ROYAL GLOBAL UNIVERSITY
GUWAHATI

# Royal School of Applied and Pure Sciences

## Department of Mathematics

## M.Sc. Mathematics

**COURSE STRUCTURE & SYLLABUS**
**(BASED ON NATIONAL EDUCATION POLICY 2020)**

**W.E.F**

**AY- 2025 – 26**

# STRUCTURE OF THE SYLLABUS FOR 2 YEAR PG PROGRAMME

**SCHOOL NAME: ROYAL SCHOOL OF APPLIED AND PURE SCIENCES**

**DEPARTMENT NAME: MATHEMATICS**

**PROGRAMME NAME: MASTER OF SCIENCE (M.Sc.)**

| **1ST SEMESTER** | | | | |
|---|---|---|---|---|
| **COURSE CODE** | **COURSE TITLE** | **LEVEL** | **CREDIT** | **L-T-P** |
| MAT014C101 | Mathematical Methods | 400 | 4 | 4-0-0 |
| MAT014C102 | Linear Algebra | 400 | 4 | 4-0-0 |
| MAT014C103 | Real Analysis and Lebesgue Measure | 400 | 4 | 4-0-0 |
| MAT014C104 | Ordinary Differential Equations | 400 | 4 | 4-0-0 |
| MAT014C105 | Classical Mechanics and Tensor | 400 | 4 | 4-0-0 |
| SWAYAM CODE 1 | Swayam 1 | 400 | 3/4/5 | |
| **TOTAL CREDIT FOR 1ST SEMESTER** | | | **20+3/4/5** | |
| **2ND SEMESTER** | | | | |
| **COURSE CODE** | **COURSE TITLE** | **LEVEL** | **CREDIT** | **L-T-P** |
| MAT014C201 | Partial Differential Equations | 500 | 4 | 4-0-0 |
| MAT014C202 | Numerical Analysis and Computational Programming | 500 | 4 | 3-0-2 |
| MAT014C203 | Algebra | 500 | 4 | 4-0-0 |
| MAT014C204 | Topology | 500 | 4 | 4-0-0 |
| MAT014C205 | Complex Analysis | 500 | 4 | 4-0-0 |
| SWAYAM CODE 2 | Swayam 2 | 500 | 3/4/5 | |
| **TOTAL CREDIT FOR 2ND SEMESTER** | | | **20**+3/4/5 | |
| **TOTAL CREDIT FOR 1st YEAR=40+6/8/10** | | | | |
| **3RD SEMESTER** | | | | |
| **COURSE CODE** | **COURSE TITLE** | **LEVEL** | **CREDIT** | **L-T-P** |
| MAT014C301/ MAT014C302 | Graph Theory / Mathematical Logic | 500 | 4 | 4-0-0 |
| MAT014C303/ MAT014C304 | Functional Analysis / Algebraic Topology | 500 | 4 | 4-0-0 |
| MAT014C305/ MAT014C306/ MAT014C307 | Continuum Mechanics / Relativity / Differential Geometry | 500 | 4 | 4-0-0 |
| MAT014C308/ MAT014C309/ MAT014C3010 | Number Theory and Cryptography / Financial Mathematics / Advanced Ring Theory | 500 | 4 | 4-0-0 |
| MAT014C321 | Research Project-I | 500 | 8 | 0-0-8 |
| SWAYAM CODE 3 | Swayam 3 | 500 | 3/4/5 | |
| **TOTAL CREDIT FOR 3RD SEMESTER** | | | **24**+3/4/5 | |
| **OR 3rd SEMESTER (For students with 3rd and 4th Semester Research)** | | | | |
| | **RESEARCH PROJECT – PHASE I** | **500** | **24 +3/4/5** | 0-0-0 |

| 4TH SEMESTER | | | | |
|---|---|---|---|---|
| **COURSE CODE** | **COURSE TITLE** | **LEVEL** | **CREDIT** | **L-T-P** |
| | **Dissertation (students with research in 4th Sem)** | | | |
| ***(for 'Coursework only' in lieu of Research)*** | | | | |
| MAT014C401 | Measure Theory and Fuzzy Set Theory | 500 | 4 | 4-0-0 |
| MAT014C402 | Operation Research and Machine Learning | 500 | 4 | 4-0-0 |
| MAT014C403/ MAT014C404 | Operator Theory / Dynamical System and Fractional Calculus | 500 | 4 | 4-0-0 |
| MAT014C405/ MAT014C406/ MAT014C407 | Fluid Dynamics / Probability and Statistics / Bio-Mathematics | 500 | 4 | 4-0-0 |
| MAT014C421 | Research Project-II | 500 | 12 | 0-0-12 |
| SWAYAM CODE 4 | Swayam 4 | 500 | 3/4/5 | |
| **TOTAL CREDIT FOR 4TH SEMESTER** | | | **28**+3/4/5 | |
| **OR 4th SEMESTER (For students with 3rd and 4th Semester Research)** | | | | |
| | **RESEARCH PROJECT – PHASE 2** | **500** | **28**+3/4/5 | 0-0-0 |
| **TOTAL CREDITS FOR 2nd YEAR = 52+6/8/10** | | | | |

| SYLLABUS (1st SEMESTER) |
|---|

**Subject Name: Mathematical Methods** **Subject Code: MAT014C101**

**Level: 400** **Credi Units: 4** **L-T-P-C: 4-0-0-4** **Scheme of Evaluation: T**

**Objective**: The objective of the course **Mathematical Methods (MAT014C301)** is to provide the concepts of different mathematical methods and transformation and to develop specific skills to solve problems in application fields.

**Course Outcomes:**

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| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Understand** the different mathematical methods and transformation. | BT2 |
| CO2 | **Apply** different mathematical methods and transformation.to solve related problems. | BT3 |
| CO3 | **Analyze** the solution of problems obtained by different mathematical methods and transformation. | BT4 |
| CO4 | **Interpret** the solution of problems obtained by applying appropriate mathematical methods. | BT5 |

**Prerequisite:**

- Concept of calculus and differential equations.

**Detailed Syllabus:**

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Calculus of variations:** Linear functionals, general variation of a functional, Euler-Lagrange equation. Variational problems with fixed boundaries. Variational problems in iso-perimetric form. Variational problems with moving boundaries. | **18** |

| | | |
|---|---|---|
| **II** | **Integral equations** I:<br>Definition of Integral Equation, Reduction of ordinary differential equations into integral equations., Linear integral equations of the first and second kind of Fredholm and Volterra type, Fredholm integral equations with separable kernels, Eigen values and Eigen functions, Method of successive approximation, Iterative scheme for Fedholm Integral equations of second kind. | **18** |
| **III** | **Integral equations II:**<br>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 kernels. | **18** |
| **IV** | **Laplace and Fourier transforms**<br><br>Introduction to Laplace transforms, Laplace transforms of some standard functions, Properties of Laplace transforms, Convolution theorem for Laplace transforms, Laplace transforms of periodic functions, Applications of Laplace transforms, Fourier transforms, Fourier sine and cosine transforms, Convolution theorem for Fourier transforms. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Assignment, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Textbooks:***


1. *Calculus of Variations with Applications;* Gupta, A, S.; 2003; Prentice Hall of India; New Delhi
2. *Integral equations and boundary value problems*; M. D Raisinghania; 2016; S. Chand and Co.; New Delhi
3. *Green's Functions;* Roach, G. F.; 1995; *Cambridge University Press*

***Reference Books:***


1. G. M. Ewing; *Calculus of Variations with Applications*; Revised Edition, 2016, Dover Publications.
2. H. Sagan; *Introduction to Calculus of Variations;* Revised Edition; 2012; Dover Publication.
3. *Green's Functions;* Roach, G. F.; 1995; *Cambridge University Press*
4. Mikhlin, S. G.; *Integral equations; 1960, Hindustan Publishing Corp.*
5. Brown J. W. and Churchill, R.; *Fourier Series and Boundary Value Problems; 8th Edition, 2011,* 1993; McGraw Hill.
6. R.P. Kanwal; *Linear Integral Equations, Theory and Techniques*; 2014; Academic Press, New York
7. F. B. Hilderbrand; *Methods of Applied Mathematics*; 2nd Edition; 1992, Dover Publication.

| SYLLABUS (1ST SEMESTER) | | |
|---|---|---|
| **Subject Name: Linear Algebra** | | **Subject Code: MAT014C102** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Linear Algebra** (**MAT014C102)** is to develop independent thinking in various analytical properties of Linear Algebra.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** vector spaces and linear transformations. | BT1 |
| CO2 | **Understand** the theory of canonical forms, bilinear forms, and the relation of linear transformation and matrices. | BT2 |
| CO3 | **Apply** the theories to perform change of bases. | BT3 |
| CO4 | **Analyse** annihilators and decompositions. | BT4 |

***Prerequisites:***

- Concept of Set Theory and Matrices.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Vector Spaces:** Binary operation, Fields, Vector Space, basis of a vector space; Metric space, convergence of sequence, Cauchy sequence, completeness; Definition and examples of normed linear space; Inner product space, properties of inner product and norms; Cauchy-Schwarz Inequality and applications; orthogonality, orthogonal complements, orthogonal sets and bases; projections, Gram-Schmidth algorithm with applications. | 18 |

| | | |
|---|---|---|
| **II** | **Linear Transformations:**<br>Linear Transformation; Kernel and image of linear transformation, computing the kernel and image of linear transformation; singular and non-singular linear transformation, isomorphism; linear operator; Invertible operators; Matrix representation of a linear operator; Change of basis (transition) matrix; change of basis and linear operators; similarity transformations; change of basis and linear mappings. | 18 |
| **III** | **Canonical Forms:**<br>Characteristic value, annihilator polynomial, invariant subspaces, direct sum decomposition, invariant direct sum; Cyclic subspaces and annihilators, cyclic decomposition and rational forms, Jordan canonical form. | 18 |
| **IV** | **Bilinear Forms:**<br>Bilinear forms, symmetric bilinear forms, skew-symmetric bilinear forms, quadratic forms, positive definite quadratic forms and theorems, Signature and Sylvester's law of inertia. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***

1. *Linear Algebra,* Hoffman Kenneth and Kunze Ray, 2nd edition, 2015, PHI learning private limited.

***Reference Book:***

1. *Linear Algebra Done Right,* **Axler** Sheldon, 2nd edition, 2010, Springer.
2. *Linear Algebra,* Lipschutz Seymour, 2004, Tata McGraw-Hill publishing Co Ltd
3. *Linear Algebra,* Friedberg, Insel, Spence, 4th edition 2015, Pearson Education India.
4. *Linear Algebra,* Sharma A.K., 2007, Discovery Publishing House.

| SYLLABUS (1st SEMESTER) | | |
|---|---|---|
| **Subject Name: Real Analysis and Lebesgue Measure** | | **Subject Code: MAT014C103** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objective of **Real Analysis and Lebesgue Measure** (**MAT014C103)** is to build a rigorous foundation in real analysis with a focus on measure theory and the Lebesgue integral.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** improper integrals, derivative of functions of several variables, measure and measurable sets, Lebesgue integral. | BT1 |
| CO2 | **Understand** the theory of improper integrals, Riemann and Lebesgue integral, functions of several variables. | BT2 |
| CO3 | **Apply** the theories to find out convergence of improper integrals, functions of two variables and Lebesgue integration. | BT3 |
| CO4 | **Analyse** this concept to solve new problems. | BT4 |

***Prerequisites:***

- Concept of Real Analysis from graduate.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **The Riemann-Stieltjes Integral and Improper Integrals**<br>Definitions and existence of the integral, some important theorems, Types of improper integrals, Tests for convergence of improper integrals. | 18 |
| **II** | **Multivariable Analysis**<br>Power series, Uniqueness theorem for power series, Functions of several variables, linear transformation, derivatives in an open subset of $R^n$, Chain rule, partial derivatives, interchange of order of differentiation, derivatives of higher order, Taylor's theorem. | 18 |

| | | |
|---|---|---|
| **III** | **Lebesgue measure**<br>Algebra, Sigma Algebra, Lebesgue outer measure, sets of measure zero, properties of outer measure, Lebesgue measurable sets, Borel Sets, sequence of Lebesgue measurable sets, non-measurable sets, Regularity of Lebesgue Measure, Lebesgue measurable functions and their properties, Borel Measurable Functions and their properties, Lebesgue and Borel measurability of sequence of functions. | 18 |
| **IV** | **The Lebesgue integral**<br>Simple functions, Integration of non-negative functions, Lebesgue integral, properties of Lebesgue integrals, comparison of Reimann and Lebesgue integrals, Fatou's lemma, Lebesgue monotone convergence theorem, the general Lebesgue integral, Lebesgue dominated convergence theorem. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***

1. *Principles of Mathematical Analysis*; Rudin Walter; Third Edition; 2017; McGraw Hill Education.
2. *Measure Theory and Integration*, Barra, G. De.,1st Edition 2013; New Age International (P) Ltd, Publishers, New Delhi.

***Reference Books:***

1. Bartle, Robert G.; Sherbert Donald R.; *Introduction to Real Analysis*, Fourth Edition; 2014; Wiley India Pvt. Ltd.
2. Apostol T.M.; *Mathematical Analysis*; Second Edition; 2002; Narosa Publishing House; New Delhi.

3. Malik, S.C. and Arora Savita; *Mathematical Analysis*; Fifth edition; 2017; New Age Science Ltd.
4. *Real Analysis;* Royden, H. L., 4rd Edition; 2015, Pearson Education India,
5. *An Introduction to Measure and Integration;* Rana, I. K.; 2nd edition; 2007, Narosa Publishing House, India.
6. Halmos P.R., *Measure Theory*; Second Reprint, 2008, Springer.
7. L. Cohn Donald, *Measure Theory*; 2nd Edition; 2013, Birkhauser.

| SYLLABUS (1st SEMESTER) | | |
|---|---|---|
| **Subject Name: Ordinary Differential Equations** | **Level: 400** | **Subject Code: MAT014C104** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Ordinary Differential Equations** (**MAT014C104)** are to build foundational knowledge of ODEs and their applications in scientific and engineering contexts, fostering skills to model, solve, and interpret real-world phenomena. It emphasizes applying ODE theories to dynamic systems, stability analysis, and various applied or theoretical problems.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** uniqueness and the existence theorem. | BT1 |
| CO2 | **Understand** the concept of series solutions. | BT2 |
| CO3 | **Apply** the boundary value problems to various differential equations. | BT3 |
| CO4 | **Analyse** the system of linear differential equations. | BT4 |

***Prerequisites:***

- Concept of Differential Calculus and Integral Calculus.
- Concept of Differential Equations from Undergraduate Level.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Uniqueness and existence theorem, Wronskian and Exact differential equations**<br>Uniqueness and existence theorem, Linearly dependent and independent solutions, Wronskian and its properties, Exact differential equations, and equations of special forms. | 18 |

| | | |
|---|---|---|
| **II** | **Series solution**<br>Ordinary and singular points, power series solution of second-order homogeneous equations, Frobenius' method- solution about a regular singularity, solutions of Hypergeometric, Legendre, and Bessel's equations. | 18 |
| **III** | **Boundary value problems**<br>Boundary value problems for second-order differential equations, Green's function, and its applications, Eigenvalue problems, self-adjoint form, Sturm –Liouville problem and its applications. | 18 |
| **IV** | **System of linear differential equations**<br>The system of equations, critical point, Lyapunov, stability theory, a system in matrix form, Eigenvalues, and fundamental set of solutions. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***


1. S.L. Ross, *Differential Equations*, 3rd Edition, 2007, Wiley India.


***Reference Books:***


1. M.D. Raisinghania, *Ordinary and Partial Differential Equations*, 19th edition, 2017, S. Chand and Co., New Delhi.
2. E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, Indian Edition, 2017, Tata McGraw-Hill, New Delhi.
3. Jr Frank Ayers, *Schaum's Outline Series of Theory and problems of differential equations*, Reprint, 1989, Tata McGraw-Hill, New Delhi.

| SYLLABUS (1st SEMESTER) | | |
|---|---|---|
| **Subject Name: Classical Mechanics and Tensor** | **Level: 400** | **Subject Code: MAT014C105** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Classical Mechanics and Tensor** (**MAT014C105)** are to develop the ability to apply advanced mathematical tools, including differential equations, to solve problems in classical mechanics using Newtonian, Lagrangian, and Hamiltonian frameworks. It also introduces the fundamentals of tensor analysis, covering covariant and contravariant tensors, Christoffel symbols, Riemannian metrics, and covariant derivatives.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** motion in two- and three-dimensional ways and some basic theorems. | BT1 |
| CO2 | **Understand** the Lagrangian and Hamiltonian mechanics. | BT2 |
| CO3 | **Apply** the fundamentals of tensor analysis. | BT3 |
| CO4 | **Analyse** the tensor calculus and differential operators further. | BT4 |

***Prerequisites:***

- Concept of dynamics and statics from Undergraduate Level.
- Concept of vector Analysis.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Classical Mechanics on Rigid Body**<br>Motion in two and three dimensions under finite and impulsive forces; velocity and acceleration in cylindrical and spherical coordinates; motion on curved surfaces. D'Alembert's principle, rigid body motion under impulsive forces, application of virtual work, Carnot's, Kelvin's, and Bertrand's theorems. Motion of a rigid body about a fixed point, Euler's geometrical and dynamical systems, and motion without external pressure. | 18 |
| **II** | **Lagrangian and Hamiltonian Mechanics**<br>Generalized coordinates; Lagrange's equations of motion for finite and impulsive forces in holonomic systems; conservative force systems and theory of small oscillations. Hamilton's equations of motion, variational methods, Hamilton's principle, and the principle of least action. | 18 |

| | | |
|---|---|---|
| **III** | **Fundamentals of Tensor Analysis**<br>Transformation laws of covariant and contravariant tensors, mixed tensors, rank, symmetric and anti-symmetric tensors, and related theorems. Algebraic operations on tensors: contraction, inner and outer products, quotient law, and group properties. Christoffel's brackets of the first and second kinds, their properties, Riemannian metric, definitions of metric tensors, and transformation laws of Christoffel brackets. | 18 |
| **IV** | **Tensor Calculus and Differential Operators**<br>Covariant derivatives of tensors $A^i, A_i, A^{ij}, A_{ij}, A^i_j$; generalizations and applications; covariant derivatives of metric tensors and scalar invariant functions. The angle between vectors, gradient, divergence, and curl of vectors; Laplacian in tensor form. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***


1.S.L. Loney, *An Elementary Treatise on Dynamics of a Particle and of Rigid Bodies,* New Age International Private Limited, 2016.
2.H. Goldstein, C. P. Poole, J. L. Safko, *Classical Mechanics (3rd edition)*, Pearson,2001.
3.B.C. Kalita, *Tensor Calculus and Applications - Simplified Tools and Techniques*, CRC Press, 2019.


***Reference Books:***


1. J.L. Synge and B.A. Griffith, *Principles of Mechanics*, 2008, Milward Press.
2. R.D. Gregory, *Classical Mechanics*, 2008, First South Asian Edition, Cambridge Univ. Press.
3. N.C. Rana and P.S. Joag, *Classical Mechanics*, 2017, Tata McGraw- Hill.
4. P.K. Nayak, *Tensor Calculus and Differential Geometry*, 2012, Prentice Hall India Learning Private Limited.
5. D. Kay, *Schaums Outline of Tensor Calculus*, 2011, McGraw-Hill Education.
6. C.E. Weatherburn*: An Introduction to Riemannian Geometry and Tensor Calculus*, Cambridge University Press, 2008

| SYLLABUS (2nd SEMESTER) | | |
|---|---|---|
| **Subject Name: Partial Differential Equations** | | **Subject Code: MAT014C201** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Partial Differential Equations (MAT014C201)** are

- To introduce the concepts and explain how to solve Partial Differential with different methods.
- To enable developing the ability to apply partial differential equations to significant applied and/or theoretical problems.
- To enable finding and interpreting the solutions of the PDE appearing in dynamical systems, stability theory and a number of applications to scientific and engineering problems.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** basic concepts, terminology, and classifications of Partial Differential Equations (PDEs). | BT1 |
| CO2 | **Understand** and explain the formation, types, and solutions of PDEs through theoretical frameworks. | BT2 |
| CO3 | **Apply** suitable methods to solve PDEs arising in mathematical, scientific, and engineering contexts. | BT3 |
| CO4 | **Analyse** the behavior and solutions of PDEs in dynamical systems, stability theory, and real-world models. | BT4 |

***Prerequisites:***

- Concept of Differential Calculus and Integral Calculus.
- Concept of Ordinary and Partial Differential Equations from B.Sc. level.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **First and second Order PDE**<br>First order PDE: Classification, Complete and general integral, Solution by Lagrange's method, Second order PDE: Linear PDE with constant | 18 |

| | | |
|---|---|---|
| | coefficient, classification of linear Second order PDE in two independent variables, characteristic curve. | |
| **II** | **Elliptic Equations**<br>Laplace Equation: Boundary value problems, Fundamental solution, Solution of Dirichlet problem on a rectangle by method of separation of variables, Mean value property, Maximum principles, Dirichlet principle. | 18 |
| **III** | **Parabolic Equations**<br>The diffusion equation (Heat Conduction equation), Elementary solutions of the Diffusion Equation, Separation of variables, Similarity solutions, Use of Laplace Transform, Maximum and minimum principle, Duhamel's Principle. | 18 |
| **IV** | **Hyperbolic Equations**<br>Wave equation: Solution of one-dimensional wave equation, Cauchy problem, Mixed type problems, General solutions of the wave equation and corresponding solution in two dimensions, the non-homogeneous Wave equation, Duhamel's Principle. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***


1. Sneddon, I. N**.** *Elements of Partial Differential Equations*. Reprint, Dover Publications Inc., 2006.


***Reference Book:***


1. Raisinghannia M.D., *Advanced Differential Equations*, 19th Edition, 2018, S. Chand and Co., New Delhi.
2. Evans L. C. *Partial Differential Equations*, Vol. 19, 1998, American Mathematical Society.
3. Logan J. David, *Applied Partial Differential Equations*, 3rd Edition, 2014, Springer Nature.
4. **Tveito** Aslak, **Winther** Ragnar.**,** *Introduction to partial differential equations: a computational approach*, Vol. 25, 2005, Springer-Verlag Berlin Heidelberg.


***E-Reference*: [ https://onlinecourses.nptel.ac.in/noc21_ma51/preview]** for Module IV

**SYLLABUS (2nd SEMESTER)**

Subject Name: Numerical Analysis and Computational Programming

Level : 500 Subject Code: MAT014C202

L-T-P-C: 3-0-2-4 Credit Units: 4 Scheme of Evaluation: T + P

**Objective**: The objectives of Numerical Analysis and Computational Programming **(MAT014C202)** are to enable solving algebraic and transcendental equations, numerical methods to solve a differential equation, system of equations, error analysis, definite integral, developing code in a modern computer language.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** Errors used in numerical analysis. | BT1 |
| CO2 | **Understand** matrix computations, singular value decomposition, stability and ill-conditioning of a system. | BT2 |
| CO3 | **Relate** interpolation to the real-life data. | BT4 |
| CO4 | **Evaluate** differential equations using Numerical integration and computational code. | BT5 |

**Prerequisites:**

- Calculus ("value theorems", Sequences and series, Taylor series both single and multivariate)
- Linear Algebra (linear systems of equations, Eigenvalues of a matrix)
- Differential equations.

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I** | **Errors:**<br>Definition of errors, Error analysis, Source of errors, IEEE floating point arithmetic, Truncation and rounding errors, fixed and floating-point arithmetic, Propagation of errors.<br>Solutions of nonlinear equations; Bisection method and coding, Newton's method and its variants and coding, fixed point iterations and coding, convergence analysis and coding. | **18** |
| **II** | **Iterative Methods**:<br>Fundamentals - overview of matrix computations, norms of vectors and matrices, singular value decomposition (SVD), stability and ill-conditioning; Linear systems - LU factorization, Gaussian eliminations, Cholesky factorization, Jacobi and Gauss-Seidel methods for successive iterations and related computer programming. | **18** |
| **III.** | **Interpolation:**<br>Finite differences, polynomial interpolation, Newton forward/backward interpolation, Lagrange's and Newton's divided difference Interpolation, Hermite interpolation, spline interpolation and computer programming. | **18** |
| **IV** | **Quadrature**:<br>Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature, Richardson extrapolation; Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, multistep methods and stability; Boundary value problems - finite difference method, collocation method, computer programming. | **18** |
| **Total** | | **72** |

***Text Book:***


1. *Elementary Numerical Analysis - An Algorithmic Approach*, Conte S. D. and De Boor Carl, 3rd Edn., Reprint, 2012, McGraw Hill.


***Reference Books:***


1. Kincaid D. and Cheney W., *Numerical Analysis: Mathematics of Scientific Computing*, 3rd Edn., Reprint, 2012, Orient Blabkswan.
2. Atkinson K. E., *Introduction to Numerical Analysis*, 2nd Edn., 1989, John Wiley,
3. Gupta Amritava, Bose S.C, *Introduction to Numerical Analysis*, 2013, Academic Publishers.

| SYLLABUS (2nd SEMESTER) | | |
|---|---|---|
| **Subject Name: Algebra** | **Level: 500** | **Subject Code: MAT014C203** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **ALGEBRA (MAT014C203)** are:

1. To provide the continuous approach to the subject of algebra, which is one of the basic pillars of modern mathematics and to inculcate in students the power of accurate analysis.
2. To provide an insight for further study into applications of abstract algebra in certain areas by knowing to perform algorithms.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the fundamentals of group theory and ring theory. | BT1 |
| CO2 | **Understand** the difference between prime and maximal ideal. | BT2 |
| CO3 | **Apply** the theories to find out ED, PID and UFD. | BT3 |
| CO4 | **Analyse** the theory of algebraic extensions and modules. | BT4 |

**Prerequisites:**

- Concept of Groups (groups, subgroups, permutations, order of element, order of group, coset, normal subgroup, cyclic group)

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I** | **Group Theory:** Homomorphism of groups, Direct product and Direct sums of Groups. Decomposable groups. Normal and Subnormal series of groups, composition series, Jordan Holder theorem and its applications, solvable groups. | **18** |

| | | |
|---|---|---|
| **II** | **Ring theory:**<br>Ideals, Homorphisms, quotient rings, Prime and Maximal Ideals, Quotient Field of an Integral Domain, Polynomial Rings. Divisibility Theory: Euclidean Domain, Principal Ideal Domain, Unique Factorization Domain and their properties | **18** |
| **III** | **Fields:**<br>Extensions of fields, Algebraic and Transcendental elements, Algebraic field extensions, Algebraic extensions of Splitting field, Separable extension, perfect Field | **18** |
| **IV** | **Modules:**<br>Modules, definition and examples, submodules, simplicity, indecomposability, Classification of finitely generated modules over PID's. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***

1. *Modern Algebra*; Singh Surajeet and Zameeruddin Qazi; Eighth Edition; 2006; Vikash Publishing House Pvt Ltd.
2. *Contemporary Abstract Algebra* ; Gallian J. A.; 8th edition; 2013; Cengage Publication.

***Reference Books:***

1. Malik D. S., Mordeson J.N., Sen M. K. ; *Fundamentals of Abstract Algebra* ; 1996; McGraw Hill Company.
2. I. N. *Herstein*; *Topics in Algebra*; 2nd edition; 2006; John *Wiley* & Sons; New York.
3. *Fraleigh John* B.; *A First Course in Abstract Algebra*; 7th edition; 2013; Pearson Education India.
4. Dummit D. and Foote R.; *Abstract Algebra*; 3rd edition; 2011; *Wiley*; New York.
5. Jacobson, N.*; I & II Basic Algebra*; Second edition; 2009; Hindusthan Publishing Corporation, India.

***E-Reference:*** **[https://nptel.ac.in/courses/111/106/111106137/] for Module IV**

| SYLLABUS (2nd SEMESTER) | | |
|---|---|---|
| **Subject Name: Topology** | **Level: 500** | **Subject Code: MAT014C204** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Topology** (**MAT014C204)** are to develop an understanding of set cardinality, topological spaces, continuity, connectedness, compactness, countability, limit points, neighbourhoods, and continuity in metric and topological spaces.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the topological spaces and their basis. | BT1 |
| CO2 | **Understand** the concept of continuity, homeomorphism and connectedness. | BT2 |
| CO3 | **Apply** the concept of compactness and countable spaces. | BT3 |
| CO4 | **Analyse** the countability and separation axioms. | BT4 |

***Prerequisites:***

- Concept of set theory, metric spaces and real analysis.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Cardinal Number and Topological Spaces**<br>Equipotent sets, Cardinality and denumerability, cardinal numbers, order types and ordinal numbers. Definition and examples of topological spaces, open sets, usual topology for $R$, metric topologies, bases, sub-bases and relative topologies, closed sets, closure, dense subsets, neighbourhoods, accumulation point and derived sets. | 18 |
| **II** | **Continuity, Homeomorphism and Connectedness**<br>Continuity in topological spaces, homeomorphism, and theorems on continuity and homeomorphism. Connected and disconnected sets, continuity and connectedness, components, totally disconnected spaces, locally disconnected spaces, arcwise connectivity. | 18 |

| | | |
|---|---|---|
| **III** | **Compactness and Countable Spaces**<br>Compactness, Heine-Borel theorem, countable, sequential and local compactness, compactness in metric spaces, continuity and compactness. First and second countable spaces, Lindelof's theorem, separable spaces, second countability and separability. | 18 |
| **IV** | **Countability and Separation axioms**<br>$T_0$ spaces, $T_1$ spaces, $T_2$ spaces (Hausdorff spaces), $T_3$ spaces (Regular spaces), $T_4$ spaces (normal spaces), their characterisations and basic properties, Urysohn's lemma. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***

1.J. R. Munkres, *Topology*, Second Edition, PHI Learning Private Limited, 2015.
2.S. Kumaresan and V. Aithal, *Topology*, First Edition, Techno World, 2023.

***Reference Books:***

3.K. D. Joshi, *Introduction to General Topology*, Second Edition, New Age International (P) Limited, 2017.
4.W. J. Pervin, *Foundations of General Topology*, Academic Press, 2014.
5.T. W. Gamelin and R. E. Greene, *Introduction to Topology*, Second Edition, Dover Publications, 1999.

**SYLLABUS (2nd SEMESTER)**

| | | |
|---|---|---|
| **Subject Title: Complex Analysis** | **Level: 500** | **Subject Code: MAT014C205** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

***Objective:*** The objectives of **Complex Analysis** (**MAT014C205)** are to extend the concepts of real variable analysis to complex variables and to develop problem-solving skills for further study in related fields.

***Course Outcomes:***

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the concept analytic functions and conformal mappings. | BT1 |
| CO2 | **Illustrate** the complex integration and Cauchy's theory. | BT2 |
| CO3 | **Apply** the power series and local behaviour of functions. | BT3 |
| CO4 | **Analyze** residue theory along with its applications | BT4 |

***Prerequisite:***

- Concept of analytic function

***Detailed Syllabus:***

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I** | **Analytic Functions and Conformal Mappings**<br>Analytic functions as mappings; isogonal and conformal mapping; necessary and sufficient conditions for conformality; fixed points of transformations; Mobius (bilinear) transformations; invariance of cross ratio; branch points and branch lines; concept of the Riemann surface; branch of logarithm. | **18** |
| **II** | **Complex Integration and Cauchy's Theory**<br>Complex line integrals; Goursat's theorem; Cauchy's theorem (basic and homotopic version); simple connectedness; Cauchy's integral formula; higher-order derivatives; Morera's theorem; index of a closed curve; counting zeros; open mapping theorem. | **18** |

| | | |
|---|---|---|
| **III** | **Power Series and Local Behaviour of Functions**<br>Zeroes and singularities of analytic functions; classification of singularities; power series representation; Taylor's and Laurent's theorems; Cauchy's inequality; Maximum Modulus Principle; Minimum Modulus Theorem; Schwarz's Lemma; Liouville's Theorem; Fundamental Theorem of Algebra; Gauss's Mean Value Theorem. | **18** |
| **IV** | **Residue Theory and Applications**<br>Residues and their computation; Cauchy's Residue Theorem; contour integration and evaluation of real definite integrals; Argument Principle; Rouché's Theorem; special techniques and theorems used in evaluating integrals; Mittag-Leffler's Theorem. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***

1. *Complex Variables and Applications;* Churchill R.V. and Brown J.W.; 8th edition; 2017; McGraw Hill Education.
2. *Functions of one complex variable;* Conway J. B.; Springer International Student edition; 2012; Narosa Publishing House, New Delhi.

***Reference Books:***


1. Spiegel M.R.; *Schaum's Outline of Complex Variables*; 2edition; 2017; McGraw-Hill.
2. Ahlfors L. V.; *Complex Analysis*; 3nd Edition; 2000; McGraw-Hill.
3. D. Sarason; *Complex Function Theory*; 2008; Hindustan Book Agency, Delhi.
4. Rudin, W.; *Real and Complex Analysis*; 3rd edition; 2017; McGraw-Hill.
5. Needham T.; *Visual complex Analysis*; Reprint edition; 1998; Oxford University Press; USA.

| SYLLABUS (3rd SEMESTER) | | |
|---|---|---|
| **Subject Name: Graph Theory** | **Level: 500** | **Subject Code: MAT014C301** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective:** The objectives of the course **Graph Theory (MAT014C301)** are

- To enable understanding and apply the fundamental concepts in graph theory.
- To impart the application of graph theory based tools in solving practical problems.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the fundamentals concepts of graph theory. | BT1 |
| CO2 | **Understand** theory of Euler graphs and Hamiltonian circuits. | BT2 |
| CO3 | **Application** of graph theory in Traveling Salesman Problem and königsberg bridge problem. | BT3 |
| CO4 | **Analyse** the theory of trees and colour theorems. | BT4 |

**Prerequisites:**

- Set theory, Matrices

**Detailed Syllabus:**

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Introduction**<br>Graph theoretic basic concepts- finite and infinite graphs, incidence and degree, isolated and pendant vertices, null graph; Paths and Circuits- isomorphism, subgraphs, walks, connected and disconnected graphs and components, Euler graphs, Bi-partite graphs, Hamiltonian paths and circuits. Shortest path problem, Traveling Salesman Problem. Directed graphs- definition, types, directed paths and connectedness, Euler digraph. | **18** |

| | | |
|---|---|---|
| **II** | **Trees & Fundamental circuits:**<br>Definition and Properties of trees, distance and centers, rooted and binary trees, on counting trees, spanning trees, fundamental circuits, spanning trees in weighted graphs. Cycles, cocycles, cycle space, cocycle spaces, Connectivity, cut vertices, cut edges and blocks, connectivity parameters, Menger's theorem. Cut-sets, connectivity and separability, network flows; Matrix representation of graphs- incidence matrix, submatrices, circuit matrix, cut-set matrix, path matrix, adjacency matrix; trees with directed edges. | **18** |
| **III** | **Eulerian and Traversable graphs** :<br>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. | **18** |
| **IV** | **Planarity and colorability**:<br>Plane and planar graphs, outer planar graphs, Euler's Polynedron formula, Kuratowski's theorems. Coloring, Covering and Partitioning- basic concepts; Chromatic number. Five colour theorem, Four Colour conjecture, chromatic polynomial. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***


1. *Graph Theory*, Harary F., 1st Edition, 1994, West View Press..
2. *Basic Graph Theory*, Parthasarathy H. R., 1998, McGraw Hill Publishing.


***Reference Books***


1. West D. B., *Introduction to Graph Theory*, 2nd edition, 2002, Prentice Hall, India.
2. Diestel. R., *Graph Theory (Graduate Texts in Mathematics),* 5th edition, 2017, Springer.
3. Bondy, J. A. and Murty,U.S.R., '*Graph Theory* ', 2010. Springer.
4. Deo N., *Graph Theory with Applications to Engineering and Computer Science*, 1st Edition Reprint, 2016, Dover Publication..
5. Chartrand G. and Zhang P., *Introduction to Graph Theory*, 2007, Tata McGraw Hill.

**SYLLABUS (3rd SEMESTER)**

**Subject Name: Mathematical Logic** **Subject Code: MAT014C302**

**L-T-P-C: 4-0-0-4** **Credit Units: 4** **Scheme of Evaluation: T**

**Objective**: The objectives of the course **Mathematical Logic (MAT014C302)** are

- To introduce the concepts of statement and truth values assigned
- To enable establishing different theories of mathematical logic;
- To make the student understand the application of mathematical logic.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | Course Outcome | Bloom's Taxonomy Level |
| CO1 | Define a logical system using valuation and consistency. | BT1 |
| CO2 | Understand informal and formal predicate calculus. | BT2 |
| CO3 | Express a logical sentence in terms of predicates, quantifiers, and logical connectives. | BT3 |
| CO4 | Reformulate statements from common language to formal logic. | BT4 |

**Prerequisites:**

- Concept of set theory.

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I.** | **Informal statement calculus**: Statements and connectives, truth functions and truth tables, formal forms, adequate sets of connectives, arguments and validity. | **18** |

| | | |
|---|---|---|
| **II.** | **Formal statement calculus**: Formal definitions of Proof, Theorem and Deduction, the formal theory of statement calculus, the deduction theorem and its converse. | **18** |
| **III.** | **Adequacy theorem for Logic** : Valuation in Logic, tautology , the Soundness theorem, extensions of Logic, consistency of an extension, the adequacy theorem of Logic | **18** |
| **IV.** | **Informal Predicate Calculus**: Symbolism of predicate calculus, first order language, interpretation, truth-values of well-formed formulas, satisfaction and truth.<br>**Formal Predicate Calculus**: Predicate Calculus as a normal theory, the adequacy theorem of K. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text book***:


1. *Logic for Mathematicians***,** Hamilton A.G., 1988, Cambridge University Press.


***Reference Book*:**


1. Elliot Mendelson, *Introduction to mathematical Logic*, Revised 6th Edition, 2015, Chapman and Hall.
2. Stephen Cole Kleene, *Mathematical Logi*c, reprint edition 2002, Dover Publications Inc.

**SYLLABUS (3rd SEMESTER)**

**Subject Name: Functional Analysis** **Level:500** **Subject Code: MAT014C303**

**L-T-P-C: 4-0-0-4** **Credit Units: 4** **Scheme of Evaluation: T**

**Objective**: The course Functional Analysis (MAT014C303) aims to introduce function spaces, completeness in inner product and normed spaces, bounded linear operators and their spectrum, and core concepts with applications.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | State the fundamental properties of normed linear spaces and list standard examples. | BT1 |
| CO2 | Understand decomposition of the complex plane in terms of spectrum. | BT2 |
| CO3 | Extend basic notions from calculus to inner product spaces and normed vector spaces | BT3 |
| CO4 | Analyse various mappings on finite and infinite-dimensional normed vector spaces | BT4 |

**Prerequisites:**

- Concept of vector spaces, metric space and completeness.

**Detailed Syllabus:**

| **Modules** | **Topics / Course content** | **Periods** |
|---|---|---|
| **I** | **Normed Linear Spaces, Banach Spaces:**<br><br>Normed linear spaces / Banach spaces and examples / further properties of normed linear spaces / finite dimensional normed linear spaces / compactness and finite dimension / linear operator, bounded and continuous operator/compact operator / normed linear spaces of linear operators and dual space. | **18** |

| | | |
|---|---|---|
| **II** | **Inner Product Space, Hilbert Space:**<br><br>Inner product space, Hilbert space and examples / Cauchy-Schwarz Inequality and applications / orthogonal complement and direct sums / orthonormal sets and sequences, Bessel inequality, Gram-Scmidth process / Riesz's theorem( functional on Hilbert spaces) / Riesz's representation (sesquilinear form) / Hilbert adjoint operator and its properties /self adjoint, unitary and normal operators. | **18** |
| **III** | **Fundamental Theorems for Banach Spaces:**<br><br>Zorn's lemma / Hahn-Banach theorem(vector space version), Hahn-Banach theorem(normed linear space version) / reflexive space / Baire's category theorem/Zabreiko's lemma /Uniform boundedness theorem / strong and weak convergence / convergence of sequences of operators and functionals / Open mapping theorem / closed graph theorem. | **18** |
| **IV** | **Banach Fixed Point and Spectral Theory :**<br>Banach fixed Point, contraction, Banach fixed point theorem (contraction theorem)<br>Spectrum of bounded linear operators, resolvent set, point spectrum, continuous spectrum, residual spectrum and numerical range.<br>Banach algebra, spectrum and spectral radius, spectral mapping theorem. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***


1. *Introductory Functional Analysis with Applications*, Kreyszig Erwin, 2007, Wiley India Pvt. Ltd.


***Reference Books:***


1. Conway John B., *A Course in Functional Analysis*, 1st edition, 2010, Springer Verlag.
2. Rudin Walter, *Functional Analysis*, 2nd edition, 2017, McGraw-Hill Education (ISE Editions)
3. Balmohan V. Limaye , *Functional Analysis*, 2014, New Age International Private Limited.
4. Nair M. Thamban , *Functional Analysis: A First Course*, 2001, PHI Learning Pvt. Ltd.

| SYLLABUS (3rd SEMESTER) | | |
|---|---|---|
| **Subject Name: Algebraic Topology** | | **Subject Code: MAT014C304** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Algebraic Topology** (**MAT014C304)** is to develop the ability to use the algebraic tools to understand topological spaces.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** homotopy and coverings. | BT1 |
| CO2 | **Understand** the theory of fundamental groups and simplicial complexes. | BT2 |
| CO3 | **Apply** the theories of algebra to understand topological spaces. | BT3 |
| CO4 | **Analyse** covering spaces and homology. | BT4 |

***Prerequisites:***

- Concept of Point Set Topology and Algebra.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Fundamental Group:**<br>Review of: open and closed sets, continuity, compactness, connectedness, spheres, tori, and real projective spaces.<br>Product spaces, Projection mappings, Quotient spaces, Fundamental Group, Homotopy of maps between topological spaces, Homotopy equivalence, Contractable and simply Connected Spaces, Fundamental Groups of $S^1$and $S^1 \times S^1$. | 18 |
| **II** | **Van Kampen Theorem:**<br>Calculation of Fundamental Group of $S_n$, $n > 1$ using Van-Kampen's theorem, Brouwer's Fixed Point theorem, Introduction to Simplicial Homology, homology groups of spheres. | 18 |

| | | |
|---|---|---|
| **III** | **Covering:**<br>Covering spaces, Unique Path Lifting theorem, Covering Homotopy Property, Group of Covering Transformations, Classification of Covering Spaces. | 18 |
| **IV** | **Homology:**<br>Singular Homology, Reduced Homology, Eilenberg-Steenrod axioms of Homology (no proof for homotopy invariance axiom, excision axiom and exact sequence axiom) and their application, homology of CW-Complexes. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***


1. *Algebraic Topology*, Hatcher A., 1st Edition, 2001, Cambridge University Press.
2. *A Concise Course in Algebraic Topology*, May J. P., 1st edition, 1999, University of Chicago Press.


***Reference Book:***


1. *Elements of Algebraic Topology,* Munkres J. R., 1st edition, Reprint, 2018, CRC Press.
2. *An Introduction to Homological Algebra,* Rotman J.J, 2nd edition 2009, Springer. *Linear Algebra,* Sharma A.K., 2007, Discovery Publishing House.
3. *Topology,* Sharma J.N., 2014, Krishna Prakashan Media P. Ltd.-Meerut

**SYLLABUS (3rd SEMESTER)**

**Subject Name: Continuum Mechanics** **Subject Code: MAT014C305**

**Level: 500** **Credit Units: 4** **L-T-P-C: 4-0-0-4** **Scheme of Evaluation: T**

**Objective**: The objective of the course **Continuum Mechanics** (**MAT014C305**) is to provide the basic concepts of continuum mechanics and to apply theory of continuum mechanics to solve problems of solid and fluid dynamics.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Understand** the basic concept and principle of continuum mechanics. | BT2 |
| CO2 | **Apply** the concept of stress and strain to solve related problems. | BT3 |
| CO3 | **Analyze** the fluid flow problems for different coordinate systems. | BT4 |
| CO4 | **Determine** the solution of fluid flow problems using continuum concept. | BT5 |

**Prerequisites:**

- Concept of dynamics and tensor from B.Sc. level.

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I.** | **Analysis of Stress**<br>The continuum concept, homogeneity, isotrophy, mass density, body force and surface force, Cauchy's stress principle, Stress tensor, Equations of equilibrium, Stress quadric of Cauchy, Principal stress, Stress invariants, Deviator and Sperical stress tensors | **18** |

| | | |
|---|---|---|
| **II.** | **Analysis of Strain** :<br>Continuum confiruation, Lagrangian and Eulerian descriptions, Deformation tensors, Finite strain 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. | **18** |
| **III.** | **Motion and Flow**:<br>Material derivatives, Velocity and acceleration, Path lines and stream lines, Steady motion, Rate of deformation and vorticity with their physical interpretations, Material derivatives of volume, Surface and line elements, Fundamental laws of continuum Mechanics, Continuity equation, Equation of motion, Equilibrium Equation, Energy equation. | **18** |
| **IV.** | **Linear elasticity and fluids**:<br>Generalized Hooke's Law, Strain energy function, Elastic constants for isotropic media, Elastostatic and Elastodynamic problems, Viscous stress tensor, Barotrophic flow, Stokesian fluids, Newtonian fluids, Navier stokes equations, Irrotational flow, Perfect fluids, Bermouli's equation, Circulation theorem. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Assignment, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***

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

***Reference Books:***


1. Chatterjee R., *Mathematical Theory of Continuum Mechanics,* Revised Edition, 2016, Narosa Publishing House.
2. Chandrasekharaiah D.S. and Debnath Lokenath, *Continuum Mechanics,* 1994, Prism Books Pvt. Ltd.Bangalore.
3. Rutherford Aris, *Vectors, Tensors and Basic equations of Fluid Mechanics* Dover Publications Inc., 1962, New York.

| SYLLABUS (3rd SEMESTER) | | |
|---|---|---|
| **Subject Name: Relativity** | **Level: 500** | **Subject Code: MAT014C306** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objective of **Relativity** (**MAT014C306)** is to provide a comprehensive understanding of the principles of special and general relativity, including space-time structure, relativistic mechanics, and gravitational theory. It equips students with the mathematical and physical tools needed to analyse phenomena involving high velocities and strong gravitational fields, with applications in modern physics and cosmology.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the special theory of relativity. | BT1 |
| CO2 | **Understand** the geodesics and curvature in space-time. | BT2 |
| CO3 | **Apply** the vibrant concept of the general theory of relativity. | BT3 |
| CO4 | **Analyse** cosmology and relativistic models. | BT4 |

***Prerequisites:***

- Basic knowledge of classical mechanics, vector calculus, and differential equations.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Special Theory of Relativity**<br>Inertial frames; postulates of special relativity; Lorentz transformations; length contraction; time dilation; variation of mass; composition of velocities; relativistic mechanics; world events and light cone; Minkowski space-time; mass-energy equivalence. | 18 |
| **II** | **Geodesics and Curvature in Space-Time**<br>Derivation of the differential equation of geodesics; geodesic coordinates; intrinsic derivatives; first curvatures; parallel transport and related theorems. Riemann-Christoffel curvature tensors and their properties; | 18 |

| | | |
|---|---|---|
| | Ricci tensor; Ricci scalar curvature; Bianchi identities; Einstein tensor and its divergence. | |
| **III** | **General Theory of Relativity**<br>Introduction to general relativity; principles of covariance and equivalence; energy-momentum tensor for a perfect fluid and conservation of energy-momentum. Newtonian equations as approximations of geodesic equations. Einstein's field equations in vacuum and in presence of matter and energy; modified field equations with cosmological constant; Poisson's equation as an approximation. Schwarzschild exterior and isotropic solutions, mass relations; relativistic planetary motion and Kepler's law analogues. Crucial tests of general relativity: advance of perihelion, bending of light, and gravitational redshift. Schwarzschild interior solution and boundary conditions. | 18 |
| **IV** | **Cosmology and Relativistic Models**<br>Mach's Principle and the Cosmological Principle; Einstein and de-Sitter static models and their comparison with observations. Friedmann-Lemaître-Robertson-Walker (FLRW) metric; geometry and dynamics of FLRW space-time; cosmological redshift and derivation of Hubble's Law; flatness problem and horizon problem. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***


1. K.D. Krori, *Fundamentals of Special and General Relativity*, PHI Learning Private Ltd., 2010
2. S. Weinberg, *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*, John Wiley & Sons Inc., 1972


***Reference Books:***


1. S.K. Srivastava, *General Relativity and Cosmology*, PHI Learning Private Limited, 2008.
2. B.F. Schutz, *A First Course in General Relativity*, Cambridge University Press, 2009
3. S.W. Hawking and G.F.R. Ellis, *The Large Scale Structure of Space-time*, Cambridge University Press, 1975.

| SYLLABUS (3rd SEMESTER) | | |
|---|---|---|
| **Subject Name: Differential Geometry** | | **Subject Code: MAT014C307** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Differential Geometry (MAT014C307) are**

- To study space curves and their properties like curvature, torsion, and Frenet-Serret formulas.
- To understand surfaces and their representations, including curves on surfaces and intrinsic properties.
- To analyze surface curvature, including principal curvatures, minimal and ruled surfaces, and key geometric theorems.
- To explore geodesics and their properties, along with concepts like Gaussian curvature and the Gauss-Bonnet theorem.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** key concepts related to space curves and surfaces, including curvature, torsion, and geodesics. | BT1 |
| CO2 | **Understand** the geometric structure of curves and surfaces, and the relationships between intrinsic and extrinsic properties. | BT2 |
| CO3 | **Apply** differential geometry techniques to compute curvatures, torsions, and geodesic equations on surfaces. | BT3 |
| CO4 | **Analyse** the behavior of curves and surfaces using fundamental theorems and interpret geometric implications. | BT4 |

***Prerequisites:***

- Basic Concept of differential calculus, physical quantities and geometry.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Space curves**<br>Introduction to differential geometry, parametric representation of space curves, change of parameter, arc length, unit tangent vector to a curve, point of inflexion, Normal lines and normal plane, principal normal, | 18 |

| | | |
|---|---|---|
| | Binormal, Rectifying plane, curvature and torsion, helix, involutes and evolutes, Bertrand curves, Intrinsic equations, fundamental existence theorem, uniqueness theorem for space curves. | |
| **II** | **Concept of surface**<br>Definition of surface. Curves on a surface. Surfaces of revolution. Sphere, Helicoids, surface in Monge's form Direction on a surface, coefficients of direction. Families of curves, Intrinsic properties, orthogonal trajectories, Double family of curves. | 18 |
| **III** | **Curvature**<br>Principal curvatures. Lines of curvature. Developable, Developable associated with space curves. Developable associated with curves on surfaces, Minimal surfaces and ruled surfaces, umbilics, Fundamental equations of Surface theory. Parallel surfaces, Gaussian or mean curvature. Complete surfaces, Fundamental existence theorem for surfaces, Bonnet's theorem for parallel surface. | 18 |
| **IV** | **Geodesics**<br>Canonical geodesic equations, Normal property of geodesics. Existence theorems. Geodesic parallels. Geodesic curvature.<br>Gauss Bonnet theorem. Gaussian curvature. Surfaces of constant curvature. Conformal mapping. Geodesic mapping. Conjugate points on geodesics. Intrinsically defined surfaces. | 18 |
| Total | | 72 |

***Text Book:***

2. T.J. Willmore, *An Introduction to Differential Geometry*, Reprint Edition, Dover Publications, 2013.

***Reference Book:***


1. M.P. do Carmo, *Differential Geometry of Curves and Surfaces*, 2nd Edition, Dover Publications, 2016.
2. **Peter Petersen**, *Riemannian Geometry*, 3rd Edition, Springer, 2016.


| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

| SYLLABUS (3rd SEMESTER) | | |
|---|---|---|
| **Subject Name: Number Theory and Cryptography** | | **Subject Code: MAT014C308** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objective of **Number Theory and Cryptography** (**MAT014C308)** is to develop a deep understanding of classical and modern number theory concepts and their applications in secure communication.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the basic definitions of number theory and cryptography. | BT1 |
| CO2 | **Understand** the theory of congruence, number theoretic functions, public and private key cryptography. | BT2 |
| CO3 | **Apply** the theories to solve problems and use it in real life situations. | BT3 |
| CO4 | **Analyse** these concepts to develop critical and independent thinking for further self-study. | BT4 |

***Prerequisites:***

- Concept of Number Theory from undergraduate.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **The theory of congruences**<br>Congruences, basic properties of congruence, linear congruences, the Chinese Remainder theorem, Fermat's theorem, Wilson's theorem, the Diophantine equation, linear Diophantine equations, Pythagoras equation, sum of two squares. | 18 |

| | | |
|---|---|---|
| **II** | **Number-theoretic functions**<br>Number-theoretic functions, divisor functions (function, σ function), perfect numbers, multiplicative function, the mobius inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, properties of phi-function. | 18 |
| **III** | **Primitive Roots**<br>Primitive roots and indices, order of an integer modulo n, primitive roots for primes, composite numbers and primitive roots, quadratic reciprocity, quadratic residue, Legender's symbol and its properties, quadratic reciprocity law, quadratic congruences with composite moduli. | 18 |
| **IV** | **Cryptography**<br>Public and Private Key cryptography, Diffie-Hellmann key exchange, Discrete logarithm-based crypto-systems, RSA crypto-system, Signature Schemes, Knapsack problem. Introduction to elliptic curves and Elliptic Curve Cryptography. | 18 |
| Total | | 72 |

***Text Books:***


1. *Elementary Number Theory,* Burton, D. M., 7th edition, 2010, McGraw-Hill Education
2. *An introduction to number theory,* Ivan Nivam & H.S. Zuckerman, 5th Revised edition, 2008, John Wiley & Sons.
3. N. Koblitz, A Course in Number Theory and Cryptography, Graduate Texts in Mathematics, Springer 2006.
4. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.


***Reference Books:***


1. Hardy, G.H. and Wright, E. M., *An Introduction to the Theory of Numbers*; 6th edition, 2008, Oxford University Press.
2. Andrews, G.E., *Number Theory,* Revised Edition 1994, Dover Publication.
3. Telang, S. G., *Number Theory*, 2003, Tata McGraw-Hill, New Delhi.
4. J. Pipher, J. Hoffstein and J. H. Silverman, An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.

5. J. A. Buchmann, Introduction to Cryptography, Second Edition, Undergraduate Texts in Mathematics, Springer-Verlag, New York, (2004).
6. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.
7. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

| SYLLABUS (3rd SEMESTER) | | |
|---|---|---|
| **Subject Name: Financial Mathematics** | **Level: 500** | **Subject Code: MAT014C309** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objective of **Financial Mathematics** (**MAT014C309)** is to provide a foundational understanding of Financial Management, including its goals and key decision areas. It also covers essential concepts such as the time value of money, return and risk analysis, and the Parity Theorem.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the fundamentals of financial management and the time value of money. | BT1 |
| CO2 | **Understand** the return and risk analysis. | BT2 |
| CO3 | **Apply** the bond valuation and advanced risk metrics. | BT3 |
| CO4 | **Analyse** financial derivatives and arbitrage pricing. | BT4 |

***Prerequisites:***

- Basic understanding of financial concepts, mathematics, and accounting principles.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Fundamentals of Financial Management and Time Value of Money** Overview, nature, and scope of financial management; goals and key decisions; distinction between risk, speculation, and gambling. Concept of the time value of money - interest and discount rates; present and future value under discrete and continuous compounding; annuities and their types. | 18 |

| | | |
|---|---|---|
| **II** | **Return and Risk Analysis**<br>Meaning and computation of return, including Internal Rate of Return (IRR); numerical methods such as Newton-Raphson for IRR; returns under uncertainty. Meaning and types of risk; the distinction between risk and uncertainty; measurement of risk and return for individual securities and portfolios; Markowitz Model and Sharpe's Single Index Model; systematic vs. unsystematic risk. | 18 |
| **III** | **Bond Valuation and Advanced Risk Metrics**<br>Application of Taylor series in finance, bond valuation, calculation of duration and convexity of bonds. Concepts of pricing and risk assessment in fixed-income securities. | 18 |
| **IV** | **Financial Derivatives and Arbitrage Pricing**<br>Overview of financial derivatives - futures, forwards, swaps, options; call and put options, and their parity theorem; pricing of contingent claims through arbitrage and the Arbitrage Pricing Theorem. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***

1. S.M. Ross, An Introduction to Mathematical Finance, Cambridge University Press,2011

***Reference Books:***

2. A. Damodaran, *Corporate Finance- Theory and Practice*, Wiley, 2007.
3. C.D. Daykin, T. Pentikainen and M. Pesonen, *Practical Risk Theory for Actuaries*, Chapman & Hall,1993
4. J.C. Hull and S. Basu, *Options, Futures, and Other Derivatives*, Pearson, 2016

**SYLLABUS (3rd SEMESTER)**

**Subject Title: Advanced Ring Theory** **Level: 500** **Subject Code: MAT014C3010**

**L-T-P-C: 4-0-0-4** **Credit Units: 4** **Scheme of Evaluation: T**

***Objective:*** The objective of **Advanced Ring Theory** (**MAT014C3010)** is to study the structure of rings and their ideals, including homomorphisms and factor rings. It focuses on prime, semiprime, and primitive ideals, as well as matrix rings. Special emphasis is placed on understanding Jacobson and prime radicals in ring theory.

***Course Outcomes:***

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Recall** the definitions, properties, classifications, and key concepts of rings, including ideals, homomorphisms, and quotient rings | BT1 |
| CO2 | **Understand** the theory of principal and nilpotent ideals, complete matrix rings, subdirect sums, and Zorn's Lemma. | BT2 |
| CO3 | **Develop** an understanding of prime and semiprime ideals, their equivalent formulations, conditions for primality, and the prime radical of a ring. | BT3 |
| CO4 | **Analyze** prime rings, Jacobson radicals, primitive rings, and the prime radical. | BT4 |

***Prerequisite:***

- Basic knowledge of Ring Theory, especially rings and ideals.

***Detailed Syllabus:***

| Modules | Topics / Course content | Periods |
|---|---|---|
| I | **Ideals in Ring Theory**<br><br>A review of the definition, classifications, and fundamental properties of rings; Boolean rings; Nilpotent and idempotent elements; Characteristics of rings; Subrings and ideals; Sum and direct sum of ideals; Ring homomorphisms and embeddings; Minimal and maximal ideals; Quotient rings. | **18** |
| II | **Complete Matrix Ring and Subdirect Sum**<br><br>Principal ideal and ideals generated by a subset, Nilpotent ideals and nil Ideals, Complete matrix ring and subdirect sum complete matrix ring, Ideals in complete matrix ring, Subdirect sum of rings and its characterizations, Zorn's Lemma, Subdirectly irreducible rings. | **18** |
| III | **Prime Ideals and Prime Radical**<br><br>Prime ideals and m-systems, Different equivalent formulation of prime ideals, Semiprime ideals and n-systems, Equivalent formulation of semi-prime ideals, Necessary and sufficient conditions for an ideal to be a prime ideal, Prime radical of a ring. | **18** |
| IV | **Prime Rings and Jacobson Radical**<br><br>Prime rings, Jacobson radical prime rings and its characterization in terms of prime ideals, Primeness of complete matrix rings, Descending chain condition for ideals and the prime radical, Jacobson radical, Relationship between Jacobson radical and prime radical of a ring, Primitive rings, Jacobson radical of primitive rings. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 72 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***

1. N. H. McCoy: The Theory of Rings, Macmillan, New York, 1964.
2. I. N. Herstein, Topics in Algebra, 3rd ed., Wiley, New York, 1996.

***Reference Books:***

3.D. S. Dummit and R.M. Foote, Abstract Algebra, John Wiley, New York, 2004.

4. J. A. Gallian, Contemporary Abstract Algebra, Narosa Publ. House, New Delhi, 1998.

5. S. Singh and Q. Zameeruddin: Modern Algebra, Vikas Publ. House, New Delhi, 2002.

6. I. S. Luthar and I. B. S. Passi, Algebra, Vol. 2: Rings, Narosa Pub. House, New Delhi, 1999.

7. F. W. Anderson and K. R. Fuller: Rings and Categories of Modules, Springer-Verlag, New York, 1992.

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

| SYLLABUS (4th SEMESTER) | | |
|---|---|---|
| **Subject Name: Measure Theory and Fuzzy Set Theory** | | **Subject Code: MAT014C401** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objective of **Measure Theory and Fuzzy Set Theory (MAT014C401)** is to provide a strong theoretical foundation in classical measure theory and introduce the principles of fuzzy set theory for modeling uncertainty.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** differentiation and integration in measure, fuzzy sets and relations. | BT1 |
| CO2 | **Understand** the foundations of measure and integration, Fuzzy sets and operations, Fuzzy relations. | BT2 |
| CO3 | **Apply** Lebesgue integration techniques and Fuzzy set theory in interdisciplinary applications. | BT3 |
| CO4 | **Analyse** convergence and function spaces, Fuzzy set theory to perform operations and reasoning. | BT4 |

***Prerequisites:***

- Concept of Lebesgue measure and Set Theory.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Differentiation and integration**<br>The four derivatives, functions of bounded variation, differentiation of an integral, absolute continuity, Lebesgue Stieltje measure, Lebesgue Stieltje integrals with applications. | 18 |

| | | |
|---|---|---|
| **II** | **Extension of measure and integration**<br>Signed measure, properties of signed measure, measure spaces and their properties, integration with respect to a general measure, Holder and Minkowski inequalities, product spaces, product measure, convergence in measure, L(p) spaces and their properties, convex functions, Riesz Representation Theorem. | 18 |
| **III** | **Fuzzy Sets and Operations on Fuzzy Sets:**<br>Classical sets vs Fuzzy Sets, Need for fuzzy sets, Definition and Mathematical representations, Level Sets, Fuzzy functions, Zadeh's Extension Principle, Operations on [0,1], Fuzzy negation, triangular norms, t-conorms, fuzzy implications, Aggregation Operations. Fuzzy Numbers. | 18 |
| **IV** | **Fuzzy Relations**<br>Fuzzy Binary and n-ary relations, composition of fuzzy relations, Fuzzy Equivalence Relations, Fuzzy Compatibility Relations, Fuzzy Relational Equations. | 18 |
| Total | | 72 |

***Text Books:***


1. *Measure Theory and Integration*, Barra, G. De.,1st Edition 2013; New Age International (P) Ltd, Publishers, New Delhi.
2. *Real Analysis;* Royden, H. L., 4rd Edition; 2015, Pearson Education India,
3. Fuzzy Sets and Fuzzy Logic: Theory and Applications, George J Klir and Bo Yuan, Prentice Hall NJ,1995.


***Reference Books:***


1. L. Cohn Donald, *Measure Theory*; 2nd Edition; 2013, Birkhauser.
2. Halmos P.R., *Measure Theory*; Second Reprint, 2008, Springer.
3. *An Introduction to Measure and Integration;* Rana, I. K.; 2nd edition; 2007, Narosa Publishing House, India.
4. Zimmermann H.J., *Fuzzy Set Theory and its Applications*, 3rd Edition, 2014, Springer.
5. John N. Mordeson and Premchand S.Nair , *Fuzzy Mathematics-An Introduction for engineers and Scientists*, 2010, Springer Books.
6. Anastassiou George *A, Fuzzy Mathematics-Approximation Theory.* 2010 Springer Publication.

**SYLLABUS (4th SEMESTER)**

**Subject Name: Operation Research and Machine Learning**

**Level: 500** **Subject Code: MAT014C402**

**L-T-P-C: 3-0-1-4** **Credit Units: 4** **Scheme of Evaluation: T + P**

***Objective:*** The general objectives of the course **Operation Research and Machine Learning (MAT014C402)** are to enable learning to formulate and solve different linear programming models and machine learning technique.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Memorize** the key concepts, characteristics, and scope of Operations Research. | BT1 |
| CO2 | **Discuss** the formulation and solution methods for Linear Programming Problems (LPP). | BT2 |
| CO3 | **Apply** methods to solve Transportation, Assignment, and Game Theory problems. | BT3 |
| CO4 | **Analyze** data using machine learning techniques. | BT4 |

***Prerequisites:***

- Concepts of basic statistics.

***Detailed Syllabus:***

| Modules | Topics / Course content | Periods |
|---|---|---|
| I | Basics of Operations Research, Linear Programming (LPP), Formulation of LPP, General, canonical and standard form of LPP, Simplex Method, Artificial variable Techniques, Big M method, Two Phase method. Application of Simplex method, Dual of LPP. | 12 |
| II | **Transportation model**: Introduction to the model, Formulation and solution of Transportation model, Variations in Transportation model, Post optimality analysis. **Assignment model**: Introduction to Assignment Problem, Mathematical representation, Comparison of assignment problem | 12 |

| | | |
|---|---|---|
| | with transportation problem, The Hungarian method of Assignment problem, Variation of assignment problem. **Game theory**: Two-person Zero-sum Game, Game with Pure and Mixed Strategies, Dominance Principle, Arithmetic Method, and Graphical Method for Solving (2× n) and (m×2) Games. | |
| III | Machine Learning technique:<br>Supervised learning, Unsupervised learning, Regression, simple linear regression, multiple linear regression, model evaluation using visualization, Polynomial Regression, Pipelines, Under-fitting, Over-fitting, Logistic Regression. Detection and prediction of data (Use available data sets), Support vector machine, Random Forest Model. | 12 |
| IV | Machine Learning technique:<br>Unsupervised learning: clustering- K-Means clustering, Gaussian mixture models, Connectivity based methods: Hierarchical clustering, dimension reduction- Principal Component Analysis (PCA), association rule- Apriori algorithm, Reinforcement learning: Model-Based Methods, **Model-Free Methods,** Semi-supervised learning: Semi-Supervised Learning: Semi Supervised Classification, Self-Training in Semi-Supervised Learning, Few-shot learning in Machine Learning. | 12 |
| Total | | 48 |

***Text Book:***


1. **Gupta P.K., and Hira D.S.**, *Problems in Operations Research (Principles and Solutions)*, Revised Edition, Sultan Chand and Sons, New Delhi, 2015.
2. Tom M. Mitchell, *Machine Learning*, Indian Edition, McGraw-Hill International Edition, 2017.


***Reference Books :***


1. Swarup Kanti, Gupta P.K., and Mohan M., *Operations Research*, Sultan Chand and Sons, New Delhi, 2014.
2. Hadley G., *Linear Programming*, Narosa Publishing House, 2002.
3. Shai Shalev-Shwartz, Shai Ben-David, Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press, 2014.

| SYLLABUS (4th SEMESTER) | | |
|---|---|---|
| **Subject Name: Operator Theory** | **Level: 500** | **Subject Code: MAT014C403** |
| **L-T-P-C: 4-0-0-4** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of Operator Theory (MAT014C403) are to highlight the advantages of studying Banach algebras, enable understanding of the spectral behaviour of bounded linear operators, and explain the behaviour of operators in C*-algebras.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | Recall the basic notions of Banach algebras and C*-algebras. | BT1 |
| CO2 | Describe the spectral properties of self-adjoint operators. | BT2 |
| CO3 | Apply the concepts of Banach algebras to analyze various operators. | BT3 |
| CO4 | Analyze the spectral characteristics of operators within Banach and C*-algebras. | BT4 |

**Prerequisites:**

- Concept of vector spaces, normed spaces, bounded linear operators and completeness.

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I** | **Banach Algebras:**<br><br>Definition of Banach Algebra and examples, The spectrum of an element, Gelfand Formula, Multiplicative Linear Function, and the maximal ideal space, Gleason Kahane Zelazko Theorem.<br><br>The Gelfand Transforms, Isometric Gelfand Transform. | **18** |

| | | |
|---|---|---|
| **II** | **Spectral properties of Compact operator:**<br><br>Spectral properties of bounded linear operators, Properties of Resolvent set and spectrum. The Spectral Mapping Theorem.<br><br>Compact linear operators on normed spaces, Properties of Compact linear operators. Spectral properties of compact linear operators. | **18** |
| **III** | **Spectral properties of bounded self-adjoint operators:**<br><br>Self-adjoint linear operators, Spectral properties of bounded self-adjoint linear operators, Positive operators. Square roots of a positive operator, Projection operator, properties of projections, Normal operators, Spectral family, Statement of spectral representation theorem. | **18** |
| **IV** | **C* algebras:**<br><br>$*$-algebra, $*$-isomorphism, C*-algebras (definition and examples), Properties of C*-algebras, commutative C*-algebras, Positive elements in C*-algebras, Operators and Sesquilinear form, Polar decomposition. | **18** |
| **Total** | | **72** |

***Text Books:***


1. *A Course in Functional Analysis*, Conway J. B., 2008, Springer.


***Reference Books:***


1. Kreyszig Erwin, *Introductory Functional Analysis with Applications*, 2007, Wiley India Pvt. Ltd.
2. Rudin Walter, *Functional Analysis*, Reprint 2nd revised edition, 2017, McGraw-Hill Education (ISE Editions).
3. Murphy G.J., *C*-algebras and operator theory*, Reprint 1st edition, 2014, Academic Press;
4. Conway J. B, *A Course in Operator Theory*, 2012, Orient Blackswan.

**SYLLABUS (4th SEMESTER)**

**Subject Title: Dynamical System and Fractional Calculus Level: 500 Subject Code: MAT014C404**

**L-T-P-C: 4-0-0-4 Credit Units: 4 Scheme of Evaluation: T**

***Objective:*** The objectives of **Dynamical System and Fractional Calculus** (**MAT014C404)** are to provide an understanding of dynamical systems, chaos theory, and fractional calculus, and to study their applications in science, engineering, and other fields.

***Course Outcomes:***

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the fundamental concepts in dynamical systems, including phase space, stability, fixed points, and limit cycles. | BT1 |
| CO2 | **Understand** discrete-time dynamical systems, bifurcation theory, chaos, Lyapunov exponent, strange attractors, and their real-world applications. | BT2 |
| CO3 | **Apply** the fundamentals of fractional calculus, including fractional derivatives, integrals, and their applications in differential equations and Laplace transforms. | BT3 |
| CO4 | **Analyze** fractional-order dynamical systems, their stability, applications in engineering and biology, and numerical method(**s**) for solving them. | BT4 |

***Prerequisite:***

- Differential Equations

- Linear Algebra
- Basics of Calculus

***Detailed Syllabus:***

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I** | **Introduction to Dynamical Systems**<br><br>Overview of Dynamical Systems, Phase Space and Trajectories, Fixed Points and Equilibrium, Stability of Systems, Linear vs. Nonlinear Systems, Phase Portraits in 2D Systems, Limit Cycles and Oscillatory Behavior. | **18** |
| **II** | **Discrete Dynamical Systems and Chaos**<br><br>Discrete-Time Dynamical Systems, The Logistic Map, Bifurcation Theory, Introduction to Chaos, Lyapunov Exponent, Strange Attractors, Applications of Chaos Theory. | **18** |
| **III** | **Basics of Fractional Calculus**<br><br>Introduction to Fractional Calculus, Riemann-Liouville Fractional Derivative, Caputo Fractional Derivative, Properties of Fractional Derivatives, Fractional Integral, Fractional Differential Equations, Laplace Transform and Fractional Operators. | **18** |
| **IV** | **Fractional Dynamical Systems and Applications**<br><br>Fractional-Order Dynamical Systems, Stability of Fractional Systems, Fractional Logistic and Lorenz Models, Fractional Control Systems, Applications in Engineering, Fractional Systems in Biology and Medicine, Numerical Solutions of Fractional Systems. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***

1. *Differential equations, dynamical systems, and an introduction to chaos;* Hirsch, M. W., Smale, S., & Devaney, R. L.; 3rd edition; 2012; Academic Press.
2. *An introduction to fractional calculus and fractional differential equations*; Miller, K. S., & Ross, B., 1993; Wiley.

***Reference Books:***


1. Strogatz S. H., *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*, 2nd edition, 2015, Westview Press.
2. Alligood, K. T., Sauer, T. D., & Yorke, J. A., *Chaos: An introduction to dynamical systems*, 1996, Springer.
3. Peitgen, H.O., Jürgens, H., & Saupe, D., *Dynamical systems and fractals: The mathematics of chaos*, 2004, Springer.
4. Podlubny, I., *Fractional differential equations: An introduction to fractional derivatives, fractional differential equations, to methods for their solution and some applications*, 1999, Academic Press.
5. Oldham, K.B. and Spanier, J., *The fractional calculus: Theory and applications of differentiation and integration to arbitrary order*, 2006, New York: Dover Publications. (Originally published 1974)

| SYLLABUS (4th SEMESTER) | | | |
|---|---|---|---|
| **Subject Name: Fluid Dynamics** | | | **Subject Code: MAT014C405** |
| **Level: 500** | **Credit Units: 4** | **L-T-P-C: 4-0-0-4** | **Scheme of Evaluation: T** |

**Objective**: The objective of the course **Fluid Dynamics** (**MAT014C405**) is to impart basic concepts and fundamental laws of fluid dynamics and to develop problem solving skills to solve the fluid flow problems.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Understand** the governing equations of fluid motion and its role in fluid flow problems. | BT2 |
| CO2 | **Apply** the fundamental laws of fluid dynamics to solve related problems. | BT3 |
| CO3 | **Analyze** fluid flow problems with the application of the momentum and energy equations. | BT4 |
| CO4 | **Determine** the solution of fluid flow problems in different coordinate system with Navier Stokes Equations. | BT5 |

**Prerequisites:**

- Concept of dynamics and vector from B.Sc. level.

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|
| **I.** | **Basics of fluid dynamics:** Real and ideal fluids, types of flows, Lagrarian and Eulerian methods, Velocity and acceleration, Streamlines, streaklines and pathlines, velocity potential and stream function, source, sink and | **18** |

| | | |
|---|---|---|
| | doublet, Equation of continuity. Equations of motion of a fluid, Fluid pressure, Euler's equation of motion, Bernoulli's equation. | |
| **II.** | **Viscous fluid motion:**<br>Viscous fluid, coefficient of viscosity, Navier- Strokes equation of motion, Rate of change of vorticity and circulation, Energy dissipation due to viscosity, Diffusion of vorticity. | **18** |
| **III.** | **Exact solution of Navier Strokes Equations:**<br>Flow between plates, Flow through a pipe (circular), Suddenly accelerated plane wall, Flow near an Oscillating flat plate, Circular motion through cylinders. Stoke's linearization process, Oseen's approximation. | **18** |
| **IV.** | **Boundary Layer Theory:**<br>General outline of Boundary layer flow, Boundary layer thickness, Displacement thickness, momentum thickness, Similarity solution of boundary layer equations, Two-dimensional Boundary layer equations, Momentum equation and energy integral equation, Blasius solution for flow past a cylindrical surface, Separation of boundary layer. | **18** |
| **Total** | | **72** |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Assignment, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Book:***


1. *Textbook of Fluid Dynamics,* F. Chorlton, CBS Publishers & Distributors, 1985.
2. *Boundary Layer Theory*, Schlichting H. translated by Kertin J., 9th Edition, 2017, Springer.


***Reference Books:***

1. Raisinghania M. D., *Fluid Dynamics,* 2010 (Reprint), S. Chand and Co., New Delhi.
2. Goldstein S., *Modern development of Fluid Dynamics,* Vol. 1, 1965, Dover Publication, New York.
3. Horace Lamb, *Hydrodynamics*, Cambridge University Press, 1953.
4. Batchelor G. K., *An Introduction to Fluid Dynamics,* 2007, Foundation Books, New Delhi.

## SYLLABUS (4th SEMESTER)

**Subject Name: Probability & Statistics** **Level: 500** **Subject Code: MAT014C406**

**L-T-P-C: 4-0-0-4** **Credit Units: 4** **Scheme of Evaluation: T**

**Objectives**: The objectives of **Probability & Statistics** (**MAT014D101)** are to enable learning fundamental concepts of probability theory, random variable, correlation, regression and inferential statistics.

**Course Outcomes:**

| After successful completion of the course, student will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Recall** basics of Probability, Random experiments, conditional probability. | BT1 |
| CO2 | **Recognize** Random Variables and Probability distribution. | BT2 |
| CO3 | **Apply** probability in case of joint distribution, central limit theorem, law of large numbers. | BT3 |
| CO4 | **Analyse** data using sampling techniques and decision-making processes. | BT4 |

**Prerequisites:**

- Sets and elements of Sets, Operation on Sets, Algebra of Sets.

**Detailed Syllabus:**

| Modules | Topics / Course content | Periods |
|---|---|---|

| | | |
|---|---|---|
| **I** | **Probability:**<br>Introduction to Probability: Random experiments, Sample space, Simple and compound events, Event space. Definition of probability: Classical, Statistical & Axiomatic approach, their drawbacks. Some Consequences of Axiomatic approach of Probability. Inclusion-Exclusion identity, Properties, Conditional probability, conditional probability as probability function, general multiplicative theorem Bayes theorem, independence of events. Condition for n independent events. | **18** |
| **II** | **Random Variables and Probability distribution:**<br>Definition of single random variate, Discrete and continuous random variable, Probability mass function, Cumulative distribution function, probability density functions, Independence of random variables, Statistical regularity. Properties of PMF, CDF and PDF of random variables.<br>Expectation. Moments, Moment generating function, characteristic function. Some important random variates. Discrete: Binomial, negative binomial, Geometric, Poisson distribution, Continuous: Uniform, Normal, exponential, gamma, Weibull, Cauchy, Beta, Rayleigh distribution<br>Transformation of random variables | **18** |
| **III** | **Joint Distribution:**<br>Definition of jointly distributed random variables. Two-dimensional probability distributions. Discrete and continuous distributions in two-dimensions. Joint probability mass function, Joint probability density function, conditional distributions. Transformation of random variables in two -dimensions. Joint Uniform, Gamma and Normal distributions.<br>Two-dimensional expectation. Covariance, Correlation co-efficient, Joint- characteristic function. Multiplication rule for expectations. Conditional expectation. Introduction, Chebyshev's Inequality and Weak law of large numbers, The Central Limit Theorem, The Strong Law of Large Numbers, Chernoff's bounds, Jesen's inequality. | **18** |
| **IV** | **Sampling Techniques**<br>Random sample. Concept of sampling and various types of sampling.<br>Sampling distribution of a statistic, Standard error of a statistic, Estimates of a population characteristic or parameter. Unbiased and consistent estimates. Sample characteristics as estimates of the corresponding population characteristics. Sampling distributions of the sample mean and variance.<br>Statistical decisions, Statistical hypothesis and alternative hypothesis. Error in hypothesis, Level of significance and critical region. One tailed and two tailed tests.<br>Neyman-Pearson theorem (Statement only) and its application to normal population Testing of Hypotheses, Tests based on Normal, t and F Distributions for Testing of Mean, Variance and Proportions. Chi-square test. | **18** |
| **Total** | | **72** |

***Text Book:***

1. *A First Course in Probability*, Ross S; 9th Edition, 2019; Pearson Education India.

***Reference Books:***

1. Gupta S. C., Kapoor V.K; "*Fundamentals of Mathematical Statistics*"; Tenth Revised Edition; 2014; Sultan Chand & Sons Publishers.
2. Spiegel Murray R, Schiller John J, Srinivasan R. Alu; "*Schaum's outline: Probability and Statistics*"; 4th Edition; 2017; McGraw –Hill Education.
3. Jacod J. and Protter P., *Probability Essentials*, 2004 Springer.
4. Grimmett G. R. andStirzaleer D. R., *Probability and Random Processes*, 3rd Edition, 2001, Oxford University Press.

| **SYLLABUS (4th SEMESTER)** | | |
|---|---|---|
| **Subject Name: Bio-Mathematics** | **Level: 500** | **Subject Code: MAT014C407** |
| **L-T-P-C: 4-0-0** | **Credit Units: 4** | **Scheme of Evaluation: T** |

**Objective**: The objectives of **Bio-Mathematics (MAT014C405)** are to introduce the formulation of mathematical models for real-life biological phenomena in ecology, epidemiology, and physiology.

**Course Outcomes:**

| After successful completion of the course, students will be able to | | |
|---|---|---|
| **CO Level** | **Course Outcome** | **Bloom's Taxonomy Level** |
| CO1 | **Define** the fundamentals of mathematics in biology. | BT1 |
| CO2 | **Understand** ecological modeling and interacting populations. | BT2 |
| CO3 | **Apply** the epidemiological models in further studies. | BT3 |
| CO4 | **Analyse** the theory of diffusion and biofluid mechanics. | BT4 |

***Prerequisites:***

- Concept of differential equations, linear algebra, and basic calculus.
- General familiarity with biological concepts.

***Detailed Syllabus:***

| Modules | Topics /Course content | Periods |
|---|---|---|
| **I** | **Fundamentals of Mathematical Modeling in Biology**<br>Introduction to mathematical modeling and its relevance to biological systems. Types and classifications of models. Formulation, solution, and interpretation of models. Linear and nonlinear growth and decay models. Leslie matrix-based population models and continuous single-species models. Logistic growth and Fibonacci's rabbit population model. The connection between the Fibonacci sequence and the golden ratio. | 18 |

| | | |
|---|---|---|
| | Introduction to compartmental models and discussion of model limitations. | |
| **II** | **Ecological Modeling and Interacting Populations**<br>Basic terminology and concepts in ecology. Mathematical models for interacting populations: prey-predator, competition, and mutualism. The Lotka-Volterra equations and their dynamical behavior. Equilibrium points and their stability analysis. Geometrical interpretation of ecological systems and analysis of nearly linear systems. | 18 |
| **III** | **Epidemiological Models**<br>Overview of mathematical modeling in the spread of infectious diseases. Construction and analysis of SI, SIS, and SIR epidemic models. SIR endemic model and extensions for real-world applications. Mathematical modeling of diseases such as HIV and AIDS. Concepts like the window period, ELISA test, and disease transmission. Strategies for disease control and the role of vaccination. | 18 |
| **IV** | **Diffusion and Biofluid Mechanics**<br>Application of Fick's laws to diffusion processes in biology. Diffusion through membranes and biological slabs. Introduction to biofluid mechanics and various types of biological flows. Viscosity, continuity equation, and basic equations of fluid motion. Anatomy and function of the circulatory system. Mathematical modeling of blood flow using Poiseuille's law. Analysis of pulse wave transmission in arteries. | 18 |
| Total | | 72 |

| **Credit Distribution** | | |
|---|---|---|
| **Theory** | **Practicum** | **Experiential Learning** |
| 72 | - | 48 (Problem solving, Presentation, Project, Internship, Seminar, Workshop, Field Trip) |

***Text Books:***


1. J. N. Kapur, *Mathematical Modelling*, New Age International Publishers.
2. J. R. Chasnov, *Mathematical Biology*, Hong Kong Press.


***Reference Books:***


1. J. D. Murray, *Mathematical Biology (An Introduction, Vol. I & II)*, Springer- Verlag.
2. S. I. Rubinow, *Introduction to Mathematical Biology*, John Wiley and Sons, 1975.
3. M. A. Khanday, *Introduction to Modeling and Biomathematics*, Dilpreet Publishers New Delhi, 2016.