models and optimal harvesting policies.

Syllabus:

Single Species Population Models: Malthus Model of Exponential Growth, Formulation of the models of (i) continuous-time version and (ii) discrete-time version, solution and interpretation, limitations, applications.

Logistic Growth Model: Formulation of the model, solution and interpretation, limitations, applications. Harvesting of the population at a constant rate, solution and interpretation, Biological Overexploitation., catch-per-unit-effort hypothesis, minimum viable population level. Yield-Effort Curve for a pure compensation model, depensation model and critical depensation model, irreversible extinction process.

Two-Species Population Models: Types of interactions between two species, Prey-predator Model, Formulation, analytic solution and interpretation, stability, examples. Lotka-Volterra model for two competing species, formulation, solution and geometrical interpretation, limitations, applications. Autonomous system of two first order equations, trajectory (orbit) of the system, equilibrium, almost linear system, stability of the system.

Epidemics: Simple Epidemic Model, Formulation, Solution and Interpretation, Limitations. General Epidemic Model, Formulation, Solution and Interpretation, Kermac-Mckendrick Threshold Theorem, Limitations. Recurrent Epidemic Model, Solution and Interpretation, Limitations. Recurrent Epidemic Model, Formulation, Solution and Interpretation, Limitations. Recurrent Epidemic Model with Undamped Waves.

Economic Methods of Renewable Resource Harvesting:

The open access fishery, Gordon's model and principal results, Opportunity cost, Externality, Economic Overfishing, Cobb-Douglas Production Function, constant-return-to-scale, decreasing-return-to-scale and increasing-return-scale-properties. Interest and discount rate, concept of the *present value (PV)* of a payment due to be paid after arbitrary number of years. The harvesting model considered by the biologist M.B. Schaefer, bionomic equilibrium and economic overfishing, the optimal harvest policy in the Schaefer model

Beverton-Holt Fisheries Model:

Beverton-Holt fisheries model, natural mortality rate and fishing mortality rate, knife-edge selectivity of the fishing gear, relation between the total annual yield from all cohorts and the total life-time yield of a single cohort., dynamic optimization in the Beverton-Holt model, application of Pontryagin's Maximum Principle.

Multiple Species Model:

A model of combined harvesting of two ecologically independent fish populations assuming that fishing costs are proportional to harvesting effort, net economic revenue, bionomic equilibrium, ultimate extinction of the species, optimal harvest policy, optimal equilibrium solution, singular control. Gause's model of inter-specific competition, biotic potentials, functional response, competitive exclusion.

Harvesting competing populations, Clark's investigation.

References:

1. Thomas Malthus (1798) An Essay on the Principle of Population, J. Jonson, London.
2. A. J. Lotka (1925) Elements of Physical Biology, Williams and Wilkins, Baltimore, Md.
3. M. Martcheva (2015) An Introduction to Mathematical Epidemiology, Volume 61, New York: Springer.
4. F. Brauer and C. Castillo-Chavez (2012) Mathematical Models in Population Biology and Epidemiology (Second Edition), New York: Springer.
5. M. J. Keeling and P. Rohani (2011) Modelling Infectious Diseases in Humans and Animals, Princeton University Press.
6. C. W. Clark (1990) Mathematical Bio economics: The Optima/ Management of Renewable Resources (Second Edition), John Wiley & Sons, New York.
7. C. W. Clark (1985) Bio economic Modelling and Fisheries Management, John Wiley & Sons, New York.
8. M. B. Schaefer (1954) Some aspects of the dynamics of populations important to the management of commercial marine fisheries, Bulletin of Inter-American Tropical Tuna Commission, **1**:25-26.
9. H. S. Gordon (1954) Economic theory of a common property resource: the fishery, Journal of Political Economy, **62**: 124-142.
10. R. J. H. Beverton and S.J. Holt (1957) on the dynamics of Exploited Fish Populations, Ministry of Agriculture, Fisheries investigations series **2(19)**, London.

PG2 MATH 4014A: Operational Research-III

Full Marks: 50

Course Objectives:

1. To develop an understanding of optimality conditions and constraint qualifications in nonlinear programming.
2. To study Kuhn–Tucker and Fritz–John conditions and duality principles in nonlinear optimization.
3. To introduce numerical methods for one-dimensional and constrained optimization.
4. To develop knowledge of geometric programming and dynamic programming techniques.
5. To introduce goal programming and its graphical and simplex-based solution methods.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. understand advanced optimality conditions and constraint qualifications.
2. apply Kuhn–Tucker, Fritz–John and nonlinear programming duality concepts.
3. solve one-dimensional and constrained optimization problems.
4. apply geometric and dynamic programming techniques.
5. formulate and solve goal-programming problems.

Syllabus:

Optimization: Nature and Scope of optimization, Optimality criterion of linear programming Application of Farka's theorem, Existence theorem for linear systems, Theorems of the alternatives, Slater's theorem of alternatives, Motzkin theorem of alternatives, Saddle point optimality criteria without differentiability.

Slater's and Karlin's constraint qualifications and their equivalence, strict constraints qualification, KuhnTucker's saddle point necessary optimality theorem, Fritz-John saddle point optimality theorem, Optimality criterion with differentiability and Convexity, Kuhn-Tucker's sufficient optimality theorem,

Fritz-John stationary point optimality theorem, Duality in non-linear programming, Weak duality theorem, Wolfe's duality theorem, Duality for quadratic programming.

One-dimensional optimization: Function comparison method, Fibonacci and Golden section methods for unimodal functions.

Constrained optimization: Methods of feasible direction and cutting hyperplane method.

Geometric Programming: Geometric programming (both unconstrained and constrained) with positive and negative degree of difficulty.

Dynamic programming: Basic features of dynamic programming problems, Bellman's principle of optimality, multistage decision process-forward and backward recursive approaches, Dynamic programming approach for solving (i) linear and nonlinear programming problems, (ii) routing problem, (iii) reliability optimization problem, (iv) inventory control problem, (v) cargo loading problem (vi) Allocation problem.

Goal Programming: Introduction, Difference between LP and GP approach, Concept of Goal Programming, Graphical solution-method of Goal Programming, Modified simplex method of Goal Programming.

References:

1. Mokhtar S. Bazaraa, Hanif D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, 2006.
2. Olvi L. Mangasarian, Nonlinear Programming, Society for Industrial and Applied Mathematics, 1994.
3. S.S. Rao, Engineering Optimization: Theory and Practice, John Wiley & Sons, 1996.
4. Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2010.

PG2 MATH 4014B: Fluid Mechanics –III

Full Marks: 50

Course Objectives:

1. To introduce the mathematical and statistical description of turbulent fluid motion.
2. To develop an understanding of Reynolds-averaged Navier–Stokes equations and Reynolds stresses.
3. To study free-shear turbulent flows and turbulent boundary layers.
4. To introduce two-point statistical correlations and the theory of homogeneous and isotropic turbulence.
5. To develop an understanding of turbulence modelling and its limitations.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. describe turbulent motion using statistical concepts such as homogeneity, isotropy, stationarity, and ergodicity.
2. formulate Reynolds-averaged equations and interpret Reynolds stress and eddy-viscosity concepts.
3. analyze turbulent wakes, mixing layers, jets, pipe flows, and turbulent boundary layers.
4. interpret two-point correlation functions and apply the Kármán–Howarth equation to isotropic turbulence.
5. compare one-equation and two-equation turbulence models and recognize their applicability and limitations.

Syllabus:

Turbulent Flows: Nature of turbulent motion, Statistical description of turbulent flow, Statistical symmetry, Self-preserving turbulence, Homogeneous and isotropic turbulence, Statistical stationary and stationary increments, Ergodicity and fully developed turbulence, Reynolds Averaged Navier-Stokes Equations, Reynolds stress tensor, Eddy viscosity, Closure problem, Phenomenological theories, Mixing length, Prandtl's momentum transfer theory, Taylor's vorticity transfer theory, Karman similarity hypothesis, velocity distribution in channel flow under constant pressure gradient.

Spread of Turbulence: Free-shear turbulent flows, Mixing layer between two parallel flows, Turbulent wake, Turbulent boundary layer flow in a planar jet, Turbulent flow through smooth circular pipe, Seventh power velocity distribution law.

Two-point statistics: Double correlation between velocity components, Triple and multi correlation functions, Longitudinal and lateral correlations, Correlations in homogeneous and isotropic turbulence, Self-similarity, Karman-Howarth equation, Decay of isotropic turbulence.

Turbulent boundary layer flows: Description of turbulent boundary layer flows, Mean momentum equations, Two-layer hypothesis, Overlap region, Logarithmic law, Channel flow and Couette flow.

Turbulence models: Eddy viscosity and mixing length models and their limitations, One equation and two-equations models, Remarks on turbulence modelling.

References:

1. Frisch, U., Turbulence: The Legacy of A. N. Kolmogorov (Cambridge University Press, Cambridge, 1995).
2. Pope, S.B., Turbulent Flows, Cambridge University Press, 2000.
3. Batchelor, G. K., The Theory of Homogeneous Turbulence, Cambridge University press, 1953.
4. Hinze, J.O., Turbulence, 2nd edition (McGraw-Hill, New York, 1977).

PG2 MATH 4014C: Advanced Algebra -II

Full Marks: 50

Course Objectives:

1. To study Noetherian and Artinian modules and their composition structures.
2. To develop an understanding of semisimple rings and the Wedderburn–Artin theorem.
3. To study prime, semiprime, regular, and primitive rings.
4. To understand Jacobson semisimple rings and their relationships with other classes of rings.
5. To introduce subdirect sums and representation theorems for rings and Boolean rings.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. analyze Noetherian and Artinian modules using composition series and simple modules.
2. characterize semisimple rings and apply the Wedderburn–Artin theorem.
3. distinguish and analyze prime, semiprime, regular, and primitive rings.
4. establish relationships among semisimple, regular, and Jacobson semisimple rings.
5. apply subdirect decomposition and representation theorems, including Stone's representation theorem.

Syllabus:

Noetherian module and Artinian module, composition series, simple and semi simple modules, semi simple ring, Group ring, Characterizations of semi simple ring, Wedderburn-Artin theorem on semi simple ring, simple ring, characterization of Artinian simple ring.

Prime and semiprime ideal, m -system and n -system, prime radical, prime rings, semiprime ring, ring derivation on prime and semiprime rings.

Jacobson semi simple ring, relation between Jacobson semi simple ring and semi simple ring, regular ring, idempotents in regular rings, lifting of idempotents, relation among semi simple ring, regular ring and Jacobson semi simple ring, primitive ring, structure of primitive ring, Jacobson-Chevalley density theorem, Wedderburn-Artin theorem on primitive ring.

Subdirect sum of rings, Representation of a ring as a subdirect sum of rings, sub directly irreducible ring, Birkhoff theorem on sub directly irreducible ring, sub directly irreducible Boolean ring, Stone Representation Theorem.

References:

1. T.Y. Lam; Noncommutative Rings; Springer-Verlag.
2. I.N. Herstein; Noncommutative rings; Carus monographs of AMS, 1968.
3. N. Jacobson; Structure of Rings; AMS.
4. L.H. Rowen; Ring theory (student edition); Academic Press, 1991.
5. T.W. Hungerford; Algebra; Springer, 1980.

PG2 MATH 4014D: Algebraic Topology -I

Full Marks: 50

Course Objectives:

1. To introduce homotopy, homotopy equivalence, contractibility, and deformation retracts.
2. To develop the theory of fundamental groups and their applications.
3. To study covering spaces, lifting properties, and the Monodromy theorem.
4. To introduce major topological fixed-point and separation results.
5. To develop the relationship between fundamental groups and topological properties of spaces.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. determine and analyze homotopy relations, homotopy classes, and deformation retracts.
2. compute and interpret fundamental groups of important spaces.
3. apply the Van Kampen theorem and covering-space techniques.
4. use lifting properties and covering projections to investigate fundamental groups.
5. explain and apply results such as the Fundamental Theorem of Algebra, Brouwer Fixed Point Theorem, Borsuk-Ulam Theorem, and Ham-Sandwich Theorem.

Syllabus:

Homotopy between continuous maps, homotopy relative to a subset, homotopy class, null homotopy, contractibility of spaces, homotopy equivalent spaces, homotopy properties.

Deformability, deformation retracts, strong deformation retracts, homotopy between paths, product of paths, fundamental group $\Pi(X, x)$ of a space X based at the point $x \in X$, induced homomorphism and related properties, simply connected space, special Van Kampen theorem and fundamental group of S^n ($n \geq 2$).

Fundamental Group of S^1 , fundamental group of the product and of Torus, $\mathbb{R}^2$ and $\mathbb{R}^n$ ($n > 2$) are not homeomorphic.

Fundamental theorem of algebra and Brouwer fixed point theorem, covering projection, covering spaces, lifting of paths and homotopies, the fundamental group of a covering space. the Monodromy theorem, the Borsuk-Ulam theorem and Ham-Sandwich theorem.

References:

1. A. Dold; Lectures on Algebraic Topology; Springer-Verlag (1972).
2. W. Fulton; Algebraic Topology: A First Course; Springer-Verlag (1995).
3. M. Greenberg; Lectures on Algebraic Topology; W. D. Benjamin, N.Y. (1967).
4. Allen Hatcher; Algebraic Topology; Cambridge Univ. Press (2002).
5. C. Kosniowski; A First Course in Algebraic Topology; Cambridge University Press (1980).
6. W. S. Massey; Algebraic Topology: An Introduction; Springer-Verlag, N.Y. (1990).
7. James R. Munkres; Topology (2nd Edit.); Pearson Education Inc. (2004).
8. E. H. Spanier; Algebraic Topology; McGraw Hill Book Co. N.Y. (1966).
9. C. T. C. Wall; A Geometric Introduction to Topology; Addison-Wesley Publ. Co. Inc (1972).

Course Objectives:

1. To introduce Banach algebras, spectra, spectral radius, and Gelfand theory.
2. To develop an understanding of C^* -algebras and their fundamental elements.
3. To study C^* -homomorphisms, subalgebras, and spectral properties.
4. To introduce the Spectral Theorem and positive linear functionals.
5. To develop an understanding of states and the GNS construction.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. analyze elements of Banach algebras using spectra, resolvents, and spectral radius.
2. identify and work with self-adjoint, unitary, normal, positive, and projection elements in C^* -algebras.
3. apply Gelfand transforms and spectral mapping results.
4. analyze C^* -homomorphisms, subalgebras, and representations of commutative C^* -algebras.
5. explain positive linear functionals, states, and the GNS construction.

Syllabus:

Banach Algebra Definition of Banach algebra and examples, Singular and Non-singular elements, The spectrum of an element, The spectral radius, Gelfand formula, Multiplicative linear functionals and the maximal ideal space, Gleason-Kahane-Zelazko theorem, The Gelfand Transforms, The spectral mapping theorem, Isometric Gelfand transform. C^* - Algebras: Definition of C^* -Algebras and examples, Self-adjoint, Unitary, Normal, Positive and Projection elements in C^* -Algebras, Commutative C^* -Algebras, C^* -Homomorphisms, Representation of commutative C^* -Algebras, subalgebras and the spectrum, The Spectral Theorem, Positive linear functionals in C^* -algebras, States and the GNS construction. Group discussion on some concepts like the spectrum of an element, Gleason-Kahane-Zelazko theorem, C^* -Homomorphisms, will be conducted. Assignments will be given on subalgebras and the spectrum, the Spectral Theorem, Positive linear functionals in C^* -algebras.

References:

1. Bonsall and Duncan, Complete Normed algebras, Springer-Verlag.
2. Kadison and Ringrose, Fundamentals of operator theory, Vol. I and II, Academic press.
3. Rickart, General theory of Banach Algebras: Van Nostrand.
4. W. Arveson, An invitation to C^* -Algebras, Springer-Verlag.
5. Palmer, Banach Algebras and the general theory of C^* -algebras, Cambridge University Press.

PG2 MATH 4014F: MOOC Course**Full Marks: 50**

The course will be selected based on its availability on the MOOC platform and must be compatible with the Mathematics curriculum. The chosen MOOC should carry 4 credits. The University will conduct the examination and evaluation in accordance with the guidelines prescribed for the respective MOOC.

Course Objectives:

1. To introduce the fundamental concepts and mathematical techniques of optimal control theory.
2. To develop an understanding of reliability, maintainability, availability, and reliability optimization.
3. To introduce information theory, entropy, channel capacity, and encoding techniques.
4. To develop skills in project planning and management using PERT and CPM techniques.
5. To introduce stochastic programming and multi-objective nonlinear programming.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. understand and apply optimal-control techniques and Pontryagin's principle.
2. analyze reliability, maintainability and availability of systems.
3. apply information-theory concepts such as entropy, channel capacity and encoding.
4. plan and control projects using PERT/CPM and resource-allocation techniques.
5. understand stochastic programming and multi-objective nonlinear programming.

Syllabus:

Optimal Control Theory: Introduction to Optimal Control: Control and Optimal Control, Examples, The Basic Optimal Control Problem, Variational Calculus; Optimal Control with Unbounded Continuous Controls: The Hamiltonian, Extension to Higher Order Systems; Bang-Bang Control, Pontryagin's Principle, Switching Curves, Transversality Conditions; Applications of Optimal Control in Economic Growth, Exploited Populations, and Advertising Policies.

Reliability: Definition of reliability, Measures of reliability, system reliability, System Failure rate, reliability of different systems, like series, parallel, series parallel, parallel-series, k-out-of-n, etc., MTBF, MTTF, optimization using reliability, reliability and quality control comparison, reduction of life cycle with reliability, maintainability, availability, Effect of age, stress, and mission time on reliability. Idea of reliability optimization.

Information Theory: Introduction, Communication Processes— memory less channel, the channel matrix, Probability relation in a channel, noiseless channel. Measure of information- Properties of Entropy function, Measure of other information quantities — marginal and joint entropies, conditional entropies, expected mutual information, Axiom for an Entropy function, properties of Entropy function. Channel capacity, efficiency and redundancy. Encoding-Objectives of Encoding. Shannon-Fano Encoding Procedure, Necessary and sufficient Condition for Noiseless Encoding.

Project Network: PERT and CPM: Introduction, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis, Probability in PERT analysis, Project Time-Cost, Trade-off, Updating of the project, Resource allocation — resource smoothing and resource levelling.

Stochastic Programming: Chance constraint programming technique.

Multi-objective Non-linear Programming: Introductory concept and solution procedure.

Texts / References:

1. Swarup, K., Gupta, P. K and Man Mohan, Operation Research, Sultan Chand & Sons.
2. Sharma, J.K Operation Research – Theory and Application, Macmillan.
3. Gupta, P.K. and Hira, D.S., Operation Research, S. Chand & Co. Ltd.
4. Taha H.A., Operation Research –an Introduction, PHI.
5. Bronson, R. and Naadimuthu. G., Theory and problems of Operations Research, Schum's Outline Series, MGH.

Course Objectives:

1. To introduce the fundamental principles of electrodynamics and their mathematical formulation through Maxwell's equations.
2. To develop an understanding of electrically conducting fluids and the basic equations of magnetohydrodynamics.
3. To study MHD approximations, conservation laws, and dimensionless parameters such as the Lundquist criterion.
4. To introduce MHD wave propagation, including Alfvén waves and flux-freezing phenomena.
5. To study steady, unsteady, magnetohydrostatic, force-free, and geomagnetic MHD phenomena.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. formulate and interpret Maxwell's equations, electromagnetic boundary conditions, and the Poynting theorem.
2. formulate the basic MHD equations and analyze the interaction between conducting fluids and electromagnetic fields.
3. apply conservation laws and dimensional analysis to MHD flows.
4. explain Alfvén's theorem, flux freezing, magnetic diffusion, and Alfvén wave propagation.
5. analyze standard MHD problems such as Hartmann flow, Couette flow, pinch configurations, and dynamo processes.

Syllabus:

Electrodynamics: Laws of electrodynamics, Electro-magnetic fields, Electromagnetic induction, Faraday's law, Energy in magnetic field, Maxwell's equations, Reminder of electrodynamics laws before Maxwell, Physical significance of Maxwell's equations, Related boundary conditions, Energy transfer and Poynting theorem.

Magnetohydrodynamics: Physical description of electrically conducting fluids, Maxwell's electromagnetic field equations, Basic MHD equations, Energy flow, Lorentz force, Ohm's law.

MHD approximations: The low frequency dynamics of the electromagnetic field, Conservation laws for mass, momentum and energy in MHD, Dimensional analysis and Lundquist criterion, Convection dominated flows.

MHD wave propagation: The full significance of Faraday's law, Faraday's law in ideal conductor, Alfvén's theorem and its physical interpretation, Flux-freezing phenomena, Diffusion dominated case, Physical interpretation of Lorentz force, Alfvén waves.

Steady MHD flow: Parallel steady flow, One-dimensional steady viscous flow, Hartmann flow, Couette flow.

Unsteady MHD flow: MHD Rayleigh problem.

Magnetohydrostatics: Basic equations, Pinch effect, Linear pinch, Stability of pinch configurations with applications.

Force free-field: Basic equations and their general solutions, Toroidal and Poloidal fields

Geo-magnetism: Dynamo problem in earth, Dynamo theory, Symmetric fields, Cowling's theorem, Isorotation, Ferraro's law of isorotation.

References:

1. Cowling, T.G., Magnetohydrodynamics, Interscience Publishers Ltd., 1956.
2. Ferraro, V.C.A. & Plumpton, C., An introduction to Magneto-Fluid Mechanics, Clarendon Press, 1966.
3. Shercliff, J.A., A text book of Magnetohydrodynamics, Pergaman Press, 1965.
4. Davidson, P. A., An Introduction to Magnetohydrodynamics, Cambridge University Press, 2001.

Course Objectives:

1. To introduce categories, morphisms, functors, and natural transformations.
2. To develop an understanding of representable functors and Yoneda's lemma.
3. To study adjoint functors, limits, colimits, pullbacks, and pushouts.
4. To introduce lattice theory and its fundamental structures.
5. To study distributive, complete, semimodular, and Boolean lattices and their representation theorems.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. formulate mathematical structures in categorical terms using objects, morphisms, and functors.
2. distinguish special morphisms and apply natural transformations and Yoneda's lemma.
3. construct and analyze limits, colimits, pullbacks, pushouts, and adjunctions.
4. analyze lattices, ideals, congruences, and lattice homomorphisms.
5. apply representation theorems for distributive lattices, Boolean algebras, and related structures.

Syllabus:

Category, examples, dual category, special morphisms, monic and epic, retraction and co retraction, Functor, forgetful functor, faithful functor, product category, bifunctor, natural transformation, representable functor, embedding, Yoneda's lemma and its applications, Adjoint functor, Initial object, terminal object, zero object, Limit and colimit, pull back diagram and push out diagram.

Lattice, sublattice, generators of a sublattice, ideal, dual ideal, homomorphisms and isomorphisms, congruences, distributive lattice, characterization theorems and representation theorems on distributive lattice, complete lattice, structure of the lattice of congruences of lattices, semi modular lattices, characterization theorems and representation theorems, Stone's representation theorem on Boolean Algebra, algebraic lattice – characterization theorems and representation theorems, correspondence between ideals and congruences of lattices, Boolean Algebra and generalized Boolean Algebra.

References:

1. S. MacLane; Category theory for working mathematician; Springer-Verlag.
2. B. Mitchel; Theory of categories; Academic Press (1969).
3. G. Szasz – Lattice Theory
4. G. Birkhoff – Lattice Theory
5. B. H. Arnold – Logic and Boolean Algebra
6. D. E. Rutherford – Lattice Theory

PG2 MATH 4015D: Algebraic Topology -II**Full Marks: 50****Course Objectives:**

1. To introduce simplicial complexes, simplicial mappings, and simplicial homology.
2. To develop techniques for computing homology groups and related invariants.
3. To study singular homology, Mayer–Vietoris sequences, and homotopy invariance.
4. To introduce CW-complexes, cellular homology, and Euler characteristic.
5. To study homology with coefficients and the Künneth formula.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. construct simplicial complexes and compute their simplicial homology groups.
2. determine Betti numbers and torsion coefficients using homological methods.
3. compute singular homology and apply the Mayer–Vietoris sequence.

4. analyze CW-complexes using cellular homology and Euler characteristic.
5. apply the Universal Coefficient Theorem and Künneth formula to suitable spaces.

Syllabus:

Barycentric co-ordinates, simplex, geometric complexes and polyhedrons, simplicial mappings and simplicial approximation theorem. Oriented complexes, incidence numbers, chains, cycles and boundaries; Simplicial homology groups, computation of simplicial homology groups, the decomposition theorems for abelian groups, Betti numbers and torsion coefficients.

Computation of singular homology groups, Mayer-Vietoris sequence; Homotopy invariance; Equivalence of simplicial and singular homology; Relation between fundamental group and first homology group. Borsuk Ulam theorem, Brouwer's no-retraction theorem, Brouwer fixed point theorem, Invariance of dimensions, etc.

Relative homology and Excision theorem

CW-complex, sub-complex and CW-pairs; Euler characteristic, Euler- Poincare theorem.

Simplicial approximation to CW-complex. Computation of homology of CW-complex.

Degree of a map from a sphere to itself; Cellular homology of a CW-complex; Isomorphism between singular and cellular homology of a CW-complex.

Homology with coefficient and Universal coefficient theorem.

Kunneth formula for homology of the product of two spaces.

References:

1. G.E.Bredon; Topology and Geometry; Springer-Verlag GTM 139 (1993).
2. A.Dold; Lectures on Algebraic Topology; Springer-Verlag (1980).
3. W.Fulton; Algebraic Topology, A First Course; Springer-Verlag (1995).
4. M. J. Greenberg and J. R. Harper; Algebraic Topology : A first course; Perseus Books (Mathematical Lecture Notes series) (1981).
5. A.Hatcher; Algebraic Topology; Cambridge University Press (2002).
6. William S.Massey; A Basic Course in Algebraic Topology; Springer-Verlag, New York Inc.(1993).
7. C.R.F.Maunder; Algebraic Topology; Dover Pub. N.Y. (1996).
8. J.J.Rotman; An Introduction to Algebraic Topology; Springer-Verlag, N.Y. (1988).
9. H.Schubert; Topology; Macdonald Technical and Scientific, London (1964).
10. James W. Vick; Homology Theory : An introduction to Algebraic Topology; Springer-Verlag, N. Y.(1994).

PG2 MATH 4015E: Operator Algebra -II

Full Marks: 50

Course Objectives:

1. To introduce von Neumann algebras and their fundamental structural properties.
2. To study commutants, double commutants, and the Kaplansky density theorem.
3. To develop an understanding of Abelian von Neumann algebras and their representations.
4. To study projection lattices, central projections, and different types of projections.
5. To develop familiarity with advanced operator-algebraic structures through project work and seminars.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. identify and analyze von Neumann algebras and their operator-theoretic structures.
2. apply the commutant and double-commutant framework and understand Kaplansky density.
3. analyze Abelian von Neumann algebras and their representations.
4. work with projection lattices, centres, cyclic and separating vectors, and related structures.
5. present and discuss selected advanced topics in operator algebras through project/seminar work.

Syllabus:

Von Neumann Algebras: Von Neumann algebras, Monotone sequence of operators, Range Projections, The Commutant, The doublecommutant theorem, The Kaplansky density theorem, L^∞ as Von Neumann algebra, Maximal Abelian algebras, Abelian Von Neumann algebras, Cyclic and separating vectors, Representation of Abelian Von Neumann algebras, The L^∞ functional calculus, Connectedness of the unitary group, The projection lattice, Kaplansky's formula, The centre of a Von Neumann algebra, Various types of projections. Project work and seminar will be conducted on The Kaplansky density theorem, L^∞ as Von Neumann algebra, Connectedness of the unitary group, The projection lattice, Kaplansky's formula, The centre of a Von Neumann algebra etc.

References:

1. Bonsall and Duncan, Complete Normed algebras, Springer-Verlag.
2. Kadison and Ringrose, Fundamentals of operator theory, Vol. I and II, Academic press.
3. Rickart, General theory of Banach Algebras,; Van Nostrand.
4. W. Arveson, An invitation to C^* -Algebras, Springer-Verlag.
5. Palmer, Banach Algebras and the general theory of C^* -algebras, Cambridge University Press.

PG2 MATH 4015F: MOOC Course

Full Marks: 50

The course will be selected based on its availability on the MOOC platform and must be compatible with the Mathematics curriculum. The chosen MOOC should carry 4 credits. The University will conduct the examination and evaluation in accordance with the guidelines prescribed for the respective MOOC.

PG2 MATH 4032: Dissertation & Field Visit

Full Marks: 50

Dissertation

Full Marks: 40 (Project Work-20, Presentation-10 & VivaVoce-10)

Project Work of each student will be evaluated by the concerned internal teacher/supervisor and one External Examiner.

Field Visit

Full Marks: 10

Field Visit will be done according to the decision of the Department in every year.

Course Work + Research

Semester-III

PG2 MATH 3011: Functional Analysis

Full Marks: 50

Course Objectives

1. To develop a rigorous understanding of normed linear spaces, Banach spaces, inner product spaces, and Hilbert spaces and their fundamental properties.
2. To introduce the concepts of bounded linear operators and linear functionals and develop the ability to analyze their properties.
3. To familiarize students with fundamental results of functional analysis, including the Hahn–Banach Theorem, Uniform Boundedness Principle, Open Mapping Theorem, and Closed Graph Theorem.
4. To develop an understanding of dual spaces, quotient spaces, orthogonality, projections, and approximation in normed and inner product spaces.
5. To introduce the theory of operators on Hilbert spaces, including adjoint, self-adjoint, normal, unitary, and positive operators.
6. To develop students' ability to apply abstract functional-analytic concepts to mathematical problems and proofs.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. analyze normed and Banach spaces: Define and distinguish normed linear spaces and Banach spaces, establish their basic properties, and work with equivalent norms, finite-dimensional spaces, and quotient spaces.
2. apply fundamental theorems: Apply the Riesz Lemma, best approximation property, Hahn–Banach Theorem, Uniform Boundedness Principle, Open Mapping Theorem, and Closed Graph Theorem to appropriate problems.
3. understand Hilbert spaces: Explain the structure and properties of inner product and Hilbert spaces and apply the Cauchy–Schwarz inequality, parallelogram law, orthogonality, and projection concepts.
4. work with orthonormal systems: Construct and analyze orthonormal and complete orthonormal systems and apply Bessel's inequality and Parseval's identity to problems in Hilbert spaces.
5. classify special operators: Identify and establish basic properties of self-adjoint, normal, unitary, and positive operators and apply related results to elementary problems in functional analysis.

Syllabus:

Normed Linear Space (NLS), Banach Space and its basic properties, Equivalent norms, Finite dimensional NLS, Heine – Borel Theorem, Riesz Lemma and best approximation property, Quotient space of normed linear space and its completeness, bounded linear operators and its basic properties, Space of bounded linear operators, uniform boundedness principle and some applications, Open Mapping Theorem, Closed Graph Theorem, Linear functional, Hahn-Banach Theorem, Dual Space, Inner Product Space (IPS), Hilbert Space, orthonormal basis, Complete orthonormal basis, Cauchy-Schwarz inequality, Parallelogram law, Bessel's inequality, Parseval's identity, Orthogonal complement and Projection Theorem, Inner product is a continuous operator, Relation between IPS and NLS, Strong and weak convergence of sequence of operators, Reflexivity of Hilbert Space, Riesz Representation Theorem for bounded linear functional on a Hilbert Space, Adjoint of an operator on a Hilbert Space, Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related simple theorems.

References

1. B.V. Limaye, Functional Analysis, 2nd Edition, New Age International Private Limited New Delhi, 2014.
2. J. B. Conway, A Course in Functional Analysis, 2nd Edition, Springer-Verlag New York, 1985.
3. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1989.

PG2 MATH 3012: Advanced Numerical Analysis

Full Marks: 50

Course Objectives:

1. To enhance the problem-solving skills using numerical methods.
2. To handle large system of equations, non-linearity and that are often impossible to solve analytically
3. To solve ordinary and partial differential equations by numerical methods

Course Learning Outcomes:

After completion of this course, students will be able to

1. apply advanced interpolation, approximation, curve fitting, numerical integration, and polynomial root-finding techniques to solve mathematical and scientific problems.
2. analyze and solve systems of linear and nonlinear algebraic equations using direct and iterative numerical methods, and evaluate their convergence, stability, and computational efficiency.
3. implement numerical methods for ordinary differential equations and boundary value problems, including Runge–Kutta, predictor–corrector, shooting, finite difference, and finite element methods.
4. develop and analyze numerical schemes for solving partial differential equations using finite difference methods, including explicit, implicit, and Crank–Nicolson methods, while assessing their stability, consistency, and convergence.

Syllabus:

Cubic spline interpolation, Lagrange's bivariate interpolation, Approximation of function, Chebyshev polynomial: Minimax property, Curve fitting by least square method, Use of orthogonal polynomials, Economization of power series.

Numerical integration: Newton-Cotes formulae-open type, Gaussian quadrature: Gauss-Legendre, Gauss Chebyshev, Integration by Monte Carlo method.

Roots of polynomial equation: Bairstow method.

System of linear equations: Pivoting, Matrix inverse, LU decomposition method, Tri-diagonal system of equations, Ill-conditioned linear systems, Relaxation method.

System of non-linear equations, Fixed point method, Newton methods, Convergence, Rate of convergence.

Eigen value problem, Power method, Jacobi's method.

Ordinary differential equation: Runge-Kutta method for linear ODEs and second order IVP, Predictor corrector method: Milne's method, Stability, second order BVP: Shooting method, finite difference method, finite element method.

Partial differential equation: Finite difference scheme, Explicit and implicit methods of Hyperbolic and Parabolic equations, Crank-Nicolson method, Elliptic equation, Stability, Consistency and convergence.

References:

1. A. Gupta and S.C. Bose, Introduction to Numerical Analysis, Academic Publishers, Calcutta, 1989.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, 1984.
3. E.V. Krishnamurthy and S.K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
4. J.H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, 2nd ed. Prentice Hall, Inc., N.J., U.S.A., 1992.
5. E.A. Volkov, Numerical Methods, Mir Publishers, Moscow, 1986.

Course Objectives:

1. To develop a systematic understanding of deformation, strain, and stress in continuous media.
2. To introduce the mathematical formulation of conservation laws for mass, momentum, and energy.
3. To study the fundamental concepts and governing equations of classical elasticity.
4. To develop an understanding of fluid media, including path lines, streamlines, and bounding surfaces.
5. To introduce the mathematical theory of water waves, including progressive and stationary waves.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. formulate and interpret finite and infinitesimal strain tensors, principal strains, and strain invariants.
2. analyze stress tensors, stress transformations, principal stresses, and equilibrium conditions.
3. apply conservation laws and derive the fundamental equations of continuum mechanics.
4. formulate and analyze constitutive relations and field equations for isotropic elastic media.
5. analyze basic water-wave problems, including wave energy, particle paths, and group velocity.

Syllabus:

Theory of strain: Configuration of a continuous medium, Continuum hypothesis, Material & Spatial description, Deformation Gradients, Strain measures, Finite strain tensors. Small deformation theory, infinitesimal strain tensor. Relative displacement, Rotation tensor. Interpretation of linear strain tensors. Stretch ratio. Finite strain interpretation. Principal strains. Strain invariant. Cubical dilatation. Saint Venant's Compatibility equation for strain.

Theory of Stress: Body force. Surface forces. Cauchy's stress principle. Stress vector. State of stress at a point. Stress tensor. Stress vector–stress tensor relationship. Stress equation of equilibrium, Stress tensor symmetry, Stress quadric of Cauchy. Stress transformation laws, Principal stress. Stress invariant. Stress ellipsoid, extremum normal stress and shearing stress.

Conservation Laws: Reynold's Transport Theorem, Conservation of mass, Equation of continuity, Principle of conservation of momentum, Cauchy's first equation of motion, Cauchy's second equation of motion, Conservation of energy, First law of Thermodynamics.

Elasticity: Ideal materials, Classical elasticity, Generalized Hooke's Law, Isotropic materials, Constitutive equation (stress-strain relations) for isotropic elastic solid, Strain-energy function, Beltrami-Michell compatibility equations for stresses, Field equations of linear elasticity, Fundamental boundary value problems of elasticity and uniqueness of their solutions (Statement only), Saint-Venant's principle. Hook's law, Strain energy function, Isotropic media, Waves in isotropic elastic media, Navier's equations of motion.

Fluid media: Path lines, stream lines and streak lines, Bounding surface, Lagrange's criterion for bounding surface.

Water Waves: General features, Condition at the free surface, Cisotti's equation, Complex potential, energy and path of particles for progressive waves and stationary waves, group velocity.

References:

1. Mechanics of Continua: A. C. Eringen, Wiley, 1967.
2. Mathematical Theory of Continuum Mechanics: R. N. Chatterjee (Narosa Publishing House, New Delhi, 1999).
3. Continuum Mechanics: T. J. Chung, Prentice Hall.

4. Continuum Mechanics: Schaum's out line of Theory and Problems of Continuum Mechanics:
5. Gedrge R. Mase, Mc Graw Hill.
6. Continuum Mechanics: D. S. Chandra Sekharaiah and L. Debnath, Academic Press.
7. Continuum Mechanics: A.J.M. Spencer, Long man.
8. Mathematical theory of Elasticity: I. S. Sokolnikoff, Tata Mc Grow Hill Co.

PG2 MATH 3014A: Operational Research-I

Full Marks: 50

Course Objectives:

1. To develop an understanding of advanced linear programming and simplex-based optimization techniques.
2. To introduce decomposition, parametric, and post-optimality analysis of large-scale optimization problems.
3. To study convexity, integer programming, and algorithms for solving integer optimization problems.
4. To develop knowledge of classical and quadratic programming techniques.
5. To introduce modern unconstrained optimization methods such as gradient, Newton, conjugate-gradient, and quasi-Newton methods.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. solve linear programming problems using revised and dual simplex methods.
2. perform parametric and post-optimality analysis of optimization problems.
3. apply convexity concepts and integer programming techniques.
4. solve quadratic and constrained optimization problems.
5. apply gradient, Newton, conjugate-gradient and quasi-Newton methods.

Syllabus:

Revised simplex method (with and without artificial variable). Modified dual simplex.

Large Scale Linear Programming: Decomposition Principle of Dantzig and Wolf.

Parametric and post-optimal analysis: Change in the objective function. Change in the requirement vector, Addition and deletion of variables, Addition and deletion of constraints., Parametric analysis of cost and requirement vector.

Convex and concave functions: Basic properties and some fundamental theorems of convex/concave functions, Differentiable convex and concave functions.

Integer Programming: Gomory's cutting plane algorithm, Gomory's mixed integer programming algorithm, Branch and bound algorithm.

Classical optimization techniques: Single variable optimization, multivariate optimization (with no constraint, with equality constraints and with equality-inequality constraints).

Quadratic Programming: Wolfe's modified simplex method, Beale's method, convex programming.

Unconstrained optimization: Gradient methods, Steepest descent method, conjugate gradient method, Newton's method, Quasi-Newton's method, Daviddon-Fletcher-Powel method.

Texts / References:

1. Edwin K. P. Chang & S. Zak. An Introduction to Optimization. John Wiley & Sons Inc., 2004.
2. S. S. Rao. Engineering optimization: theory and practice. John Wiley & Sons, 2009.
3. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
4. Belegundu, Ashok D., and Tirupathi R. Chandrupatla. Optimization concepts and applications in engineering. Cambridge University Press, 2011.
5. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.

Course Objectives:

1. To introduce the fundamental concepts, assumptions, and classifications of fluid mechanics.
2. To develop an understanding of inviscid and irrotational fluid motion.
3. To study velocity potential, circulation, stream functions, and complex potential methods.
4. To introduce vortex motion and the fundamental theorems governing vorticity.
5. To develop the mathematical formulation of viscous incompressible flows and their applications.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. classify fluid motion and formulate basic equations governing inviscid fluid flow.
2. apply Euler's equation, Bernoulli's equation, and Helmholtz's equation to appropriate fluid-flow problems.
3. analyze two-dimensional and three-dimensional irrotational flows using velocity potential, stream function, and complex potential.
4. analyze vortex motion and apply Helmholtz's theorems and related results.
5. formulate and apply the Navier–Stokes equations to standard viscous flows such as Poiseuille and Couette flows.

Syllabus:

Basic concepts of fluid: Continuum hypothesis, Fluid and its classification, Newton's law of viscosity, Classification of fluid motion.

Inviscid fluid: Inviscid incompressible fluid, Constitutive equation, Euler's equation of motion & its vector invariant form, Bernoulli's equation and applications to some special cases, Helmholtz's equation for vorticity, impulsive generation of motion and some properties, Boundary Conditions.

Irrotational motion of fluid: Irrotational motion, Velocity potential, Circulation, Kelvin's circulation theorem, Irrotational motion in simply connected and multiply connected regions, Kelvin's theorem of minimum kinetic energy, Acyclic irrotational motion and some properties (Using Green's theorem), Stream function, Complex potential, Two dimensional motion, Source, sink and doublets for two dimensional flows, Complex potentials for simple source, sink and doublet, Circle theorem, Uniform flow past a circle, Image of a source with respect to a plane boundary, image of a source outside a circle, image of a doublet outside a circle, Motion of translation and rotation of circular cylinder in an infinite liquid, Blasius theorem, Kutta-Joukowski's theorem, Axi-symmetric motion, Stokes' stream function, Three-dimensional motion, Source, sink, doublet for three dimensional flows.

Vortex motion: Vortex lines, vortex filaments and vortex surface, Helmholtz's theorems for vorticity, rectilinear vortices, Vortex pair and doublets, Image of a vortex with respect to a circle.

Flow of viscous incompressible fluid: Viscous incompressible fluid, Navier Stokes' Equations of motion, Boundary conditions, Reynolds number and its significance, Poiseuille flow, Couette flow, Flow through parallel plates, Flow through pipes of circular and elliptic cross sections, Vorticity transport equation, Energy dissipation due to viscosity.

References:

1. Ramsay, A.S., Hydrodynamics (Bell).
2. Kundu, P.K. & Cohen, I.M., Fluid Mechanics, 4th edition (Academic Press, 2008).
3. Lamb, H., Hydrodynamics (Cambridge)
4. Landau, L.D., Lifchiz, E.M., Fluid Mechanics (Pergamon), 1959
5. Milne-Thomson, I.M., Theoretical Hydrodynamics
6. Chorlton, F., Textbook of Fluid Dynamics, Van Nostrand Reinhold Co., London, 1990.

Course Objectives:

1. To develop a deeper understanding of modules, submodules, quotient modules, and module homomorphisms.
2. To introduce exact sequences, tensor products, projective, injective, and flat modules.
3. To study ideals, radicals, localization, and rings of fractions.
4. To understand Noetherian and Artinian rings and their fundamental properties.
5. To introduce primary decomposition and major structural results in commutative algebra.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. analyze modules and establish relationships through homomorphisms, isomorphisms, and exact sequences.
2. construct and apply tensor products and distinguish projective, injective, and flat modules.
3. work with radicals, localization, and extensions and contractions of ideals.
4. identify and apply the properties of Noetherian and Artinian rings.
5. apply the Hilbert Basis Theorem, Cohen's theorem, and primary decomposition in appropriate algebraic settings.

Syllabus:

Module, Submodule, Quotient module, Homomorphism and isomorphism of modules, Exact sequences, short and split exact sequences, tensor product of modules, definition and existence, universal mapping property, further properties of the tensor product of modules, projective modules, injective modules, flat Modules, direct sum of projective modules, direct product of injective modules.

Nilradical and Jacobson radical, Chinese remainder theorem, extension and contraction of ideals, rings and modules of fractions, local ring, characterizations of local ring, localization, Extended and contracted ideals in rings of fractions, Noetherian rings, Artinian rings, Hilbert Basis Theorem, Cohen's Theorem, Primary Decomposition in Noetherian Rings.

References:

1. Dummit, D.S. and Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.
2. Atiyah, M., MacDonald, I.G., Introduction to Commutative Algebra, Addison-Wesley, 1969.
3. Lang, S., Algebra, Addison-Wesley, 1993.
4. Lam, T.Y., A First Course in Non-Commutative Rings, Springer Verlag.
5. Hungerford, T.W., Algebra, Springer.
6. Jacobson, N., Basic Algebra, II, Hindusthan Publishing Corporation, India.
7. Gopalakrishnan, N. S., Commutative Algebra, 2nd edition, Orient Blackswan, 2015.
8. Balwant Singh, Basic Commutative Algebra, World Scientific Publishing Co Pte Ltd,

PG2 MATH 3014D: Advanced Topology –I**Full Marks: 50****Course Objectives:**

1. To introduce nets, filters, directed sets, and their role in general topology.
2. To develop convergence-based characterizations of topological properties.
3. To study arbitrary product spaces and their compactness, connectedness, separation, and countability properties.
4. To introduce major compactification techniques, including one-point and Stone–Čech compactification.
5. To develop an understanding of metrization, paracompactness, and related embedding theorems.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. use nets, subnets, filters, and ultrafilters to study convergence and compactness.
2. characterize important topological properties using nets and filters.
3. analyze product spaces and apply Tychonoff's and embedding theorems.
4. explain and distinguish different compactification constructions.
5. apply Urysohn's and Tietze's theorems and understand the role of para compactness in metrization.

Syllabus:

Nets and Filters: Directed sets, Nets and its convergence, Cluster point of a net, Subnets, Characterization of topological properties in terms of convergence of nets, Filter, Filter associated with nets and nets associated with filters, Base and subbase of a filter, Filters in Topology, Ultra filter and its properties, ultra filter and compactness.

Product space: Product of an arbitrary family of topological spaces, Productive properties of compactness and connectedness, separation and countability axioms, Embedding Lemma and Tychonoff embedding theorem.

Compactification: One-point compactification, Stone-Cech compactification, Hausdorff compactification.

Separation and Metrization: Urysohn's lemma and Tietze Extension Theorem, Pseudometric spaces, Equicontinuity, Urysohn's embedding theorem, Urysohn's Metrization theorem, Paracompactness.

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
4. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1955.
5. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
6. Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York.

PG2 MATH 3014E: Advanced Functional Analysis –I

Full Marks: 50

Course Objectives:

1. To develop an understanding of topological vector spaces and their fundamental structures.
2. To study locally convex spaces, seminorms, Minkowski functionals, and normability.
3. To introduce fundamental functional-analytic theorems in topological vector spaces.
4. To develop an understanding of weak and weak* topologies and compact convex sets.
5. To introduce barreled and bornological spaces and their characterizations.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. identify and analyze topological vector spaces using local bases and separation properties.
2. work with seminorms, locally convex structures, quotient spaces, and criteria for normability.
3. apply the Banach–Steinhaus, Open Mapping, Closed Graph, and Hahn–Banach theorems.
4. distinguish weak and weak* topologies and apply the Banach–Alaoglu theorem.
5. characterize barreled and bornological locally convex spaces.

Syllabus:

Topological vector spaces: Definition and different examples of Topological vector space, Local base and its properties, Separation properties, Symmetric sets, Balanced sets, absorbing sets, convex sets, Bounded sets in topological vector space.

Linear operators over topological vector space: Definition and properties, Locally compact topological vector spaces and its dimension, Metrization of topological vector space, Boundedness and continuity of linear operator.

Local convexity and seminorms: Locally convex topological vector spaces, Semi-norms, Minkowski functional, Generating family of semi norms in locally convex topological vector spaces, Criterion for normability, Quotient spaces

Fundamental theorems on topological vector space: Equicontinuity, The Banach-Steinhaus theorem and its consequences, the open mapping theorem, the closed graph theorem, The Hahn-Banach Theorem and its consequences.

Weak topologies: The weak and weak* topology of a topological vector space, convergence, closure, Compact convex sets, The Banach-Alaoglu theorem and its applications in separable and locally convex topological vector space.

Barreled spaces and Bornological spaces: Definition and several examples, Criterion for locally convex topological vector spaces to be (i) Barreled and (ii) Bornological.

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Kelly J. L. & Namioka I., Linear Topological spaces, Springer-Verlag, New York, Heidelberg, Berlin.
3. Schaffer, A.A., Topological Vector Spaces, Springer, 2nd Edn., 1991
4. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
5. Diestel, Application of Geometry of Banach Spaces
6. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985
7. Simmons, G. F., Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963

PG2 MATH 3014F: MOOC Course

Full Marks: 50

The course will be selected based on its availability on the MOOC platform and must be compatible with the Mathematics curriculum. The chosen MOOC should carry 4 credits. The University will conduct the examination and evaluation in accordance with the guidelines prescribed for the respective MOOC.

PG2 MATH 3015A: Operational Research-II

Full Marks: 50

Course Objectives:

1. To develop mathematical models for inventory, replacement, and maintenance decision problems.
2. To introduce queueing models and techniques for analyzing the performance of service systems.
3. To study sequencing models and methods for obtaining optimal job schedules.
4. To develop an understanding of simulation, Monte Carlo methods, and their applications in operational systems.
5. To introduce game theory, bi-matrix games, and Nash equilibrium with optimization-based solution approaches.

Course Learning Outcomes:

On successful completion of the course, students will be able to

1. formulate and solve inventory, replacement and maintenance problems.
2. analyze queueing systems and their operating characteristics.
3. solve sequencing problems involving multiple jobs and machines.
4. apply simulation and Monte Carlo techniques to operational problems.
5. analyze basic game-theory models and Nash equilibrium

Syllabus:

Inventory control: Deterministic Inventory control including price breaks and multi-item inventory models with constraints. Probabilistic inventory control (with and without lead time), Dynamic inventory models. Basic concept of Supply chain management and two echelon supply chain model.

Replacement and Maintenance Models: Introduction, Failure Mechanism of items, Replacement of items deteriorated with time, Replacement policy for equipment when value of money changes with constant rate during the period, Replacement of items that fail completely— individual replacement policy and group replacement policy, other replacement problems — staffing problem, equipment renewal problem.

Queueing Theory: Basic features of queueing systems, operating characteristics of a queueing system, arrival and departure (birth & death) distributions, inter-arrival and service times distributions, transient, steady state conditions in queueing process. Poisson queueing models- $M/M/1$, $M/M/C$ for finite and infinite queue length. Machine-Maintenance problem (steady state), power supply model, non-Poisson queueing models- $M/E_k/1$, $M/G/1$, mixed queueing model $M/D/1$, cost models in queueing system.

Sequencing: Sequencing problems, Solution of sequencing problems, Processing of n jobs through two machines, Processing of n jobs through three machines, Optimal solutions, Processing of two jobs through m machines, Graphical method of solution, Processing of n jobs through m machines.

Simulation: Introduction, Steps of simulation process, Advantages and disadvantages of simulation, Stochastic simulation and random numbers— Monte Carlo simulation, Random number generation, Simulation of inventory problems, Simulation of queueing problems, Role of computers in simulation, Applications of simulations.

Theory of Games: Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming).

Texts / References:

1. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
2. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.
3. Sharma J.K. Operations Research: theory and application, Macmillan Publishers, 2006.
4. Hillier, F.S., 2012. Introduction to operations research. Tata McGraw-Hill Education.

PG2 MATH 3015B: Fluid Mechanics –II

Full Marks: 50

Course Objectives

1. To develop an advanced understanding of viscous fluid dynamics and the Navier–Stokes equations.
2. To study slow and creeping flows and their classical solutions.
3. To introduce boundary-layer theory and Prandtl's assumptions.
4. To study analytical solutions of important boundary-layer flows.
5. To develop an understanding of integral methods for solving boundary-layer equations.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. formulate and analyze viscous-flow problems using the Navier–Stokes equations and dimensionless parameters.
2. analyze creeping flow and apply Stokes’ and Oseen’s solutions to slow flows.
3. formulate boundary-layer equations and identify important boundary-layer parameters and separation phenomena.
4. analyze Blasius boundary-layer flow and other self-similar boundary-layer solutions.
5. apply the Kármán integral equation and Kármán–Pohlhausen method to estimate boundary-layer characteristics.

Syllabus:

Viscous fluid dynamics: Continuum hypothesis, Fluid, Fluid viscosity, Newton’s law of viscosity, Classification of fluids, Flow and its classification, Stokes’ hypothesis, Stokes’ law of friction, Navier–Stokes’ equations and its dimensionless form, Reynolds number and its significance, Flow due to suddenly accelerated plane wall, Flow due to harmonic oscillation of plane wall, Flow around orthogonal stagnation–point and oblique stagnation-point, von-Karman flow near a rotating disk.

Slow motion: Creeping motion and its examples, Steady flow past a fixed sphere (Stokes’ flow), Steady motion between parallel planes, Stokes’ solution for slow steady parallel flow past a sphere, Stokes’ paradox, Oseen’s improvement over Stokes’ solution, Oseen’s solution for steady parallel flow past a sphere.

Boundary layer theory: Concept and properties of boundary layer flows, Prandtl’s assumptions and validity, Boundary layer equations, Boundary layer parameters, Boundary layer separation.

Solutions of some boundary layer flows: Blasius boundary layer flows, Concept of self similar flows, Blasius similar equation and series solution, Boundary layer flow in a convergent channel, Flow past a wedge, Planar jet flows .

Integral method for boundary layer equations: Basic concept of integral method, Karman’s integral equation, Karman-Pohlhausen method and its applications for estimating boundary layer parameters.

References:

1. J. L. Bansal, Viscous Fluid Dynamics, , 2nd edition (Oxford and IBH Publishing Co, 1977).
2. D. J. Tritton, Physical Fluid Dynamics. 2nd edition (Oxford Science Publications, 1988).
3. S.W. Yuan. Foundations of Fluid Mechanics. (PHI, 1970).
4. P. K. Kundu, Fluid Mechanics. (Academic Press, 1990).
5. G. K. Batchelor, An introduction to Fluid Dynamics. (Cambridge University press, 1967).
6. Thompson, P. A., Compressible fluid dynamics.
7. Shapiro, A. H., Compressible fluid flow.
8. Lipman, B., Aspects of subsonic and transonic flows.
9. Niyogi, P., Inviscid gas dynamics, Mcmillan, 1975 (India)
10. Oswatitsch, K., Gas dynamics

PG2 MATH 3015C: Universal Algebra

Full Marks: 50

Course Objectives:

1. To introduce the fundamental concepts and structures of universal algebra.
2. To study subalgebras, congruences, quotient algebras, and homomorphisms.
3. To develop an understanding of free algebras, direct and subdirect products, and varieties.
4. To study Birkhoff’s theorems and related structural results.
5. To introduce group representations, group rings, and selected representation-theoretic results.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. identify and analyze universal algebras, subalgebras, congruences, and quotient structures.
2. apply the isomorphism theorems and analyze homomorphisms and kernels.
3. construct and work with free algebras, products, and subdirectly irreducible algebras.
4. use identities, term algebras, varieties, and Birkhoff's theorem in structural analysis.
5. explain basic group representations, group rings, and apply results such as Maschke's theorem.

Syllabus:

Universal algebra, examples, subalgebra, sub universe, congruences and quotient algebra. homomorphisms of universal algebra, kernel of a homomorphism. First Isomorphism Theorem, Second Isomorphism Theorem, Third Isomorphism Theorem. semigroup of endomorphisms of a universal algebra. Birkhoff's theorem. Special faithful representation of universal algebras into semigroups, Theorem of Cohn-Rebane.

Free algebra. direct and subdirect product of universal algebras. Sub directly irreducible universal algebras.

Class operators. Turski's theorem, identities. Term algebra, universal mapping property, k -free universal Algebra, variety, Birkhoff's theorem on variety, Macev's conditions.

Group representations, group-rings, Maschke's theorem, character of a representation, regular representations, orthogonality relations, Burnside two-prime theorem.

References:

1. Stanley Burries and H. P. Sankappanavan; Universal Algebra; Springer-Verlag.
2. Curtis, C.W., Reiner, I., Representation Theory of Finite Groups and Associated Algebras, Wiley Inter science, NY.
3. Benjamin Steinberg, Representation Theory of Finite groups, An Introductory Approach, Springer, 2012.

PG2 MATH 3015D: Advanced Topology –II

Full Marks: 50

Course Objectives:

1. To study advanced metrization and topological embedding theorems.
2. To introduce uniform spaces and their associated uniform topologies.
3. To develop the theory of completeness, Cauchy nets, Cauchy filters, and completion.
4. To introduce proximity spaces and their compactification theory.
5. To study topological groups and their algebraic-topological structures.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. apply major metrization and embedding theorems to suitable topological spaces.
2. construct and analyze uniformities, uniform topologies, and uniformly continuous mappings.
3. characterize completeness using Cauchy nets and filters and understand completion results.
4. analyze proximity spaces, their products, and associated compactifications.
5. work with topological groups, continuous homomorphisms, quotient groups, and uniform structures.

Syllabus:

Metrizability Topological imbedding, Imbedding theorem of a regular space with countable base, NagataSmirnov Metrization theorem.

Uniform spaces: Uniformity and its uniform topology, neighbourhoods, bases and subbases, uniform continuity, product uniformities, uniform isomorphism, relativization and products. Characterization of metrizability, uniformity of pseudometric spaces, uniformity generated by a family of pseudometrics, Uniformizability and complete regularity, the gauge of uniformity, Completeness, Cauchy net, Cauchy

filter, complete spaces, extension of mappings, completion-existence and uniqueness, Compactness and uniformity, diagonal uniformities, uniformity via uniform covers.

Proximity Spaces: Topology induced by a proximity, subspaces and products of proximity spaces, elementary proximity, p -continuity and p -isomorphism, Compactification of proximity spaces-clusters and ultrafilters, Smirnov's theorem.

Topological Group: Definition, Example, Homeomorphism of translation mapping, Neighbourhood systems of identity, separation axioms, uniform structures, subgroups, quotient groups, continuous and open homomorphism, Isomorphism.

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Joshi, K.D., Introduction to General Topology, New age International Publishers, 1983.
4. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
5. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1955.
6. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
7. Steen, L., Seebach, J., Counter Examples in Topology, Holt, reinhart and Winston, New York.
8. Hossain, T, Introduction to topological groups, Dover Publications, Inc. Mineola, New York.

PG2 MATH 3015E: Advanced Functional Analysis –II Full Marks: 50

Course Objectives:

1. To develop the theory of strictly convex and uniformly convex Banach spaces.
2. To study approximation theory in normed linear spaces and function spaces.
3. To introduce convexity in topological vector spaces and separation results.
4. To develop the theory of Banach algebras and spectral theory.
5. To introduce Gelfand theory and representation of Banach algebras.

Course Learning Outcomes:

On successful completion of the course, the student will be able to

1. distinguish strictly convex and uniformly convex spaces and apply relevant inequalities and theorems.
2. analyze best approximation and uniqueness problems in normed linear spaces.
3. apply separation theorems, extreme-point theory, and the Krein–Milman theorem.
4. determine and analyze spectra, resolvents, spectral radius, and spectral mappings in Banach algebras.
5. explain maximal ideal spaces, Gelfand transforms, and fundamental results of Gelfand theory.

Syllabus:

Strictly convex and Uniformly convex space: Definition and several examples of strictly convex and uniformly convex Banach space. Clarkson's renorming lemma, Uniform Convexity of a Hilbert Space. Milman-Pettit theorem, Clarkson's inequalities, Reflexivity of a uniformly convex Banach space, Uniqueness of extension of functional on normed linear space.

Approximation theory: Weierstrass approximation theorem in $C[a,b]$, Stone- Weierstrass theorem in $C(X,R)$ and $C(X,C)$ where X is a compact Hausdorff space, Representation theorem for bounded linear functional on $C[a,b]$, l_p ($1 \leq p < \infty$) and $L_p[a,b]$, ($1 \leq p < \infty$). Approximation Theory in Normed Linear space, Best approximation, Uniqueness Criterion.

Convexity in topological vector space: Convex Hull and representation Theorem, Extreme points, Hyperplanes, Separation of convex sets by Hyperplanes, Krein-Milman Theorem on extreme points.

Banach Algebra: Analytic vector valued functions, normed and Banach algebra, Identity element, Gelfand Mazur Theorem, Analytic property of resolvent Operator, Compactness of Spectrum, the resolvent operator, Spectral radius and Spectral mapping Theorem for polynomials, Topological divisors of zero.

The Gelfand theory: Ideals, Maximal Ideals, Quotient space, Maximal ideal space, Gelfand topology, Gelfand mapping, Gelfand Theory on representation of Banach Algebra, involutions in Banach algebra, The Gelfand Neumark Theorem.

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Simmons, G. F., Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963
3. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
4. Kelly J. L. & Namioka I., Linear Topological spaces, Springer-Verlag, New York, Heidelberg, Berlin.
5. Schaffer, A.A., Topological Vector Spaces, Springer, 2nd Edn., 1991
6. Diestel, Application of Geometry of Banach Spaces
7. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985.

PG2 MATH 3015F: MOOC Course

Full Marks: 50

The course will be selected based on its availability on the MOOC platform and must be compatible with the Mathematics curriculum. The chosen MOOC should carry 4 credits. The University will conduct the examination and evaluation in accordance with the guidelines prescribed for the respective MOOC.

PG2 MATH 3016: Indian Knowledge System

Full Marks :25

Course Objectives

1. To understand the historical development of Indian mathematics and its contributions to number systems, algorithms, and mathematical thought.
2. To explore the contributions of ancient Indian scholars to geometry, arithmetic, algebra, and computational methods.
3. To appreciate the mathematical achievements of medieval and modern Indian mathematicians and their influence on contemporary mathematics.
4. To develop an understanding of the significance of the Indian Knowledge System in the evolution of mathematics and its relevance in modern scientific studies.

Course Learning Outcomes:

After completion of this course, students will be able to

1. explain the origin and evolution of Indian number systems, decimal place-value notation, zero, and traditional algorithms, and assess their global impact.
2. analyze the contributions of ancient Indian mathematics to geometry, arithmetic, algebra, trigonometry, and computational techniques described in classical texts.
3. evaluate the mathematical contributions of eminent Indian mathematicians such as Brahmagupta, Bhāskara II, Madhava, Aryabhata, and Srinivasa Ramanujan, and relate them to modern mathematical developments.
4. demonstrate an appreciation of the historical, cultural, and scientific significance of the Indian Knowledge System and its continuing influence on mathematics and related disciplines.

Syllabus:

Foundation of Number Systems and Algorithms: Historical overview of Indian mathematics, Influence of Indian mathematics on the world, the evolution of the decimal place-value system and the mathematical and philosophical concept of zero, Unique Indian approaches to representing large numbers, including the Bhūta Saṃkhyā (word-numerical) and Kaṭapayādi systems, Binary systems found in the Chandaś Sāstra of Pingala.

Contributions to Geometry: Vedas and Sulbasutras as sources of mathematical knowledge, Geometry in ancient Indian mathematics, Arithmetic operations and algebraic methods in ancient Indian mathematics, Trigonometry in ancient India, Geometric principles used in the construction of altars and fire rituals (Vedic altars), Geometric proofs and applications prior to Pythagoras (such as the Bodhayana theorem), Methods for squaring a circle, circling a square, and approximations of the square root and π (Pi), The development of sine and cosine tables (Jyā and Kojyā) and cyclic quadrilaterals.

Arithmetic and Algebra: Brahmagupta and his contributions to algebra and number theory, Bhaskara II and his contributions to calculus, Madhava and his contributions to infinite series and calculus, Solutions to indeterminate equations, including the Kuṭṭaka (pulverizer) and Cakravāla methods, Computational techniques from traditional texts such as the Aryabhatīya, Brahmasphuṭa siddhānta, and Lilāvati.

Indian Mathematics in the Medieval and Modern Period: Development of Indian mathematics during the medieval period, Modern developments in Indian mathematics, including Ramanujan's contributions to number theory, Influence of Indian mathematics on modern mathematics.

References:

1. "The Crest of the Peacock: Non-European Roots of Mathematics" by George Gheverghese Joseph (1991), Princeton University Press
2. "A Concise History of Mathematics in India" by Bibhutibhushan Datta and Avadesh Narayan Singh (1995), New Delhi: Motilal Banarsidass.
3. Geometry in ancient India by Saraswati Amma (1999, 2nd Ed.), Motilal Banarsidass.
4. The mathematics of India: concepts, methods, connections, sources and studies in the history of mathematics and physical sciences by P.P. Divakaran (2018), Hindustan Book Agency.
5. Mathematics in India by Kim Plofker (2009), Princeton University Press.
6. Erik Gregersen, The Britannica Guide to The History of Mathematics, Britannica.
7. Eleanor Robson, Jacqueline Stedall, The Oxford Handbook of THE HISTORY OF MATHEMATICS, Oxford.

PG2 MATH 3041: Community Engagement

Full Marks:25

Community engagement will be arranged according to the decision of the Department in every year.

Compulsory 2-credit Course:

Mahatma Gandhi: Life & Philosophy

The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA

Semester-IV

PG2 MATH 4031: Research Thesis/Project

Full Marks: 300

Topic	Marks
Preparation & Submission of Research Thesis/Project Report	150
Field Visit	25
Seminar Presentation	75
Viva-Voce	50
Total	300



PG2 MATH 3016: Indian Knowledge System

Full Marks :25

Course Objectives

1. To understand the historical development of Indian mathematics and its contributions to number systems, algorithms, and mathematical thought.
2. To explore the contributions of ancient Indian scholars to geometry, arithmetic, algebra, and computational methods.
3. To appreciate the mathematical achievements of medieval and modern Indian mathematicians and their influence on contemporary mathematics.
4. To develop an understanding of the significance of the Indian Knowledge System in the evolution of mathematics and its relevance in modern scientific studies.

Course Learning Outcomes:

After completion of this course, students will be able to

1. explain the origin and evolution of Indian number systems, decimal place-value notation, zero, and traditional algorithms, and assess their global impact.
2. analyze the contributions of ancient Indian mathematics to geometry, arithmetic, algebra, trigonometry, and computational techniques described in classical texts.
3. evaluate the mathematical contributions of eminent Indian mathematicians such as Brahmagupta, Bhāskara II, Madhava, Aryabhata, and Srinivasa Ramanujan, and relate them to modern mathematical developments.
4. demonstrate an appreciation of the historical, cultural, and scientific significance of the Indian Knowledge System and its continuing influence on mathematics and related disciplines.

Syllabus:

Foundation of Number Systems and Algorithms: Historical overview of Indian mathematics, Influence of Indian mathematics on the world, the evolution of the decimal place-value system and the mathematical and philosophical concept of zero, Unique Indian approaches to representing large numbers, including the Bhūta Saṃkhya (word-numerical) and Kaṭapayādi systems, Binary systems found in the Chandah Sāstra of Pingala.

Contributions to Geometry: Vedas and Sulbasutras as sources of mathematical knowledge, Geometry in ancient Indian mathematics, Arithmetic operations and algebraic methods in ancient Indian mathematics, Trigonometry in ancient India, Geometric principles used in the construction of altars and fire rituals (Vedic altars), Geometric proofs and applications prior to Pythagoras (such as the Bodhayana theorem), Methods for squaring a circle, circling a square, and approximations of the square root and π (Pi), The development of sine and cosine tables (Jyā and Kojyā) and cyclic quadrilaterals.

Arithmetic and Algebra: Brahmagupta and his contributions to algebra and number theory, Bhaskara II and his contributions to calculus, Madhava and his contributions to infinite series and calculus, Solutions to indeterminate equations, including the Kuṭṭaka (pulverizer) and Cakravāla methods, Computational techniques from traditional texts such as the Aryabhatiya, Brahmasphuta siddhanta, and Lilavati.

Indian Mathematics in the Medieval and Modern Period: Development of Indian mathematics during the medieval period, Modern developments in Indian mathematics, including Ramanujan's contributions to number theory, Influence of Indian mathematics on modern mathematics

References:

1. "The Crest of the Peacock: Non-European Roots of Mathematics" by George Gheverghese Joseph (1991), Princeton University Press
2. "A Concise History of Mathematics in India" by Bibhutibhushan Datta and Avadesh Narayan Singh (1995), New Delhi: Motilal Banarsidass.
3. Geometry in ancient India by Saraswati Amma (1999, 2nd Ed.), Motilal Banarsidass.
4. The mathematics of India: concepts, methods, connections, sources and studies in the history of mathematics and physical sciences by P.P. Divakaran (2018), Hindustan Book Agency.
5. Mathematics in India by Kim Plofker (2009), Princeton University Press.
6. Erik Gregersen, The Britannica Guide to The History of Mathematics, Britannica.
7. Eleanor Robson, Jacqueline Stedall, The Oxford Handbook of THE HISTORY OF MATHEMATICS, Oxford.

PG2 MATH 3031: Research Thesis/Project

Full Marks: 250

Topic	Marks
Preparation & Submission of Research Thesis/Project Report	150
Field Visit	25
Seminar Presentation	50
Viva-Voce	25
Total	250

PG2 MATH 3041: Community Engagement

Full Marks:25

Community engagement will be arranged according to the decision of the Department in every year.

Compulsory 2-Credit Course:

Mahatma Gandhi: Life & Philosophy

The Credits and Grades of this course shall be excluded from the calculation of SGPA and CGPA

Semester-IV

PG2 MATH 4031: Research Thesis/Project

Full Marks: 300

Topic	Marks
Preparation & Submission of Research Thesis/Project Report	150
Field Visit	25
Seminar Presentation	75
Viva-Voce	50
Total	300

