



Mahatma Gandhi University
Purba Medinipur-721628, West Bengal

Syllabus

M.Sc. in Mathematics

PG Curricular Structure for 1 Year PG Programmes (4+1)

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 2027-2028]

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, Topology, Mechanics, 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, Community Engagement, Field Visits**. 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: 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.

PO5: 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.

PO6: 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.

PO7: 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.

PO8: 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.

PO9: 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.

PO10: 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, Mechanics, Number Theory, 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: 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 4: 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 5: 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 6: 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 7: 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: 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.

PGA7: 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.

PGA8: 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.

1 Year PG Programme after Completion of 4 Year UG Programme (4+1)

Structure 1: Course Work

SEM	Course Type	Course Code & Level	Name of the Course	Credits (L-T-P)	IA	End Sem. Exam	Full Marks
I	Major/Core Course	PG1 MATH 1011 (500-599)	Functional Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 1012 (500-599)	Advanced Numerical Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 1013 (500-599)	Continuum Mechanics	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 1014 (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	PG1 MATH 1015 (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	PG1 MATH 1016 (500-599)	Indian Knowledge System	2 (1-1-0)	05	20	25
	Community Service	PG1 MATH 1041 (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			
1st Semester of PG				24			300
II	Major/Core Course	PG1 MATH 2011 (500-599)	Fuzzy Mathematics and Soft Computing	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 2012 (500-599)	Mathematical Methods	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 2013 (500-599)	Biomathematics	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 2014 (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	PG1 MATH 2015 (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	PG1 MATH 2032 (500-599)	Dissertation & Field Visit	4 (0-0-4)	----	50	50
2nd Semester of PG				24			300
Total: 1st 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
I	Major/Core Course	PG1 MATH 1011 (500-599)	Functional Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 1012 (500-599)	Advanced Numerical Analysis	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 1013 (500-599)	Continuum Mechanics	4 (3-1-0)	10	40	50
	Major/Core Course	PG1 MATH 1014 (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	PG1 MATH 1015 (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	PG1 MATH 1016 (500-599)	Indian Knowledge System	2 (1-1-0)	05	20	25
	Community Service	PG1 MATH 1041 (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			
1st Semester of PG				24			300
II	Research Thesis/Project	PG1 MATH 2031 (500-599)	Research Thesis/Project	24 (0-0-24)	----	300	300
2nd Semester of PG				24			300
Total: 1st Year of PG				48			600

****¹**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
I	VAC Course	PG1 MATH 1016 (500-599)	Indian Knowledge System	2 (1-1-0)	05	20	25
	Research Thesis/Project	PG1 MATH 1031 (500-599)	Research Thesis/Project	20 (0-0-20)	----	250	250
	Community Service	PG1 MATH 1041 (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			
1st Semester of PG				24			300
II	Research Thesis/Project	PG1 MATH 2031 (500-599)	Research Thesis/Project	24 (0-0-24)	----	300	300
2nd Semester of PG				24			300
Total: 1st Year of PG				48			600

****1**Compulsory 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.

Course Work

Semester-I

PG1 MATH 1011: 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

PG1 MATH 1012: 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. Gedge 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.

PG1 MATH 1014A: 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, 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.

PG1 MATH 1014B: 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.

PG1 MATH 1014C: 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,

PG1 MATH 1014D: 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.

PG1 MATH 1014E: 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

PG1 MATH 1014F: 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.

PG1 MATH 1015A: 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.

PG1 MATH 1015B: 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

PG1 MATH 1015C: 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.

PG1 MATH 1015D: 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 metrizable spaces, 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.

PG1 MATH 1015E: 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.

PG1 MATH 1015F: 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.

PG1 MATH 1016: 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 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 Aryabhatīya, 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.

PG1 MATH 1041: 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



PG1 MATH 2011: 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.

PG1 MATH 2012: 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

PG1 MATH 2013: 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, Kermack-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-to-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.

PG1 MATH 2014A: 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.

PG1 MATH 2014B: 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).

PG1 MATH 2014C: 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.

PG1 MATH 2014D: 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, R^2 and 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).

PG1 MATH 2014E: Operator Algebra –I

Full Marks: 50

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.

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.

PG1 MATH 2015A: Operational Research-IV**Full Marks: 50****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, Schaum's Outline Series, MGH.

PG1 MATH 2015B: Fluid Mechanics –IV

Full Marks: 50

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.

PG1 MATH 2015C: Category Theory

Full Marks: 50

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

PG1 MATH 2015D: 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-Poincaré 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.

Künneth 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.Mauder; 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).

PG1 MATH 2015E: 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.

PG1 MATH 2015F: 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.

PG1 MATH 2032: 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.

PG1 MATH 1011: 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

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-Michel 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, Daviddon-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.

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.

PG1 MATH 1014C: 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,

PG1 MATH 1014D: 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.

PG1 MATH 1014E: 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

PG1 MATH 1014F: 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.

PG1 MATH 1015A: 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.

PG1 MATH 1015B: 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

PG1 MATH 1015C: 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.

PG1 MATH 1015D: 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, 1995.
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.

PG1 MATH 1015E: 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.

PG1 MATH 1015F: 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.

PG1 MATH 1016: 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 Samkhya (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 Kuttaka (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.

PG1 MATH 1041: 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-II

PG1 MATH 2031: 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



PG1 MATH 1016: 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 Samkhya (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

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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.

PG1 MATH 1031: 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

PG1 MATH 1041: 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-II

PG1 MATH 2031: 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

