MA/M.Sc. Courses in Mathematics
New Revised (Version 1.4)

Approved on
27/10/2021

1st Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1	MAT 1016	Algebra	5	1	0	6
2	MAT 1026	Mathematical Methods	5	1	0	6
3	MAT 1036	Mechanics and Tensor	5	1	0	6
4	MAT 1046	Real Analysis and Lebesgue Measure	4	1	0	5
5	MAT 1056	Numerical Analysis	4	1	0	5
			Total Credit			28

2nd Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1	MAT 2016	Complex Analysis	4	1	0	5
2	MAT 2026	Topology	4	1	0	5
3	MAT 2036	Functional Analysis	4	1	0	5
4	MAT 2046	Number Theory	4	1	0	5
5	MAT 2056	Differential Equations	5	1	0	6
			Total credit			26

3rd Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1	MAT 3016	Mathematical logic (O)/ Continuum Mechanics and Hydrodynamics	5	1	0	6
2	MAT 3026	Graph Theory/ Special Theory of Relativity	5	1	0	6
3	MAT 3036	Operations Research / Computer Programming in C	4	0	2	6
4	MAT 3046	Measure Theory/ Special functions and Partial differential equations	5	1	0	6
5	MAT 3056	Project	2	2	2	6
			Total credit			30

4^{th} Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1	MAT 4016	Fuzzy Sets and Systems/ Space Dynamics	5	1	0	6
2	MAT 4026	Advanced Functional Analysis/ Dynamical System and Fractal Geometry	5	1	0	6
3	MAT 4036	Advanced Algebra (O)/ Fluid dynamics	5	1	0	6
4	MAT 4046	Algebraic Topology/ General Theory of Relativity and Cosmology	5	1	0	6
			Total credit			24

L:Lecture, T: Tutorial, P: Practical, C: Credit, O: Open

FIRST SEMESTER
MAT 1016 – Algebra

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Direct product and Direct sums of Groups. Decomposable groups. Normal and Subnormal series of groups, composition series, Jordan Holder theorem, solvable groups. **20 marks**

Unit 2: Divisibility in commutative rings, PID, UFD and their properties. Eisentein's irreducibility criterion. **20 marks**

Unit 3: Field theory – Extensions of fields. Algebraic and Transcendental elements, Algebraic extensions of Splitting field perfect Fields, Finite field (Moore's theorem etc.), Construction by ruler and compass, elements of Galois theory. **20 marks**

Unit 4: Canonical forms, similarity of linear transforms, Invariant subspaces, Reduction totriangular forms, nilpotent transformations, Primary decomposition theorem, Jordan blocks and Jordan canonical form, quadratic forms, reduction and classification of quadratic forms **20 marks**

Text Books:
1. S. Singh and Q. Zameruddin, Modern Algebra, Vikash Publishing House, 2006
2. K. Hoffman and R. Kunz, Linear Algebra, Prentice Hall, 1965

Reference Books:

1. I. N.Herstein, Topics in Algebra, John Wiley& Sons, 1975.
2. C. Musili, Introduction to Rings and Modules, Narosa Publishing House, 1994
3. D. S. Malik, J.M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGrawHill Company, 1997
4. K. B. Datta, Matrix and linear algebra, PHI Pvt. Limited, 2004
5. Seymour Lipschutz, Schaum's Outline ofLinear Algebra, The McGraw-Hill Companies, Inc., 2013.

Course outcome:

- Based on the UGC Syllabus the paper 1016 (Algebra) for 1st semester is prepared in a logical and systematic and simple way so that the students can compare the studies of different algebraic systems called groups, rings, fields and vector spaces.
- The students can justify the concept of relations, mappings and composition in the study of algebraic systems called groups and rings. The concept of groups and rings play a significant role in the development of geometry and number theory in recent times.
- The syllabus contains a detailed study of field extension and its application to geometry, so that the students are able to solve some antique unsolved problems of geometry by the theory of field extension.
- The students are able to explain that the study of vector spaces is nothing but the generalization of the analytical geometry and mechanics.

MAT-1026 Mathematical Methods

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Integral Equations:

Fredholm Integral Equations: Definition of Integral Equation, Reduction of ordinary differential equations into integral equations. Fredholm integral equations with separable kernels, Eigen values and Eigen functions, Method of successive approximation, Iterative scheme for Fredholm Integral equations of second kind

Volterra Integral Equations: Volterra Integral Equations of second kind, Resolvent kernal of Volterra equation and its results, Application of iterative scheme to Volterra equation of the second kind, Convolution type kernals **25 marks**

Unit 2: Integral Transforms:

Fourier Transform: Fourier Integral Transform. Properties of Fourier Transform, Fourier sine and cosine transforms, Application of Fourier transform to ordinary and partial differential equations of initial and boundary value problems. Evaluation of definite integrals

Laplace Transform: Basic properties of Laplace Transform, Convolution theorem and properties of convolution, Inverse Laplace Transform. Application of Laplace Transform to solution of ordinary and partial differential equations of initial and boundary value problems, Evaluation of definite integrals. The inversion theorem, Evaluation of inverse transforms by residue method **30 marks**

Unit 3: Calculus of variations: Calculus of variation with one independent variable: Basic ideas of calculus of variations, Euler's equation with fixed boundary of the functional Containing only the first order derivative of the only dependent variable with respect to one independent variable, Variational problems with functional having higher order derivatives of the only dependent variable, general case of Euler's equation, applications

Calculus of Variation with several independent variables: Variational problems with functional dependent on functions of several independent variables having first order derivatives. Variational problems in parametric form, Variational problems with subsidiary condition: Isoperimetric problems, Applications **25 marks**

Text Books:

1. R. P. Kanwal, Linear Integral Equations, Theory and Techniques, Academic Press, New York, 1971
2. M. R. Spiegel, Schaum's Outline Series: Theory and Problems of Laplace Transforms, McGraw-Hill Book Company, 1965
3. A. S. Gupta, Calculus of variation with Applications : Prentice Hall of India, 1999

Reference Books:

1. S. G. Mikhlin, Linear Integral Equations (Translated from Russia), Hindustan Book Agency, 1960
2. F. B. Hilderbrand, Methods of Applied Mathematics, Dover Publications, 1992
3. R. Courant and D. Hilbert, Methods of Mathematical Physics- Vol- I, Wiley Interscience, New York 1953.

Course outcome:

- The main objective of introducing this paper in the PG syllabus is that number theory is extensively used in the financial and defence sector of a country whereas Graph theory serves as an Mathematical model in any system involving a binary relation. Both Number and Graph Theory are used in computer application
- Students can use the concept of primitive roots and indices for solvability of congruence of higher order. The students can explain the quadratic reciprocity law using Legendere's and Jacobi's symbol.
- Students can explain Fibonacci numbers and related identities. Students can also explain partition functions, its graphical representations and generative functions.
- The students acquire basic knowledge of graphs to model some practical situation by using graphs.
- Students can analyze their social networks using graph theory and able to view social network.
- Students are able to use a combination of theoretical knowledge and independent thinking in creative investigation of questions in graph theory.

MAT 1036- Mechanics and Tensor

Total Marks: 100 Theory: 80 Sessional: 20

Mechanics

Total marks: 50 Sessional: 12

Unit1: Motion in three dimensions: Velocity and acceleration in cylindrical and spherical polar coordinates, motion on cylindrical, spherical and conical surfaces **10 marks**

Unit 2: Impulsive motions: Carnot's theorem, Kelvin's theorem and Bertrand's theorem and applications **8 marks**

Unit 3: Motion of a rigid body about a fixed point: Euler's Geometrical and Dynamical Equations, Motion under no external forces, Integrals of energy and angular momentum **12 marks**

Unit 4: Generalized coordinates: Lagrange's equation of motion for finite and impulsive forces in holonomic systems,Case of conservative forces and theory of small oscillation **12 marks**

Unit 5: Hamiltonian Theory: Hamilton's equation of motion, Variational methods, Hamilton's principle, and Principle of least action **8 marks**

Tensor

Total Marks: 30 **Sessional: 8**

Unit 1: Transformation laws of covariant and contravariant tensors, Mixed tensor, Rank of tensors, Kronecker delta. Algebraic operations on tensors: contraction, inner and outer product of tensors, Quotient law, Group property of tensors, symmetric and anti-symmetric tensors. Related theorems.

Riemannian metric and Fundamental tensors.Christoffel symbols of the first and second kinds and their properties.Transformation laws of Christoffel symbols. **15 marks**

Unit 2: Covariant derivatives of tensors A_i, A^i, A_{ij}, A^{ij} and $A^i{}_j$. Generalizations. Covariant derivatives of fundamental tensors and scalar invariant function, Application in problems. Angle between two vectors and orthogonal condition. Gradient of an invariant function. Divergence and curl of vectors. Laplacian in tensor form. **15 marks**

Text Books:

1. S L Loney, An Elementary Treatise on the Dynamics of a Particle and Rigid Bodies, Cambridge University Press, 2017
2. C. E. Weatherburn, An Introduction to Riemannian Geometry and the Tensor Calculus, Cambridge University Press, Paperback, 2008

Reference Books:

1. Dynamics, Part-2, CBS Publishers & Distributors, New Delhi-110032, India
2. F. Chorlton, Text Books of Dynamics, John Wiley & Sons, 1983
3. Murray Spiegel, Theory & problems of theoretical mechanics (Schaum's outline series),McGrawHill Education, 2017
4. L. P. Eisenhart, Riemannian Geometry, Princeton University Press, 1997
5. B. C. Kalita,Tensor Calculus and Applications: Simplified Tools and Techniques, CRC Press, 2019.

Course outcome:

Students will have knowledge:

- To differentiate the properties of motion in various coordinate systems viz. cylindrical, spherical, conical surfaces.
- To apply various tools of vector algebra as well as vector calculus, calculus of variations to discuss the motion of rigid bodies under certain constraints.
- To handle various physical laws of motion viz. Carnot's theorem, Kelvin's theorem, Hamiltonian's principle etc with mathematical tools.
- To handle rigid body motion with one point fixed.
- To construct mathematical models viz. rigid body to describe motions under certain constraints or no constraints which are able to analyze the physical scenario.

- To understand Tensors. They will be able to derive transformation laws of covariant tensors, contravariant tensors and mixed tensors and to find their ranks.
- To perform algebraic operations on tensors, to obtain covariant derivatives of various tensors and to express Laplacian in tensor form.
- To identify that application of tensors is invaluable to most of the branches of Mathematics, Engineering and Theoretical Physics such Mechanics, Elasticity, Electrodynamics, Relativity etc.

MAT-1046: Real Analysis and Lebesgue Measure

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Uniform convergence of sequenceof functions at an interval, Cauchy's criterion, Test for uniform convergence, properties of uniformly convergent sequences and series of functions, results related to uniform convergence with continuity, integration and differentiation, Weirstrass's approximation theorem, Power series, radius of convergence, Abel's and Tauber's theorem, Fundamental properties. **20 marks**

Unit 2: Vector valued function, continuity, differentiation, Functions of bounded variation, their continuity, and monotonicity, Definition, existence of R-S integral, Properties of R-S integral, integration and differentiation, Fundamental theorem of calculus, Integration of vector valued functions. **20 marks**

Unit 3: Lebesgue outer measure, Measurable sets and properties, Borel sets and their measurability, Characterization of measurable sets, Non-measurable sets, Measurable functions and their properties, Operations of measurable functions, Sets of measure zero, Sequence of measurable functions, Convergence in measure. **20 marks**

Unit 4: Lebesgue integral, Lebesgue integral of a bounded function, Comparison of Riemann integral and Lebesgue integral, Integral of a non-negative measurable function, General Lebesgue integral, Convergence of Lebesgue integral, Bounded convergence theorem, Monotone convergence theorem, Lebesgue convergence theorem. **20 marks**

Text Books:

1. S.C. Malik and Savita Arora, Mathematical Analysis, New Age International Private Limited,2017
2. H.L. Royden, Real Analysis, Prentice Hall of India, 2011
3. P.K. Jain and V.P. Gupta, Lebesgue Measure and Integration, Anshan Ltd., 2012

Reference Books:

1. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill Education, 1976
2. R.R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing, 2012.

Course outcome:

After completing this course, the student will

- Understand how Lebesgue measure on R is defined, how measures may be used to construct integrals, know the basic convergence theorems for the Lebesgue integral, the relation between series and the Hilbert space of square integrable functions.

- have familiarity with common examples and counterexamples, knowledge of the content of the major theorems, understanding of the ideas in their proofs, and ability to make direct application of those results to related problems.
- get the knowledge in sequences of functions and their uniform convergence and get the idea about how to find out the region of convergence of power series.
- develop the core skills of the subject and research skills in this areas.

MAT-1056 Numerical Analysis

Total Marks: 100 Theory: 80 Sessional: 20

Unit 1: System of linear equations and eigenvalue problem: Operational counts for direct methods of solving system linear algebraic equations. Gaussian operational count for inversion of a matrix. Eigenvalue problem. General iterative method. Jacobi and Gauss. Seidel method. Relaxation method. Necessary and sufficient conditions for convergence. Speed of convergence. S.O.R. and S.U.R. methods. Gerschgorin'scircle theorem. Determination of eigenvalue by iterative methods. Ill conditioned system.
20 marks

Unit 2: System of non-linear method equations: Solution of Non-linear Equations: Single Equation: Modified Newton-Raphson method (for real roots-simple or repeated). Aitken's □^{2}-method and Steffensen's iteration. Bairstow's method of quadratic factors, Graeffe's root squaring method. Non-Linear Systems of Equations: Newton's method, Quasi-Newton's method. **10 marks**

Unit 3: Polynomial Interpolation: Weirstrass's approximation theorem (Statement only), Runge's phenomena, Divergence of sequences of interpolation polynomials for equi-spaced interpolation points, piecewise polynomial interpolation – Hemite interpolation, Error term, Cubic spline interpolation, Convergence properties (statement only), Inverse interpolation, Numerical differentiation using equi-spaced points. **15 marks**

Unit 4: Numerical Integration: Gauss- Legendre and Gauss-Chebyshev quadratures, Euler-Maclaurin summation formula, Richardson extrapolation, Romberg integration, Simpson's adaptive quadrature
15 marks

Unit 5: Numerical Solution of Initial Value Problems for ODE: Picard, Euler, modified Euler and Runge-Kutta methods, Multistep predictor-corrector methods–Adams-Bashforth method, Adams-Moulton method, Milne's method, Convergence and stability. **20 marks**

Text Books:

1. C. F. Gerald andP. O. Wheatley,Applied Numerical Analysis, Pearson, 7th Edition, 2004
2. M.K. Jain, S. R. K. Iyengar, R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International, 2005
3. A. Ralston, A First Course in Numerical Analysis, McGraw Hill, N.Y. ,1965.
4. A. Ralston and P.Rabinowitz, A First Course in Numerical Analysis, McGraw Hill, N.Y., 1978.
5. S. D. Conte and C. DeBoor, Elementary Numerical Analysis: An Algorithmic Approach, McGraw Hill, N.Y., 1980.
6. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons, 1989.

Reference Books:

1. C.E. Fröberg, Introduction to Numerical Analysis, Addison-Wesley Publishing Company, 1969.
2. E.K. Blum, Numerical Analysis and Computation Theory and Practice,Addison-Wesley Publishing Company, Inc., London, 1972.
3. C. Pozrikidis, Numerical Computation in Science and Engineering, OxfordUniversity Press, Inc., N.Y., 1998.

Course outcome:

- The students will learn to solve any algebraic equations when no analytical method is applicable.
- Students can find the approximate solutions of boundary value problems by using numerical technique
- Students can identify different types of approximation functions such as trigonometric functions, exponential functions etc.
- Students are now able to apply the numerical technique in physical and engineering problems.

SECOND SEMESTER
MAT2016 – Complex Analysis

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Complex Integration: Cauchy-Goursat Theorem. Cauchy's integral formula, Higher order derivatives. Morera's theorem, Cauchy's inequality and Liouville's Theorem. The fundamental theorem of Algebra, Gauss's Mean Value Theorem Maximum Modulus principle, Schwarz lemma, Open mapping theorem. **20 marks**

Unit 2: Power Series: Taylor's and Laurent's Theorem, Zero and Singularity of an analytic function, The Argument Principle, Rouche's theorem. **16 marks**

Unit 3: Theory of Residues: Residue, Calculation of Residues, Cauchy's residue theorem, Evaluation of definite integrals. Special theorems used in evaluating integrals, Mittag-Leffer's theorem. **16 marks**

Unit 4: Analytic functions as mappings: Isogonal and Conformal Transformation, Necessary and sufficient condition of conformal transformation, Bilinear transformations, Geometrical inversion, Invariance of cross ratio, Fixed points of a bilinear transformation, some special bilinear transformati on eg.real axis on itself, unit circle on itself, real axis on unit circle etc.Branch point and Branch line, Concept of the Riemann surface. **16 marks**

Unit 5: Analytic Continuation: Analytical continuation, Schwarz's reflection principle, Infinite products, Gamma Function and its properties **12 marks**

Text Books:

1. M.R. Spiegel, Complex Variables. Schaum's Outlines series, McGraw Hill Education, 2017
2. E. G. Philips, Functions of a complex variables with applications, Oliver and Boyd, 1957

Reference Books:

1. Walter Rudin, Real and Complex Analysis, McGraw Hill Education, 2017
2. L. V. Ahlfors, Complex Analysis, McGraw Hill., 2000
3. H. A. Priestly, Introduction to Complex Analysis, Clarendon Press Oxford, 1990
4. Mark J. Ablowitz and A.S. Fokas, Complex Variables, Introduction and Application, CUP, 1998.
5. John B Conway, Functions of Complex Variable, Springer, 1872.

Course outcome:

- It is common to encounter an integral that seems impossible to evaluate but with the knowledge of Residue theorem and its consequences students can make it possible.

- Holonomic functions have the property that they can be uniquely analytically continued to (almost) the entire complex plane. Using the analytic continuation students can understand the behavior of a function at much larger scale by just knowing how the function behaves at a teenie-weenie open disc in the complex plane. This section has a tremendous use in physics and engineering.
- Power series expansions are largely used in every branch of physics. An important application of power series in the field of engineering is spectrum analysis. Power series is used extensively you have to solve complicated differential equations. Students having knowledge of power series can solve many complicated equations arising in physics, finance and engineering.
- Conformal mapping is an important technique used in complex analysis and has many applications in different physical situations. If the physical problem can be represented by complex functions but the geometric structure becomes inconvenient then by appropriate mapping it can be converted to a problem of convenient geometry. With the help of conformal mapping students can solve boundary value problems that arise in heat conduction, electrostatic potential and fluid flow.

MAT 2026 – Topology

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Definition and examples of topological spaces, closed sets, closure, Dense subsets, Neighbourhood, Interior, Exterior and Boundary, Accumulation Points and Derived sets, Bases and sub-bases. Subbase and Relative Topology, Continuous Functions and Homeomorphism. **12 marks**

Unit 2: Countable and uncountable sets, First and second Countable spaces, Lindelof's theorem, Separable spaces, Second Countability and Separability. **12marks**

Unit 3: Separation Axioms T_0, T_1, T_2, $T_{31/2}$, T_4 ; their characterizations and basic properties, Urysohn's lemma, Tietze Extension Theorem **12marks**

Unit 4: Compactness, continuous functions and compact sets. Basic properties of compactness, Compactness and finite intersection property, Sequentially and Countably compact sets, Local Compactness and one point compactification. Stone-Cech Compactification, Compactness in metric spaces, Equivalence of compactness, Countable compactness and sequential compactness in metric spaces. **16marks**

Unit 5: Connected spaces, connectedness on the real line, components, totally disconnected spaces, Locally connected spaces. **12marks**

Unit 6: Tychonoff product topology in terms of standard subbase and its characterizations, Project Maps, Separation Axioms and Product Spaces, Connectedness and Product spaces, Compactness and Product Spaces (Tychonoff's) Theorem, Countability and Product Spaces, Embedding and Metrization, Urysohn Metrization theorem. **16marks**

Text Books:

1. J. R. Munkres, Topology: A first course, Prentice Hall of India, 1974
2. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 2017

Reference Books:

1. K.D. Joshi, Introduction to General Topology, New Age International Private Limited, 2017
2. J. Dugundji, Topology, Allyn and Bacon, 1966 (Reprinted in India By PHI)

3. J. Hocking and G. Young, Topology, Addison Wiley Reading, 1961
4. L. A. Steen and J. A. Seebach, Counter Examples in Topology, Dover Publications, 1995.

Course outcome:
Students will have knowledge:

- to identify topological spaces and will be familiar with different types of subsets like open sets, closed sets, neighbourhoods, interior, boundary, derived sets, etc ., together with the ideas of bases, subbases, relative topology, continuous functions and homeomorphisms. They can be able to classify different spaces like first countable, second countable, separable spaces and give the characterization of these spaces using some important results like Urysohn's lemma, Tietze extension theorem.
- To use the idea of compactness and connectedness and give their different characterizations.
- To explain the product topology and its relationship with compactness, connectedness, countability, etc. They can also provide examples of metrizable spaces, and can explain the relationship between embedding and metrization.

MAT 2036 Functional Analysis

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Normed linear spaces, Banach spaces and examples, First properties of normed linear spaces, Different types of convergence of series in a normed linear space, Absorbing, balance and convex subsets of a normed linear space, Convex hull, closed convex hull, linear hull and closed linear hull of subsets of normed linear spaces. **10 marks**

Unit 2: Continuous and bounded linear operators between normed spaces, Banach space of bounded linear operators, Normed space isomorphism and isometric isomorphism, properties of finite dimensional normed linear spaces. **10 marks**

Unit 3: Fundamental theorems on normed linear spaces: Open Mapping Theorem, Closed Graph Theorem and Uniform Boundedness Principle **10 marks**

Unit 4: Quotient space, three space property, first isomorphism theorem for Banach spaces, vector space version and normed space version of Hahn Banach extension theorem, some applications, Minkowski functional, separation theorem **10 marks**

Unit 5: Dual space X* as a Banach space, dual space of R^n, c_0, l_1, l_∞ l_p. Adjoint operator of a bounded linear operator, annihilators, dual space of subspace and quotient space, second dual, reflexivity, separability **10 marks**

Unit 6: Inner product space, Hilbert space, Examples and first properties, Orthonormal sets,.Gram-Schmidt orthonormalization theorem, Bessel's inequality, Orthonormal basis and theorems on it. **15 marks**

Unit 7: Bounded operators and adjoint operator in a Hilbert space, Normal, unitary, self-adjoint and positive operator, Spectrum and numerical range, Compact self adjoint operator, Fixed point theorem and its applications. **15 marks**

Text Books:

1. R.E. Megginson, An introduction to Banach space theory, Springer, 1998
2. B.V. Limaye, Functional Analysis, New Age International, 2014
3. E. Kreyszig, Introductory Functional Analysis with applications, Wiley Classics Lib. Ed. 2007.

Course outcome:

Students will have knowledge:

- To identify normed linear spaces and Banach spaces and can provide and construct examples of these spaces. They will be familiar with different types of convergence of series in normed linear spaces and various types of subsets like absorbing, balanced, convex sets, convex hull, linear hull of a subset etc. They can be able to classify finite dimensional spaces and can provide different characteristics of such spaces.
- To explain the fundamental theorems on normed linear spaces, Hahn-Banach theorem, separation theorem and can give their different applications. They will be familiar with dual spaces of different normed linear spaces and can explain the concepts of reflexivity, separability, weak and weak topology.
- To identify inner product spaces, Hilbert spaces and can provide examples of such spaces. They can classify different types of operators like normal, unitary, self adjoint, positive, compact operators with examples and characteristics. They will also be able to explain the underlying idea of fixed point theorem, extreme points and Krein Milman theorem.

MAT-2046 Number theory

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Primitive roots: order of an integer mod m, primitive roots for primes, composite numbers having primitive roots, theory of indices **15 marks**

Unit 2: Quadratic residues: Euler's criterion, Legendre's symbol and its properties, Quadratic Reciprocity Law, Quadratic congruences with composite moduli. **15 marks**

Unit 3: Fibonacci numbers: certain identities involving Fibonacci numbers, Continued fractions, Pell's equation. **15 marks**

Unit 4: Partitions, graphical representation of partitions. Euler's theorem, generating functions, search for partition identities. **15marks**

Unit 5: Algebraic numbers, number fields, norm, trace, discriminants. Valuations, algebraic integers and integral bases. **20 marks**

Text Books:

1. David M. Burton,Elementary Number Theory (Unit 1, 2, 3), McGraw Hill Education, 2017
2. G.E. Andrews,Number Theory (Unit 4), Dover Publications, 2012
3. Richard A Molin,Algebraic number theory,Chapman and Hall/CRC, 2011

Reference Books:

1. I. Niven, H. S. Zuckerman and H. L. Montgomery,Introduction to Theory of Numbers, Wiley, 2008.

Course outcome:

- The main objective of introducing this paper in the PG syllabus is that number theory is extensively used in the financial and defence sector of a country whereas Graph theory serves as an Mathematical model in any system involving a binary relation. Both Number and Graph Theory are used in computer application

- Students can use the concept of primitive roots and indices for solvability of congruence of higher order. The students can explain the quadratic reciprocity law using Legendere's and Jacobi's symbol.
- Students can explain Fibonacci numbers and related identities. Students can also explain partition functions, its graphical representations and generative functions.

MAT 2056– Differential Equation

Total Marks: 100 Theory: 80 Sessional: 20

Unit 1: Well posed problems, Existence, uniqueness and continuity of solution of ODEs of first order, Picard's method, Existence and uniqueness of solution of simultaneous differential equations of first order, Sturm separation and comparison theorems, Homogeneous linear systems, Non-homogeneous linear systems. Variation of Parameters. **15 marks**

Unit 2. Linear homogeneous differential equation-Ordinary and singular points, Series solution, Method of Frobenius. Solutions of Bessel's and Legendre equations. **10 marks**

Unit 3: Two point boundary value problems, Green's function, Construction of Green's function, Sturm Liouville systems, Eigen values and eigen functions, Stability of autonomous system of differential equations, Critical point of an autonomous system and their classification as stable, Asymptotically stable, Strictly stable and unstable, Stability of linear systems with constant coefficients, Linear plane autonomous systems, Perturbed systems, Method of Lyapunov for nonlinear systems. **20 marks**

Unit 4: First order PDE: Characteristics of a linear first order PDE. Cauchy's problem; Solution of non-linear first order P.D.E. by Cauchy's method of characteristics **15 marks**

Unit 5: Second order linear PDE-Classification, General solution of higher order PDE with constant coefficients. Method of Characteristics. Classification of quasi-linear equations. **20 marks**

Text Books:

1. S.L. Ross, Differential Equations, Second Edition, John Wiley & Sons, India, 2007.
1. I. N. Sneddon, Elements of Partial Differential Equations, Mcgraw Hill 2006
2. W. E. Williams, Partial Differential Equations, Oxford University Press, 1980
3. F. H. Miller, Partial Differential Equations, J. Wiley & Sons; London, Chapman & Hall, 1941.
4. K.S. Rao, Introduction to partial differential equations, Prentice Hall, New Delhi, 1997.
5. A. Sommerfeld, Partial differential equations in physics, Academic Press, New York, 1967.
6. I. Stakgold, Green's functions and boundary value problems, Wiley, New York, 1979.

Reference Books:

1. Lawrence C. Evans, Partial DifferentialEquations, Second Edition, American Mathematical Society, 2014.
2. Erich Zauderer, Partial Differential Equations of Applied Mathematics, A Wiley- Interscience Publication, John Wiley and Sons, 1983.
3. H.F. Weinberger, A first course in partial differential equations, Blaisdell, 1965.
4. C.R. Chester, Techniques in partial differential equations, McGraw Hill, New York, 1971.
5. R. Courant and D. Hilbert :Methods of Mathematical Physics: Partial differential equations, Vol – II, Wiley-VCH, 1989

Course outcome:

Students will have knowledge:

- To identify and know the methods of finding solutions of differential equations in explicit form
- To Explain and able to apply whether a differential equation has a unique solution or not
- In dealing with solution in series, great prominence has been found to the method of Frobenius
- To handle partial differential equations with different methods mainly Charpit's and the Jacobi's method
- The subject Partial Differential equations have wide range of applications in engineering and technological sciences. Using Partial Differential equations, students can solve wave equations, heat equations, Laplace equations etc.
- Laplace equation that can be solved by Partial Differential Equation is used in real life situations such as electrostatics, gravitation, steady state flow of inviscid fluids, steady state heat conduction etc.
- Using Partial Differential Equations students can formulate other mathematical applications such as semiconductor modelling, mathematical models in biology, astrophysics etc.
- The students can apply Partial Differential Equations in medical sciences such as Kidney dialysis, blood circulation systems etc.

THIRD SEMESTER

MAT-3016 Mathematical Logic

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Informal statement calculus: Statements and connectives, truth functions and truth tables, formal forms, adequate sets of connectives, arguments and validity. **15 marks**

Unit 2: Formal statement calculus: Formal definitions of Proof, Theorem and Deduction, the formal theory L of statement calculus, the deduction theorem and its converse.Valuation in L, tautology in L, the Soundness theorem, extensions of L, consistency of an extension, the adequacy theorem of L. **20 marks**

Unit 3: Predicate Calculus and Formal System: Symbolism of predicate calculus, first order language, interpretation, truth-values of well-formed formulas, satisfaction and truth.
Formal predicate calculus: Predicate Calculus as a normal theory, the adequacy theorem of K. **25 marks**

Unit 4: Mathematical Systems: First order systems with equality, the theory of groups, first order arithmetic, formal set theory, consistency and models. **20 marks**

Text book:

1. A.G. Hamilton, Logic for Mathematicians, Cambridge University Press, 1978

Reference Book:

1. Elliot Mendelson,Introduction to mathematical Logic, Cambridge University Press, 2003

Course outcome:

- This course explores the logical and foundational aspects of mathematics. A special emphasis is given in understanding and writing proofs.

- This course also demonstrates knowledge of fundamental concepts of mathematics including those relating to logic, sets, functions, relations, etc. as well as helps students to precisely state fundamental definitions, axioms and theorems and utilize them to prove related results.

- Students learn to manipulate mathematical statements involving quantifiers and logical connectives.

- Students are able to write clear and rigorous proofs or disproofs of mathematical statements utilizing several proof techniques including direct proof, proof by contrapositive, proof by contradiction, proof by cases, mathematical induction, and by providing examples or counterexamples.

MAT-3016 Continuum Mechanics and Hydrodynamics

Continuum Mechanics

Total Marks: 50 **Theory: 40** **Sessional: 10**

Unit 1: Analysis of Stress: The continuum concept, Homogeneity, isotropy, mass density, Cauchy's stress principle, Stress tensor. Equations of equilibrium, Stress quadric of Cauchy, Principal stress, Stress invariants, Deviator and Spherical stress tensors **10 marks**

Unit 2: Analysis of Strain: Lagrangian and Eulerian descriptions, Deformation tensors, Finitestrain tensor, Small deformation theory, Linear strain tensor and physical interpretation, Stress ratio and finite strain interpretation, strain quadric of Cauchy, Principle strains, Strain invariants, Spherical and Deviator strain components, Equation of Compatibility **10 marks**

Unit 3: Motion and flow: Material derivatives, path lines and stream lines, Rate of deformation and Vorticity with their physical interpretation. Material derivatives of volume surface and line elements, Volume, surface and line integrals, Fundamental laws of continuum Mechanics **10 marks**

Unit 4: Constitutive equations of Continuum Mechanics: Linear elasticity, Generalization Hooke's Law, Strain energy function, Elastic constants for isotropic, homogeneous materials, Elastostatic and Elastodynamic problems, Viscous stress tensor, Barotropic flow, Stokesian fluids, Newtonian fluids, Navier Stokes equations, Irrotational flow, perfect fluids, Bernouli's equation; Circulation **10 marks**

Hydrodynamics

Total Marks: 50 **Theory: 40** **Sessional: 10**

Unit 1: Kinematics of fluids in motion and Equations of motion of inviscid fluids: Methods of describing fluid motion, Material, local and convective derivatives, Different kinds of flow, Path lines, stream lines, Velocity Potential, Vorticity Vector, Vortex lines, Equations of continuity; Equations of motion and their integrals, Boundary conditions **10 marks**

Unit 2: Motion in a plane and Motion in space : Use of complex potential, Source, Sink, doublet , Method of images, statements of Circle and Blasius theorems, Motion past a circular cylinder, Motion past a sphere, Stokes's stream function **20 marks**

Unit 3: Vortex motion and General theory of irrotational motion: Vorticity equation, Properties of vortex filaments, motion due to rectilinear vortex and a system of vortices; Kelvin's circulation theorem and its use, Green's theorem and its deductions, Acyclic and Cyclic motions, Kelvin's minimum energy theorem **10 marks**

Text Books:

1. W.H. Besant and A.S. Ramsay, A Treatise on Hydromechanics, Part II, CBS Publishers & Distributors, 2006
2. Frank Chorlton, Text Book of Fluid Dynamics, CBS Publishers & Distributors, 1985

3. G. E. Mase,Continuum Mechanics, Schaum's Outline series. McGraw Hill Co., 1969

Reference Books:

1. G.K. Batchelor,An Introduction to Fluid Mechanics, Foundation Books, 2005
2. M. D. Raisinghania, Fluid Dynamics, S. Chand and Co. Ltd, 2003
3. R. Chatterjee,Mathematical Theory of Continuum Mechanics, Narosa Publishing House, 2015.

Course outcome:

- The objective of this course is to explain the fundamental concept of the principles of classical continuum physics as applied to elasticity and fluid mechanics.
- The students can acquire the idea of constitutive equations of material behaviour.
- The students can identify specific branches of continuum mechanics such as hydrodynamics, viscous flow and classical elasticity.
- Using the theory of Cartesian tensors and matrices the students can realize the physical stress components, deformation, emphasizing force balance and constitutive models with applications in different branches of engineering and technology.

MAT-3026 Graph Theory

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Graphs: Subgraphs, walk, paths, cycles and components, intersection of graphs, Degrees, Degree sequences. Topological operations, subdivision (of cycles), Derived graphs, Binary operations **15 marks**

Unit 2: Trees: Spanning trees, Minimum spanning tree problem, cycles, cocycles, cycle space, cocycle spaces, Conrectivity, cut vertices, cut edges and blocks, connectivity parameters, Menger's theorem (statements only), Hall's marriage problem. **15 marks**

Unit 3: Eulerian and Traversable graphs: Characterization theorems, characterization attempts for Hamiltonian graphs: Two necessary and sufficient conditions for a graph to be Hamiltonian, Factorization; Basic concepts, 1-factorization, 2-factorization, coverings, critical points and lines. **15 marks**

Unit 4: Planarity: Plane and planar graphs, outer planar graphs, Euler's Polyhedron formula, Kuratowski's theorems, statement with example, Genus, thickness, coarseness and crossing number of a graph (definition with example) **15 marks**

Unit 5: Colourability: Chromatic number. Five colour theorem, chromatic polynomial. **10 marks**

Unit-6: Adjacency Matrix and Incidence Matrix of a graph. Spectrum of Graphs. Vertex partition and Spectrum. **10 marks**

Text Books:

1. F. Harary,Graph Theory, Addison-Wesley Publishing Company, 1969
2. C. Godsil and G. Royle,Algebraic Graph Theory, Springer-Verlag, 2001

Reference Books:

1. D. B. West, Introduction to Graph Theory, Pearson Education India, 2015
2. K. R. Partha Sarathy,Basic graph theory,McGraw-Hill Education, 1994
3. N. Biggs,Algebraic graph theory, CUP, 1994

Course outcome:

- The students acquire basic knowledge of graphs to model some practical situation by using graphs.

- Students can analyze their social networks using graph theory and able to view social network.
- Students are able to use a combination of theoretical knowledge and independent thinking in creative investigation of questions in graph theory.

MAT-3026 Special Theory of Relativity

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Inertial and non-inertial frames of reference, Galilean transformations, Geometry of Newtonian Mechanics, Fundamentals of Electrodynamics, Background of the Fundamental Postulates of the Special Theory of Relativity, Lorentz transformations, relativistic concept of space and time and relativity of motion, Geometrical interpretation of Lorentz transformation as a rotation. **12 marks**

Unit 2: Consequences of Lorentz transformations - (i) Lorentz-Fitzgerald contraction, (ii) Time dilation and (iii) Simultaneity of events. Proper length and proper time. Relativistic law of addition of velocities and its interpretation, Invariance of speed of light, Lorentz transformation as a group, Applications in problems. Transformation of acceleration. **16 marks**

Unit 3: Relativistic mechanics: Variation of mass with velocity, Transformation formula for mass, force and density, Equivalence of mass and energy, Relation between momentum and energy, Transformation formula for momentum and energy, Energy momentum vector, Applications in problems. **16 marks**

Unit 4: Minkowski space: World point, World line, Minkowski's space-time diagram, Geometrical representation of length contraction, time dilation and simultaneity. Light cone, Space-like and time-like intervals. Position four vectors, Four velocity, Four forces and Four momentums, Relativistic equations of motion, Lorentz transformations of space and time in four-vector form. **16 marks**

Unit 5: Transformation of differential operators, D'Alembert's operator, Maxwell's electromagnetic field equations, Electromagnetic potentials and Electromagnetic force, Lorentz condition, Lorentz condition in four vector form, Transformations of charge and current density, Transformations of electromagnetic potentials, Invariance of Maxwell's equations, The electromagnetic field tensor, Maxwell's equation in tensor form, Transformation equations of electric field strength and magnetic field induction vector, Invariance of $E^2 - H^2$ and $\vec{E}.\vec{H}$. Lorentz force. **20 marks**

Text Books:

1. Robert Resnick, Introduction to Special Relativity, Wiley Eastern Ltd., 2007
2. K. D. Krori, Fundamentals of Special and General Relativity, PHI Learning Private Ltd., 2010

Reference Books:

1. A.S. Eddington, The Mathematical Theory of Relativity, Cambridge University Press, 1923
2. S. Banerji and A. Banerjee, The Special Theory of Relativity, PHI Learning Private Ltd., 2012.

Course outcome:

Students will have knowledge:

- To find difference between classical relativity and Einstein's relativity. They will know the postulates of special theory of relativity, Lorentz transformations.
- To use addition law of velocities and its interpretation. They will learn the fact that a clock attached to any moving system runs at different rhythm from a stationary clock; and a measuring rod attached to any moving system changes its length according to the velocity of the system.
- To explain the variation of mass with velocity, the equivalence of mass and energy and the transformations of mass, momentum and energy.
- To identify Minkowski's space, unification of space and time etc.
- To study the transformation of charge and current density and the invariance of Maxwell's electromagnetic equations.

MAT-3036 Operations Research

Total Marks: 100 Theory: 64 Practical: 16 Sessional: 20

Unit 1: Linear Programming: Simplex Method, Artificial variable technique, Duality in Linear Programming, Integer Programming, Gomory's I.P.P. Method, Branch and Bound technique. Application to Industrial problems. **16 marks**

Unit 2: Transportation and Assignment Problems. **10 marks**

Unit 3: Queuing theory: General idea of queuing problem, Operating characteristics of Queuing system, Poisson Queuing systems, Queuing models –M/M/I, M/M/K. Applications in problems. **10 marks**

Unit 4: Network Analysis: Shortest path Problem, Minimum Spanning Tree Problem, Maximum Flow problem, Minimum Cost Flow Problem, Project Planning and Control with PERT-CPM. **10 marks**

Unit 5: Simulation: Theory of Simulation, Monte Carlo method, Application to the problems of replacement maintenance, inventory, queuing and financial problems. **8 marks**

Unit 6: Nonlinear programming: One and Multivariable, Unconstrained Optimization, Kuhn-Tucker conditions for constrained optimization, Quadratic programming (Beale's method). **10 marks**

Practical: (Using any software) 16 Marks

Problems:

Solving Linear Programming Problem by Graphical method, Simplex method and using artificial variable technique.

Text Books:

1. Kanti Swarup, P.K. Gupta and Man Mohan, Opeartions Research, S. Chand and Co., 2010
2. H. A. Taha, Operations Research:An Introduction, Pearson Education, 2019
3. Richard Bronson, Govindasami Naadimuthu,Operations Research, Schaum Outlines Series, McGraw Hill Education, 2017.

Reference Books:

1. F. S. Hillier and G. J. Lieberman, B. Nag and P. Basu, Introduction to Operations Research, McGraw Hill Education; Tenth edition (5 July 2017

2. P. K. Gupta and D. S. Hira, Introduction to Operations Research, S. Chand Publishing, 2012.

Course outcome:

- The subject operation Research originated during World War II where Mathematical techniques were used to tackle the problem of maximum utilization of limited military resources.
- Students studying this subject learn the technique of maximizing the profit and minimizing the cost.
- If a student with some knowledge on Operations Research goes to start an industry, he will be able to select the place for distribution of products so that total cost of transportation is minimum and to select the best advertising media with respect to time, cost etc.
- If a student with knowledge of OR becomes a personal manager, he will be able to appoint the most suitable persons on minimum salary, determine the best age of retirement and to select the number of persons to be appointed.
- If a student with knowledge on OR goes to involve himself in agriculture, he will be able to solve the problem of optimum allocation of land in various crops in accordance with climatic conditions and the problem of optimum distribution of water from various resources like canal for irrigation purposes.

MAT-3036: Programming in C

Total Marks: 100 **Theory: 50** **Practical: 50**

Unit 1: Fundamentals of C-Language: Characters used in C, Identifier, Keywords or Reserved words, Constants, Variables, Variable declaration, Basic Data types, Arithmetic Operators, Relational Operators, Logical Operators, Increment and decrement Operators, Assignment Operator, Conditional or Ternary Operator, Mixed mode operation and Automatic (Implicit) conversion, Casting or Explicit Conversion, Operator Precedence, Structure of a C program, Formatted input / output functions (scanf, printf), Character input/output functions (getchar, getch). **Marks 10**

Unit 2: Control Statements in C: Decision making with if statement, if-else statement, Nested if-else statement, switch statement. **Marks 10**

Unit 3: Loop Control Structures in C: For statement or for loop, Nested for statement or nested for loop, while statement or while loop, do-while statement or do-while loop, Comparison of the loop control structures, break and continue statement, go to statement, exit () function. **Marks 10**

Unit 4: Arrays and Subscripted Variables: One-dimensional array, two-dimensional array, declaration of arrays, initialization of values in arrays, accessing values in an array and output from an array. **Marks 10**

Unit 5: User-defined Functions: Uses of functions, User defined functions, Function declaration, Calling a function, Actual and Formal arguments, Rules to call a function, Function Prototype, Recursion and use of recursive function, Preliminary ideas about Local or internal variables, Global or External Variables, void function. **Marks 10**

Problems for practical:

1. Write a program to read n integers and print the maximum, minimum and average of the numbers.
2. Write a program to calculate the sum of the series $1^2 + 2^2 + 3^2 \cdots\cdots\cdots + N^2$ for any positive integer N given as input (without using any mathematical formula).
3. Write a program to compute the sum of the first n terms of the following series
   S = 1+1/2+1/3+1/4+......
4. Write a program to compute the sum of the first n terms of the following series:

S =1-2+3-4+5...............

5. Write a function to find whether a given number is prime or not. Use the same to generate the prime numbers less than 100.
6. Write a program to compute the factors of a given number.
7. Given two ordered arrays of integers, write a program to merge the two-arrays to get an ordered array.
8. Write a program to display Fibonacci series (i) using recursion, (ii) using iteration
9. Write a program to calculate Factorial of a number (i) using recursion, (ii) using iteration
10. Write a program to calculate GCD of two numbers (i) with recursion (ii) without recursion.
11. Write a program to calculate the factorial of any natural number given as input.
12. Write a program to find HCF of two numbers.
13. Write a program to find perfect numbers between num1 and num2 where num1 and num2 are two positive integers given as input.
14. Write a program to find pairs of amicable numbers
15. Read a list of integers terminated by 0 and print the average of negative numbers and the average of positive numbers separately.
16. Write a program that prompts the user to input a positive integer. It should then output a message indicating whether the number is a prime number.
17. Write a program that prompts the user to input the value of a, b and c involved in the equation $ax^2 + bx + c = 0$ and outputs the type of the roots of the equation. Also the program should outputs all the roots of the equation. For complex roots it should print the real part and imaginary part.
18. Write a program that uses while loops to perform the following steps:
    a. Prompt the user to input two integers: first Num and second Num (first Num should be less than second Num).
    b. Output all odd and even numbers separately between first Num and second Num.
    c. Output the sum of all even numbers between first Num and second Num.
    d. Output the sum of the squares of the odd numbers between first Num and second Num.
19. Write a program that prompts the user to enter the lengths of three sides of a triangle. Write statements to validate the input (sum of any two sides is greater than the third side). Write one function to compute the area of a triangle. Write another function to check whether the triangle is a right angled triangle or a scalene triangle. The main function should call the above to functions.
20. Write a function that takes as a parameter an integer (as a long value) and returns the number of odd, even, and zero digits. Also write a program to test your function.
21. Enter n integers into an array and sort them in an ascending/ descending order and print the sorted list of integers.
22. Write program to Multiply / Add / Subtract two matrices using two dimensional arrays. The program should do the necessary checking to see if the matrices could be added/subtracted/multiplied.
23. Using arrays read two vectors of the same size and compute the dot product of these vectors.
24. Read from a text file and write to a text file.
25. Write a function to return the HCF of two positive integers. Write a main function to read two positive integers and print their HCF and LCM by calling the above function. (use LCM × HCF = product of the numbers).
26. Write a program to find the biggest of given three numbers using nested if statement.
27. Write a program to find the value of y using

$$y(x,n) = \begin{cases} 1 + x, \quad when\ n = 1 \\ 1 + \frac{x}{n}, when\ n = 2 \\ 1 + x^n, when\ n = 3 \\ 1 + nx, when\ n > 3\ or\ n < 1 \end{cases}$$

    using both nested if and switch statement.

28. Find the sum of the series 1 + (1+2) + (1 +2 +3) +…. Upto n terms
29. Find the value of Sin(x), Cos(x) (for some input x) using their series expansion.
30. Write a Program to reverse a given integer (for example 284321 is reversed as 123482)
31. Write a program to finds the arithmetic mean, variance and standard deviation of n values using

an array
32. Write a program to sort n numbers in ascending / descending order using array
33. Write programs to add, multiply two given matrices
34. Write Programs to finds and print transpose, trace of matrix
35. Write Programs to check whether a given matrix is symmetric or not
36. Write a function to find the factorial of a given integer and use it to find the value of ${}^{n}C_{r}$
37. Write a function to finds the biggest of three given values and use it to finds the total marks obtained by a student which in turn is the sum of the best of three test scores and the best of three assignment scores
38. Write a recursive function to find the factorial of a given integer and use it to find the value of ${}^{n}C_{r}$

Text Books:

1. B. W. Kernighan and D. M. Ritchi, The C-Programming Language, Prentice Hall, 1977.
2. T. Jeyapoovan, A first course in Programming with C, Vikas Publishing House, 2004
3. E. Balagurnsamy; Programming in ANSI 'C', Tata McGraw Hill, 2004.
4. Y. Kanetkar; Let Us C, BPB Publication, 1999.
5. C. Xavier, C-Language and Numerical Methods,New Age Publishers, 1999
6. V. Rajaraman, Computer Oriented Numerical Methods, Prentice Hall of India, 1980.

Course outcome:

- Computer programming nowadays has become an integral part of any mathematics syllabus of M.Sc level particularly due to handle nonlinear equations as those can not be handled analytically. Keeping this aspect in mind the department introduced a paper on Programming since early 90s.
- This course has equipped the students to carry out long and tedious computational works particularly when they go for research in some application oriented field after completion of M.Sc degree.
- After knowing programming in C, the students can easily shift over to any other programming which are used in different fields. In fact, some of our students got job in TCS, Infosys etc. with the help of this course.
- The modern age is full of electronic programmable equipments and gadgets which are run through some programs. The students find it easier to handle with those equipments and gadgets after learning this paper.

MAT 3046 Measure Theory

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Measures: Algebras and sigma-algebras, Measures, Outer measures, Lebesgue measures, Completeness and regularity. **15 marks**

Unit 2: Functions and integrals: Measurable functions, Properties that hold almost everywhere, The integral, Limit theorems, Measurable functions again, complex valued functions, and image measures. **15 marks**

Unit 3: Convergence: Modes of convergence, Definition of $\mathcal{L}^p$ and L^p, Properties of $\mathcal{L}^p$ and $L^{p,}$ dual spaces. **10 marks**

Unit 4: Signed and complex measures: Signed and complex measures, Absolute continuity, Singularity, Functions of bounded variation, The duals of the $\mathcal{L}^p$ spaces. **15 marks**

Unit 5: Product Measures: Construction, Fubini's theorem, Applications **10 marks**

Unit 6: Measures on Locally Compact Spaces and Haar measure: Locally compact spaces, The Riesz representation theorem, Signed and complex measures; Duality, Additional properties of regular measures, Haar Measure, The existence and uniqueness of Haar measure, Properties of Haar measure.

15 marks

Text Book:

1. Donald L. Cohn, Measure Theory, Birkhäuse,2013

Reference Book:

1. P. R. Halmos, Measure Theory, Springer-Verlag, 1974
2. H.L. Royden, Real Analysis, Pearson Education India, 2015

Course outcome:

Students will have knowledge

- to identify the measure space and its properties
- to define measurable functions, to analyse its properties and its role in defining integrals in its general form.
- to analyse various variations of measure space viz signed measure, product measure, Haar measure etc. and their properties.

MAT-3046 Special functions and Partial differential equations

Total Marks: 100 Theory: 80 Sessional: 20

Unit 1.: The origin of special functions. The Gamma functions and its related functions. Legendre polynomials. Recurrence relations for the Legendre polynomials. Rodrigues formula. Series of Legendre polynomials. Legendre's associated functions. Bessel function. Recurrence relations. Integrals involving Bessel functions. Modified Bessel functions. **20 Marks**

Unit 3: Laplace's equation (**Elliptic Equation**): Occurrence of Laplace's equation. Fundamental solutions of Laplace's equation in two and three independent variables. Laplace and wave equation in polar, Spherical polar and in cylindrical polar coordinates. Use of the separation of variables method for the solution of Laplace's equations in two and three dimensions interior and exterior Dirichlet's problem for a circle. Green's function for the Laplace equation, in two and three dimensions. **20 Marks**

Unit 4.: Wave equation (**Hyperbolic Equation**). D'Alembert's formula for the vibration of an infinite string. The domain of dependence, the domain of influence. Use of the method of separation of variables for the solution of the problem of vibration of a string. Wave equation in polar and in cylindrical polar coordinates. **15 Marks**

Unit 5: Diffusion equation (**Parabolic Equation**) Elementary solutions of the Diffusion Equation, Conduction of heat in a bounded strip, First boundary value Conduction of heat in a infinite strip (Cauchy problem), Problems. Diffusion equation in polar and in cylindrical polar coordinates Solution of diffusion equation by Laplace transform method. Application of Bromwich's path. **25 marks**

Text Books:

1. I. N. Sneddon, Elements of Partial Differential Equations, Mcgraw Hill 2006
2. W. E. Williams, Partial Differential Equations, Oxford University Press, 1980
3. I. N. Sneddon, Special functions of mathematical physics and chemistry, Oliver & Boyd, 1956.
4. N. N. Lebedev, Special Functions and Their Applications, PHI, 1965
5. F. H. Miller, Partial Differential Equations, J. Wiley & Sons; London, Chapman & Hall, 1941.
6. K.S. Rao, Introduction to partial differential equations, Prentice Hall, New Delhi, 1997.
7. A. Sommerfeld, Partial differential equations in physics, Academic Press, New York, 1967.
8. I. Stakgold, Green's functions and boundary value problems, Wiley, New York, 1979.

Reference Books:

1. Lawrence C. Evans, Partial DifferentialEquations, Second Edition, American Mathematical Society, 2014.
2. Erich Zauderer, Partial Differential Equations of Applied Mathematics, A Wiley- Interscience Publication, John Wiley and Sons, 1983.
3. H.F. Weinberger, A first course in partial differential equations, Blaisdell, 1965.
4. C.R. Chester, Techniques in partial differential equations, McGraw Hill, New York, 1971.
5. R. Courant and D. Hilbert :Methods of Mathematical Physics: Partial differential equations, Vol – II, Wiley-VCH, 1989

Course outcome:

- The subject Partial Differential equations have wide range of applications in engineering and technological sciences. Using Partial Differential equations, students can solve wave equations, heat equations, Laplace equations etc.
- Laplace equation that can be solved by Partial Differential Equation is used in real life situations such as electrostatics, gravitation, steady state flow of inviscid fluids, steady state heat conduction etc.
- Using Partial Differential Equations students can formulate other mathematical applications such as semiconductor modelling, mathematical models in biology, astrophysics etc.
- The students can apply Partial Differential Equations in medical sciences such as Kidney dialysis, blood circulation systems etc.

MAT-3056 Project

FOURTH SEMESTER

MAT-4016 Fuzzy Sets and Systems

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Fuzzy sets: Basic definitions, α-level sets. Convex fuzzy sets. Basic operations on Fuzzy sets. Types of Fuzzy sets. Cartesian products. Algebraic products. Bounded sum, t-norms and t-conoroms. The extension principle. Image and inverse image of fuzzy sets. Fuzzy numbers. Elements of Fuzzy Arithmetic of fuzzy numbers. **20 marks**

Unit 2: Fuzzy relation and Fuzzy Graphs: Fuzzy relations and fuzzy sets. Composition of fuzzy relations. Min-max composition and its properties. Fuzzy equivalence relations. Fuzzy compatibility relations. Fuzzy relation equations. Fuzzy graphs, Similarity relation. **10 marks**

Unit 3: Possibility Theory: Fuzzy measures. Evidence theory. Necessity measure. Probability measure. Possibility distribution. Possibility theory and fuzzy sets. Possibility theory versus probability theory. **10 marks**

Unit 4: Fuzzy Logic: An overview of Classical Logic. Multivalued logic. Fuzzy propositions. Fuzzy quantifiers. Linguistic variable and hedges. Inference from conditional fuzzy proposition, the compositional rule of inference. Application in Civil, Mechanical and Industrial Engineering. Fuzzy expert system. Fuzzy implications and their selection. Multiconditional approximate reasoning. The role of fuzzy relation equation. **20 marks**

Unit 5: Fuzzy controllers, Fuzzification. Defuzzification and the various Defuzzification methods (the centre of area, the centre of maxima and the mean of maxima methods). Individual decision making. Multi-person decision making. Multicriteria decision making. Multi stage decision making. Fuzzy ranking methods. Fuzzy linear programming.Application in Medicine and Economics. **20 marks**

Text Books:

1. G.J. Klir and B. Yuan, Fuzzy sets and Fuzzy Logic, Theory and Applications, Prentice Hall of India, 1995
2. H. J. Zimmermann, Fuzzy set theory and its application, Allied Publishers. Ltd, 1991

Course outcome:

After completing this course, the students will:

- Be able to distinguish between the crisp set and fuzzy set concepts through the learned differences between the crisp set characteristic function and the fuzzy set membership function, able to draw a parallelism between crisp set operations and fuzzy set operations through the use of characteristic and membership functions respectively. Become aware of the use of fuzzy inference systems in the design of intelligent or humanistic systems.
- Be able to become aware of the application of fuzzy inference in the area of control. Have acquired the ability of thinking differently and have become capable, when necessary, to apply a new thinking methodology to real life problems including engineering ones.
- acquire necessary knowledge of important parts of fuzzy set theory, which will enable them to create effective mathematical models of technical phenomena and processes with uncertain information, and carry them out on PC by means of adequate implementations.
- Be presenting a more logical approach to complicated dynamical behavior and exposing the students to the current trends in system theory and applications.

MAT-4016 Space Dynamics

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Basic formulae of a spherical triangle: The Two body problem. The motion of the centre of mass, The relative motion, Kepler's equation, Solution by Hamilton Jacobi Theory. The determination of Orbits: Laplace's Gauss Methods **20 marks**

Unit 2: The three body problem: general three body problem, restricted three body problem, Jacobi integral, curves of zero velocity, stationary solutions and their stability. The n-body problem. The motion of the centre of mass, Classical integrals. **20 marks**

Unit 3: Perturbation: Osculating orbit, perturbing forces, Secular and Periodic perturbations, Lagrange's planetary Equations in terms of perturbing forces and in terms of perturbed Hamiltonian. Motion of the moon-The perturbing forces, Perturbation of Keplerian elements of the moon by the sun. **20 marks**

Unit 4: Flight Mechanics: Rocket performance in a vaccum, vertically ascending paths, Gravity twin trajectories, Multi-stage rocket in a vacuum. Definitions pertinent to sigle stage rocket, performance, limitations of single stage rockets, Definition pertinent to multi stage rockets including gravity. **20 marks**

Text Books:

1. J. M. A. Danby, Fundamentals of Celestial Mechanics, The Macmillan Company, 1962
2. E-Finlay, Freundlich, Celestial Mechanics, The Macmillan Company, 1985
3. Ralph Deutsch, Orbital Dynamics of space vehicles, Prentice Hall Inc, Engle Wood Cliff, News Jersey, 1963

Reference Books:

1. Theodre E. Stern, An Introduction to Celestial Mechanics, Intersciences Publishers, Inc., 1960
2. Angelo Miele, Flight Mechanics Vol I, Theory of flight paths, Addission Wiley Publishing Company, INC, 1962

Course outcome:

- The method of launching satellite can be known by studying the syllabus
- The necessity and use of multistage rocket which is important for any space mission can be known
- For the determination of the orbit of a satellite the primary objectives are to know the elements of the orbit involved in the system
- For orbit determination the prerequisite of it are to identify the distances of perigee and apogee which can be properly known by means of such studies.
- The knowledge of internet is essential feature for the development of science and technology. The study of space dynamics knowing the behaviours and functions of satellite can be of great help for this purpose.

MAT-4026: Advanced Functional Analysis

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Topology and Nets, Vector topologies, examples, first properties, Mazur's and Eidelheit's separation theorems, Metrizable vector topologies. **20 marks**

Unit 2: The Open Mapping Theorem, the Closed Graph Theorem and the Uniform Boundedness Principle for F-spaces, Topologies induced by families of functions, Weak and weak* topologies. **10 marks**

Unit 3: Convexity: Hahn-Banach theorem for locally convex spaces, Banach-Alaoglu Theorem for topological vector spaces, Krein-Milman theorem, Milman theorem. **10 marks**

Unit 4: Definition of Banach algebra and examples, complex homomorphisms, Gleason-Kahane-Zelazko theorem, Singular and non singular elements, the spectrum of an element, basic properties of spectra, Gelfand formula. **15 marks**

Unit 5: Commutative Banach algebras, homomorphisms and quotient algebras,the Gelfand transform, maximal ideal space and examples, isometric Gelfand transform. **10 marks**

Unit 6: C* algebras: Definition and Examples, Self Adjoint, Unitary, normal, positive and projection elements in C*-algebras, commutative C*-algebras, C*-Homomorphisms, Representation of Commutative C*-algebras, Sub Algebras and the spectrum, The spectrum theorem. The Continuous functional Calculus, Positive linear functional and states in C*-Algebras. **15 marks**

Text Books:

1. Robert E. Megginson , An Introduction to Banach Space Theory, Springer, 2012
2. W. Rudin- Functional Analysis, McGraw Hill Education, 2017
3. W. Arveson- Introduction to C* Algebra, Springer Verlag, 1976.

Reference Books:

1. F.F. Bonsall and J. Duncan, Complete Normed Algebras, Springer Verlag, 1973
2. J. Dixmier, C* Algebras, North Holland Publishing Company, 1977
3. C. E. Rickart, General Theory of Banach Algebra, Von Nostrand, 1960.

Course outcome:

After completing this course, the student will have the:

- Facility with the main, big theorems of functional analysis, the notion of C*-algebra and various examples of C*-algebras, and their basic properties

- The notion of C*-algebra, Gelfand transform, commutative C*-algebras, positive and unitary elements, weak topology and density.

- Representations of C*-algebras - the GNS-construction, algebras of compact operators.

- develop the core skills of the subject and research skills in this areas and its applications to different branches of social sciences and applied sciences.

MAT- 4026 Dynamical Systems and Fractal Geometry

Total Marks: 100 Theory: 80 Sessional: 20

Unit 1: Dynamical systems and Vector fields, Existence and uniqueness of solution, Continuity of solution with Initial condition, Orbit of a map, fixed point, equilibrium point, hyperbolicity, periodic point, phase space. Stability and condition for stability of a fixed point, equilibrium point. Bifurcation in case of maps and differential equation with examples. **15 marks**

Unit 2: Flip Bifurcation, Tangent Bifurcation, Saddle Node Bifurcation, Periodic doubling Bifurcation[in case of Logistic map and Henon map(wherever applicable)], Feigenbaum's Universal constant, Chaotic situation in case of above maps. Role of Time series plot, Lyapunov Exponent and Bifurcation Diagram in case of the above maps. **15 marks**

Unit 3: Nonlinear oscillators (Van der Pol and Duffing), Concept of limit cycle, Hopf Bifurcation **10 marks**

Unit 4: Poincare map, Chaos, Strange attractors, Various routes to chaos. **10 marks**

Unit 5: Basic idea of Fractal Geometry, Construction of the middle third cantor set, Von Koch Curve, Sierpinski triangle, self similar fractals with different similarity ratio, measure and mass distribution, Housdorff measure, Housdorff dimension and its properties **15 marks**

Unit 6: Measure of a set at scale box dimension, its equivalent versions, properties of box dimension, box dimension of middle third Cantor set and other simple sets, upper estimate of box dimension, modified box- counting dimensions, packing measures and dimensions. **15 marks**

Text Books:

1. Kathleen T. Alligood, Tim D. Sauer, James A. Yorke, Chaos: An Introduction to Dynamical Systems , Springer, 2009
2. Kenneth Falconer, Fractal Geometry: Mathematical Foundations and Applications, Wiley, 2013
3. G. C. Layek, An Introduction to Dynamical Systems and Chaos, Springer, 2015

Reference Books:

1. Robert C. Hilborn, Chaos and Nonlinear Dynamics: An Introduction for Scientists and Engineers, Oxford University Press Inc., 1994
2. Robert L. Devaney, Chaos, fractals and dynamics:Computer Experiments in Mathematics, Addison Wesley, 1980
3. Steven H. Strogatz, Nonlinear Dynamics and Chaos- With Applications to Physics, Biology, Chemistry, and Engineering, Taylor & Francis, 2014.
4. Stephen Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer, 2010
5. Heinz-Otto Peitgen, Hartmut Jürgens, Dietmar Saupe, Chaos and Fractals: New Frontiers of Science, Springer, 2004
6. G.C. Layek, An Introduction Dynamical Systems and Chaos, Springer, 2015.

Course outcome:

- Dynamical systems and Fractal Geometry is an interdisciplinary topic which became popular in late 1970s. Mainly stability aspect of nonlinear systems are discussed with taking tools from topology, functional analysis, linear algebra, differential equation, computer etc. With the introduction of this paper, the students has got acquaintance with many interesting and challenging real life problems including bio-science which are dealt with many geometrical and other tools.
- This course will enable the students to pursue for research in many application oriented fields like bio-science.
- This topic got a tremendous boost after the arrival of powerful computers as the computer is an indispensable tool for research in this topic. As a result the students have come to know how computers can be used to solve many challenging problems of real life.
- The course has introduced the students to an entirely new kind of geometry known as Fractal Geometry which is entirely different from Euclidean Geometry.

MAT-4036 Advanced Algebra

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Poset and Lattice, Modular, Distributive Lattices, Direct product (sum) of an infinite family of groups. Structure theorems for finitely generated abelian groups. **15 marks**

Unit 2: Sylow's theorem and its applications **10 marks**

Unit 3: Free abelian groups, free groups, presentation of a group **15 marks**

Unit 4: Modules, sub modules, Direct product and direct sum of modules, Prime ideals incommutative rings, complete ring of quotients of a commutative ring. **20 marks**

Unit 5: Primitive rings, Radical, completely reducible modules and rings, Artinian and Noetherian rings and modules. **20 marks**

Text Books:

1. V.K. Khanna, Lattices and Boolean Algebra- First Concepts,Vikas Publication House Pvt Ltd., 2004
2. J. Lambek, Lectures of Rings and Modules, AMS Chelsea Publishing, 2009
3. T. W. Hungerford, Algebra, Springer, 2004

Reference Books:

1. M. Artin, Algebra, PHILearning Private Limited, 2011
2. M Hall, The Theory of Groups, Macmillan, New York, 1959

Course outcome:

- Based on the UGC syllabus the paper is prepared in a logical, systematic and simple way so that the students can have the ideas on some advanced topic in Algebra like, Sylow's theorems, finitely generated abelian groups, freegroups, free abelian groups, presentation of a group, primitive rings, radical, completely reduciblerings as well as some advanced algebraic structures like poset, lattice and module.
- The students can justify the concepts of direct product of an infinite family of groups, finitely generated abelian groups, free groups, free abelian groups and presentation of a group. Sylow's theorems are playing significant roles in determining subgroups of prime power order of a group and examining whether a group is simple or not.

- The syllabus contains a detailed study of module over a ring which is nothing but generalization of a vector space over a field. The students can determine the maximal and minimal conditions in groups, rings and modules by using Artinian and Noetherian properties.
- The students are able to explain the study of poset and lattice. Lattice structure has lots of application in Boolean algebra specifically in electrical circuits and networks.

MAT-4036 Fluid Dynamics

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Waves: Long wave and surface wave, stationary wave, Energy of the waves, Waves between different media, Group velocity, Dynamical significance of Group velocity, Surface tension and Capillary waves, Effects of Surface tension in water waves **20 marks**

Unit 2: Viscous fluid motion: Navier-Stokes equation of motion, rate of change of vorticity and circulation, rate of dissipation of energy, Diffusion of a viscous filament **20 marks**

Unit 3: Exact solution of Navier Stokes Equations: Flow between plates. Flow through a pipe (circular, elliptic), Suddenly accelerated plane wall, Flow past a circular cylinder. **20 marks**

Unit 4: Laminar Boundary Layer Theory: General outline of Boundary layer flow, Boundary layer thickness, Displacement thickness, Energy thickness, Flow along a flat plate at zero incidence, Similarity solution and Blasius flow about a flat plate, Karman's momentum integral equation, Energy integral equation, Pohlhausen solution of momentum integral equation, Two dimensional Boundary layer equations for flow over a curve surface, phenomenon of separation **20 marks**

Text Books:

1. Horace Lamb, Hydrodynamics, Cambridge University Press, 1953
2. L.M. Milne Thomson, Theoritical Hydrodynamics, Dover Publications Inc.; New edition, 2011
3. H. Schlichting, Boundary Layer Theory, McGraw Hill Book Company Inc., 2016

Reference Books:

1. S. Goldstein, Modern development of Fluid Dynamics, Vol. 1, Dover Publication, 1965
2. G.K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, 2005
3. Frank Chorlton, Text Book of Fluid Dynamics, CBS Publishers & Distributors, 1985

Course outcome:

Fluid Dynamics, a branch of Physics and applied Mathematics is concerned with the study of motion of compressible and incompressible fluids. Studying fluid dynamics, students will acquire knowledge of many features. A few of them are as follows:

- Students will come across many laws of Physics in Mathematical form. For instance, law of conservation of mass in terms of Equation of continuity; law of conservation of momentum in terms of Equation of motion; law of conservation of energy in terms of Energy equation etc.
- Students will acquire knowledge in controlling the viscous drag which is a very essential part in Aeronautical Engineering. For instance, in manufacturing the wings of the aircrafts, Aeronautical Engineers keep in mind the fact that viscous drag on the wings is least. If the drag forces are controlled properly then the impact of collision of the wings with air gets reduced which in turn helps the aircrafts to avoid unwanted accident to a marginal extent.

- Further in manufacturing the wings, it is also kept in mind that the buoyancy force can be applied properly during the period of flying so that the aircrafts float at reasonable heights. This phenomenon is also associated with the principle of fluid dynamics.
- In studying this subject, students will encounter with different types of complicated linear and non-linear differential equations and so the students are to acquire knowledge of solving such type of equations.

MAT-4046 Algebraic Topology

Total Marks: 100 **Theory: 80** **Sessional: 20**

Unit 1: Homotopy between continuous maps, Homotopy relative to a subset, Homotopy class, null homotopy, contractible, path connected and simply connected spaces. Deformation retract, simplex, Affine space. **20 marks**

Unit 2: Fundamental group, fundamental group of S^1, fundamental group of product and torus, properties of free abeliangroups , Category and Functors, Homology functor, singular homology, singular complex. Dimension axioms, and related theorems. **20 marks**

Unit 3: Covering spaces, Unique Path Lifting theorem, Covering Homotopy Theorems, Group of Covering Transformations, criterion of lifting of maps in terms of Fundamental groups, Universal Covering and its existences, special cases of manifolds and topological groups. **20 marks**

Unit 4: Van- Kampen's theorem, Calculation of Fundamental Group of S^n, $n > 1$, Brouwer's Fixed Point theorem for $f : D^n \to D^n$, fundamental theorem of Algebra, Borsuk-Ulam theorem and Han-Sandwich theorem, Frobenius theorem for 3 x 3 matrices, Vector fields. **20 marks**

Text Books:

1. J. J. Rotman, An Introduction to Algebraic Topology, Springer-Verlag, N.Y. 1988.
2. Allen Hatcher, Algebraic Topology, Cambridge Univ. Press, 2002.

Reference Books:

1. A. Dold, Lectures on Algebraic Topology, Springer-Verlag, 1972.
2. W. Fulton, Algebraic Topology, A First Course, Springer-Verlag, 1995.
3. C. Kosniowski, A First Course in Algebraic Topology, Cambridge University Press, 1980.
4. W. S. Massey, Algebraic Topology: An Introduction, Springer-Verlag, N.Y. 1990.
5. E. H. Spanier, Algebraic Topology; McGraw Hill Book Co. N.Y. 1966.
6. C. T.C. Wall, A Geometric Introduction to Topology, Addison-Wesley Publ. Co. Inc 1972.
7. M.R. Adhikari, Basic Algebraic Topology and its Applications, Springer, 2016.

Course outcome:

Students will have knowledge:

- To explain the concepts of fundamental group, homotopy of maps.
- To calculate fundamental group using Van Kampen's theorem, fixed point theorem.
- To explain covering spaces, unique path lifting theorem, homotopy theorems, special cases of many folds and topological groups. Singular homotopy, relation between fundamental group and first homology.
- To calculate homology of S^n and to explain application spheres and vector fields.

MAT-4046 General Theory of Relativity and Cosmology

Total Marks: 100 Theory: 80 Sessional: 20

Unit 1: Geodesics: Derivation of the differential equation of geodesic, Geodesic co-ordinates, Intrinsic derivatives, First Curvatures, parallel transport and related theorems. **15 marks**

Unit 2: Riemann Christoffel Curvature tensors and their properties, Ricci tensor, Ricci scalar curvature, Bianchi identities, Einstein tensor, Divergence of Einstein tensor. **15 marks**

Unit 3: Theory of gravitation: Principle of Covariance and Principle of Equivalence. Simple consequences of Principle of Equivalence- (i) The equality of inertial and gravitational masses (ii) Effect of gravitational potential on the rate of a clock, (iii) The clock paradox. The energy momentum tensor: Energy momentum tensor for a perfect fluid, conservation of energy and momentum. Newtonian equations of motion as an approximation of geodesic equations. **10 marks**

Unit 4: The Einstein field equations in empty space and in presence of matter and energy, Einstein's modified field equations with cosmological constant, Poisson's equation as an approximation of Einstein's field equations. Schwarzschid exterior solution and its isotropic form, relation between M and m. Relativistic planetary orbits and analogues of Kepler's laws in General Relativity, The three crucial tests of General Relativity - (i) The advance of perihelion of planets (ii) Bending of light rays in a gravitational field (iii) Gravitational red-shift in spectral lines. Schawarzchid interior solution and boundary conditions. **20 marks**

Unit 5: Cosmology: Mach's Principle, The Cosmological Principle. Static cosmological models of Einstein and de-Sitter, their derivations, properties and comparison with the actual universe. Hubble's Law. Non-static cosmological models of Friedmann, Lemaître, Robertson and Walker. Derivation of Friedmann-Lemaître-Robertson-Walker (FLRW) metric, Geometry of FLRW space-time, Cosmological Red-shift in FLRW model, Derivation of Hubble's Law from FLRW model, Dynamical consequence of FLRW model, Flatness Problem and Horizon Problem. **20 marks**

Text Books:

1. K. D. Krori,Fundamentals of Special and General Relativity, PHI Learning Private Ltd., 2010
2. A.S. Eddington,The Mathematical Theory of Relativity, Cambridge University Press, 1923
3. B. F. Schutz, A First Course in General Relativity, Cambridge University Press, 2009
4. S. Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, John Wiley & Sons Inc., 1972
5. C. E. Weatherburn, An Introduction to Riemannian Geometry and Tensor Calculus, Cambridge University Press, 2008

Reference Books:

1. S. K. Srivastava, General Relativity and Cosmology, PHI Learning Private Limited, 2008
2. C. Moller, The Theory of Relativity, Oxford University Press, 1960
3. R d'Inverno, Introducing Einstein's Relativity, Oxford University Press, 1992
4. S. W. Hawking and G. F. R. Ellis, The Large Scale Structure of Space-time, Cambridge University Press, 1975
5. D.C. Agarwal, Tensor Calculus and Riemannian Geometry, Krishna Prakashan, 2000
6. L. P. Eisenhart, Riemannian Geometry, Princeton University Press, 1997

Course outcome:

Students will have knowledge

- To use Riemannian Geometry in Relativity
- To explain the theory of gravitation, principle of covariance and equivalence, equality of inertial and gravitational masses, clock paradox, energy momentum tensor.

- To use Einstein’s field equations in empty and in presence of matter and energy modified equations with cosmological constant. They learn the Schwarzscild solution of Einstein’s equations, the three crucial tests in relativity viz., advance of perihelion, bending of light rays and gravitational red-shift in spectral lines.
- To study cosmology, i. e. cosmological principle, Weyl’s postulate, static cosmological models of Einstein and de-sitter universe. They also study the non-static cosmological model Friedmann-Robertson-Walker space-time, Hubble’s law