# NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

## SCHEME OF INSTRUCTION AND SYLLABI

## for Two-Year M.Sc. (Applied Mathematics) Program

## Effective from 2021-2022

## DEPARTMENT OF MATHEMATICS

## Vision and Mission of the Institute

### VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

### MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating center to serve the societal needs.

## Vision and Mission of the Department

## Department of Mathematics

### VISION

To be among the best mathematics departments in the country, to build an international reputation as a centre of excellence in mathematics and computational research, training, and education, and to inculcate mathematical thinking in order to meet the challenges and growth of science and technology, as well as the needs of industry and society, with moral and ethical responsibility.

### MISSION

- To attract motivated and talented students by providing a learning environment where they can learn and develop the mathematical and computational skills needed to formulate and solve real-world problems.
- To foster an environment conducive to quality research and to train principled and highly skilled researchers with clear thinking and determination capable of meeting the dynamic challenges of science and engineering.
- To keep up with the rapid advancements of technology while improving academic standards through innovative teaching and learning processes.
- To satisfy the country's human resource and scientific manpower requirements in mathematics through learner-centered contemporary education and research.

## Department of Mathematics:

### Brief about the Department:

The Department of Mathematics is one of the highly reputed Departments in the institute which functions with excellence as its motto. The Department of Mathematics was established in 1959 along with other engineering departments, expanded in 1984 as Dept. of Mathematics & Humanities and bifurcated in 2009 as Department of Mathematics. The Department is established as a dynamic centre for academic and research activities.

The Department offers basic courses in Mathematics for B.Tech. At post-graduate level, the Department offers well-designed diverse courses for all programmes of M.Tech., M.C.A., M.B.A. and M.Sc. Tech (Engg. Physics) and also offers open electives for all UG, PG and Ph.D. Programmes.

The Department offers two P.G. Programs, M.Sc. (Applied Mathematics) started in the year 1970 and M.Sc. (Mathematics and Scientific Computing) started in 2001. The M.Sc. programs for both streams of Mathematics are designed with one laboratory course in each semester in addition to the regular rigorous theory courses. They inculcate a spirit of practical application of mathematical concept and also instil enthusiasm for research activity. Special emphasis is laid on promoting team spirit and improving the oral communication skills of the students, which enables all-round development of the students.

The Department since its inception in 1959 is known to be an active research centre in Mathematics. The frontier areas of research of the department are Fluid Mechanics, Computational Fluid Mechanics, Bio-mechanics, Numerical Analysis, Finite Element Method, Optimization Techniques, Coding Theory, Cryptography, Differential Equations etc., The Department offers Ph.D. program in Mathematics on regular basis, part-time and also under Quality Improvement Program (QIP) and the Department is the only QIP centre for Mathematics in India. So far about 115 Ph.Ds. have been awarded and several research papers have been published in national and international journals.

The Department has a full-fledged computational laboratory to meet the requirements of the M.Sc. students, research scholars and the faculty. The Department has a well-stocked library for immediate reference of the staff and students.

The Department was recognized as a National Resource Centre in Mathematics by MoE, Govt. of India to conduct Online Refresher Courses for all Mathematics Faculty members (irrespective of their seniority and designation) of all Institutions in the Country.

The department organized three international conference (ICCHMT – 2015, NHTFF – 2018), two GIAN programs. Several National conferences, Summer/refresher courses and Workshops.

The Department has successfully completed several research projects funded by various organizations like MHRD, AICTE, UGC, CSIR and DST etc and there are 3 ongoing projects

**List of Programs offered by the Department:**

| Program | Title of the Program |
|---|---|
| Integrated M.Sc. | Integrated M.Sc., Mathematics |
| M.Sc. | M.Sc., Applied Mathematics |
| | M.Sc., Mathematics and Scientific Computing |
| Minor | Mathematics |
| Ph.D. (Full time, Part-time and QIP) | Mathematics |

**Note: Refer to the following weblink for Rules and Regulations of PG programs:**
**https://nitw.ac.in/main/%20RulesandRegulations/PGProgrammes/**

# M.Sc. in Applied Mathematics

## Program Educational Objectives

| | |
|---|---|
| **PEO-1** | Provide sufficient understanding of the fundamentals of mathematics with computational techniques, and program core to address challenges faced in mathematics and other related interdisciplinary fields. |
| **PEO-2** | Facilitate as a deep learner and progressive careers in teaching, academia, research organizations, national/international laboratories and industry |
| **PEO-3** | Develop models and simulation tools for real life problems by analysing and applying mathematical and computational tools and techniques. |
| **PEO-4** | Demonstrate effective communication and interpersonal, management and leadership skills to fulfil professional responsibilities, retaining scientific fervour in day-to-day affairs. |
| **PEO-5** | Engage in lifelong learning and adapt to changing professional and societal needs |

## Program Articulation Matrix

| **PEO** / **Mission Statements** | **PEO 1** | **PEO 2** | **PEO 3** | **PEO 4** | **PEO 5** |
|---|---|---|---|---|---|
| To attract motivated and talented students by providing a learning environment where they can learn and develop the mathematical and computational skills needed to formulate and solve real-world problems. | **2** | **3** | **2** | **3** | **2** |
| To foster an environment conducive to quality research and to train principled and highly skilled researchers with clear thinking and determination capable of meeting the dynamic challenges of science and engineering. | **3** | **3** | **3** | **2** | **2** |
| To keep up with the rapid advancements of technology while improving academic standards through innovative teaching and learning processes. | **2** | **3** | **2** | **2** | **2** |
| To satisfy the country's human resource and scientific manpower requirements in mathematics through learner-centered contemporary education and research. | **3** | **2** | **3** | **3** | **3** |

**1-Slightly; 2-Moderately; 3-Substantially**

## M.Sc. in Applied Mathematics

## Program Outcomes

At the end of the program, the student will be able to:

| | |
|---|---|
| **PO1** | Gain and apply the knowledge of basic scientific and mathematical fundamentals to understand the Nature and apply it to develop new theories and models. |
| **PO2** | Design models for complex mathematics problems and find out solutions that meet the specified needs with appropriate consideration for the public health, safety, cultural, societal and environmental considerations. |
| **PO3** | Use of research-based knowledge and research methods including design of physical/computational experiments and evolve procedures appropriate to a given problem. |
| **PO4** | Create, select, and apply appropriate techniques, resources, and modern IT tools including prediction and modelling to complex real-life problems with an understanding of the limitations. |
| **PO5** | Function effectively as an individual, and as a member or leader in diverse teams to manage projects in multidisciplinary environments |
| **PO6** | Use numerical analysis and simulation modelling and interpretation of data to provide valid conclusions |

# SCHEME OF INSTRUCTION

## M.Sc. (Applied Mathematics) – Course Structure

### I - Year, I – Semester

| S. No. | Course Code | Course Name | L | T | P | Credits | Cat. Code |
|---|---|---|---|---|---|---|---|
| 1 | MA4101 | Real Analysis | 3 | 0 | 0 | 3 | PCC |
| 2 | MA4102 | Ordinary Differential Equations | 3 | 0 | 0 | 3 | PCC |
| 3 | MA4103 | Advanced Modern Algebra | 3 | 0 | 0 | 3 | PCC |
| 4 | MA4104 | Linear Algebra | 3 | 0 | 0 | 3 | PCC |
| 5 | MA4105 | Computer Programming in C++ | 3 | 0 | 0 | 3 | PCC |
| 6 | MA4106 | Numerical Analysis | 3 | 0 | 0 | 3 | PCC |
| 7 | MA4107 | CPP Lab | 0 | 0 | 3 | 1.5 | PCC |
| | | **Total** | **18** | **0** | **3** | **19.5** | |

### I - Year, II – Semester

| S. No. | Course Code | Course Name | L | T | P | Credits | Cat. Code |
|---|---|---|---|---|---|---|---|
| 1 | MA4151 | Probability & Statistics | 3 | 0 | 0 | 3 | PCC |
| 2 | MA4152 | Partial Differential Equations | 3 | 0 | 0 | 3 | PCC |
| 3 | MA4153 | Complex Analysis | 3 | 0 | 0 | 3 | PCC |
| 4 | MA4154 | Topology | 3 | 0 | 0 | 3 | PCC |
| 5 | MA4155 | Mathematical Programming | 3 | 0 | 0 | 3 | PCC |
| 6 | | ELECTIVE – I | 3 | 0 | 0 | 3 | PEC |
| 7 | MA4159 | Numeric Computing Laboratory | 0 | 0 | 3 | 1.5 | PCC |
| 8 | MA4198 | Seminar - I | 0 | 0 | 2 | 1 | SEM |
| | | **Total** | **18** | **0** | **5** | **20.5** | |

### II - Year, I – Semester

| S. No. | Course Code | Course Name | L | T | P | Credits | Cat. Code |
|---|---|---|---|---|---|---|---|
| 1 | MA5101 | Mechanics | 3 | 0 | 0 | 3 | PCC |
| 2 | MA5102 | Numerical Solution of Differential Equations | 3 | 0 | 0 | 3 | PCC |
| 3 | MA5103 | Functional Analysis | 3 | 0 | 0 | 3 | PCC |
| 4 | MA5104 | Discrete Mathematics | 3 | 0 | 0 | 3 | PCC |
| 5 | | ELECTIVE – II | 3 | 0 | 0 | 3 | PEC |
| 6 | | ELECTIVE – III | 3 | 0 | 0 | 3 | PEC |
| 7 | MA5113 | Mathematical Programming Lab | 0 | 0 | 3 | 1.5 | PCC |
| 8 | MA5148 | Seminar - II | 0 | 0 | 2 | 1 | SEM |
| | | **Total** | 18 | **0** | **5** | **20.5** | |

**II - Year, II – Semester**

| S. No. | Course Code | Course Name | L | T | P | Credits | Cat. Code |
|---|---|---|---|---|---|---|---|
| 1 | | ELECTIVE – IV | 3 | 0 | 0 | 3 | PEC |
| 2 | | ELECTIVE – V | 3 | 0 | 0 | 3 | PEC |
| 3 | MA5161 | NSDE Lab | 0 | 0 | 3 | 1.5 | PCC |
| 4 | MA5197 | Comprehensive Viva | 0 | 2 | 0 | 2 | CVV |
| 5 | MA5199 | Dissertation Work | 0 | 5 | 10 | 10 | DW |
| | | **Total** | **6** | **7** | **13** | **19.5** | |

## SCHEME OF INSTRUCTION

| Credits in Each Semester | | | | | |
|---|---|---|---|---|---|
| **Cat. Code** | **Sem-I** | **Sem-II** | **Sem-III** | **Sem-IV** | **Total** |
| PCC | 19.5 | 16.5 | 13.5 | 1.5 | 51 |
| PEC | - | 3 | 6 | 6 | 15 |
| DW | - | - | - | 10 | 10 |
| SEM | - | 1 | 1 | - | 2 |
| CVV | - | - | - | 2 | 2 |
| **Total** | **19.5** | **20.5** | **20.5** | **19.5** | **80** |

## List of Electives

| Course Code | Course Name |
|---|---|
| **I - Year, II – Semester: Elective-I** | |
| MA4156 | Integral Transforms and Integral Equations |
| MA4157 | Differential Geometry and Tensor Analysis |
| MA4158 | Finite Volume Method |
| **II - Year, I – Semester: Elective-II** | |
| MA5105 | Fluid Dynamics |
| MA5106 | Multivariate Data Analysis |
| MA5107 | Lie group Methods for Differential Equations |
| MA5108 | Distribution Theory |
| **II - Year, I – Semester: Elective-III** | |
| MA5109 | Finite Element Method |
| MA5110 | Dynamical Systems |
| MA5111 | Iterative Methods |
| MA5112 | Spectral Methods |
| **II - Year, II – Semester: Elective-IV** | |
| MA5151 | Measure and Integration |
| MA5152 | Non-Newtonian Fluids |
| MA5153 | Computational Fluid Dynamics |
| MA5154 | Dynamo Theory |
| MA5155 | Sobolev Spaces |
| **II - Year, II – Semester: Elective-V** | |
| MA5156 | Inventory, Queueing Theory and Non-Linear Programming |
| MA5157 | Heat and Mass Transfer |
| MA5158 | Bio-Fluid Mechanics |
| MA5159 | Electro-kinetic Transport Phenomena |
| MA5160 | Variational Methods and Splines |

**Note:**

1. In addition to the above listed electives, a student may register for electives from Mathematics and Scientific Computing stream on satisfying the minimum pre-requisite of the specific course(s).
2. An elective may be offered to the students, only if a minimum of 15 students opt for it.
3. Students can take maximum of TWO subjects (other than the above listed) from MOOC in any of the Elective slots with the approval of DAC - PG & R.

# DETAILED SYLLABUS FOR EACH COURSE

## M.Sc. (Applied Mathematics):: I Year I Semester

| Course Code: MA4101 | Real Analysis | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Find whether a given function can be Riemann integrable |
| **CO2** | Test whether a given improper integral can be convergent |
| **CO3** | Examine uniform convergence of given sequence and /or series of functions |
| **CO4** | Expand a given function into Fourier series |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 2 | 3 |
| **CO2** | 3 | 2 | 2 | 3 | 3 | 2 |
| **CO3** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 2 | 3 |

Syllabus:

**Basic Topology**: Introduction

**Riemann Stieltje's integral**: Definition and existence of the integral, Properties of the integral, Integration and differentiation of integral with variable limits.

**Improper integrals**: Definitions and their convergence, Tests of convergence, $\beta$ and $\Gamma$ functions.

**Uniform convergence**: Tests for uniform convergence, Theorems on limit and continuity of sum functions, Term by term differentiation and integration of series of functions.

**Power series:** Convergence and their properties.

**Fourier series**: Dirichlet's' conditions, Existence, Problems, Half range sine and cosine series.

Learning Resources:

Text Books:

1. Principles of Mathematical Analysis**, Walter Rudin,** McGraw Hill, 2017, Third Edition.
2. Real Analysis, **Brian S.Thomson, Andrew M.Bruckner, Judith B.Bruner**, Prentice Hall International, 2008.

Reference Books:

1. Introduction to Real Analysis, **William F. Trench,** Library of Congress Cataloging-in-Publication Data, Free Edition 1.04, April 2010
2. Real Analysis, N.L. **Carothers**, Cambridge University Press, 2000
3. Mathematical Analysis, **Tom M. Apostol**, Addison Wesley, 1974, Second Edition

| Course Code: MA4102 | Ordinary Differential Equations | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Determine linearly independent solutions and general solution of a non-homogeneous differential equations |
| **CO2** | Find power series solution to a differential equation containing variable coefficients |
| **CO3** | Discuss the existence and uniqueness of solution for an initial value problem |
| **CO4** | Use Green's function to solve a non-homogeneous boundary value problem |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 2 | 3 |
| **CO2** | 3 | 2 | 2 | 3 | 3 | 2 |
| **CO3** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 2 | 3 |

Syllabus:

**First Order Equations:** Picard's theorem, Non-Local existence theorem.

**Second Order Equations:** Linear dependence and independence, A formula for the Wronskian, the non-homogeneous equations, linear equations with variable coefficients, reduction of the order of the homogeneous equation, Sturm comparison theorem, Sturm separation theorem.

**Stability**: Autonomous Systems. The Phase Plane and Its Phenomena, Types of Critical Points. Stability, Critical Points and Stability for Linear Systems.

**Systems of Differential Equations:** Existence theorems, homogeneous linear systems, non-homogeneous linear systems, linear systems with constant coefficients, eigenvalues and eigenvectors, diagonal and Jordan matrices,

**Boundary value problems**: Two-point boundary value problems, Green's functions, construction of Greens functions, non-homogeneous boundary conditions.

Learning Resources:

Text Books:

1. Differential Equations with Applications and Historical Notes, **G.F. Simmons**, McGraw Hill, 2017, Second Edition.
2. An Introduction to Ordinary Differential Equations, **E.A. Coddington**, PHI Learning, 1999.
3. Ordinary Differential Equations, **Tyn Myint U**, Elesvier, North- Holland, 1978.
4. Textbook of Ordinary Differential Equations, **V. Raghavendra, Rasmita Kar, S.G. Deo, V. Lakshmikantham,** McGraw Hill India, 2015, Third Edition.

Reference Books:

1. Differential Equations and Their Applications, **M. Braun**, Springer-Verlag, 1983, Third Edition.
2. Differential and Integral Equations, **P.J. Collins**, Oxford University Press, 2006.
3. Elementary Differential Equations and Boundary Value Problems, **W.E.Boyce** and **R.C. Di-Prima**, John Wiely & Sons, 2001.

| Course Code: MA4103 | Advanced Modern Algebra | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Analyse the structure of groups |
| **CO2** | Distinguish the properties among ring structures |
| **CO3** | Understand extension of fields and their constructions |
| **CO4** | Apply the concepts and results to solve problems of Modern Algebra |
| **CO5** | Construct proofs that arise in various algebraic structures |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | 2 | 2 | 2 |
| **CO2** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO3** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO4** | 3 | 3 | 2 | 3 | 2 | 2 |
| **CO5** | 3 | 1 | 2 | 3 | 2 | 2 |

Syllabus:

**Groups**: Group actions; Cayley's theorem; Class equation, Automorphisms; Sylow theorems and applications;

**Rings**: Ring homomorphisms and quotient rings; Quadratic integer rings; Properties of ideals; Rings of fractions; The Chinese Remainder Theorem;

**Classes of Rings**: Euclidean domains – norm, division algorithm, field norm on quadratic integer rings, results; Principal ideal domains – properties and results, Dedekind-Hasse norm; Unique factorization domains – irreducible elements, prime elements, associates, properties and results; Polynomial rings over fields, polynomial rings that are UFDs, irreducibility criteria;

**Fields**: Brief introduction to fields, field extensions, finite fields;

Learning Resources:

Text Books:

1. Abstract Algebra, **David S. Dummit and Richard M. Foote**, John Wiley & Sons, 2004, Third Edition
2. Topics in Algebra, **I. N. Herstein**, John Wiley & Sons, 1975, Second Edition

Reference Books:

1. Algebra, **Michael Artin**, Pearson, 2016, Second Edition
2. Contemporary Abstract Algebra, **Joseph A. Gallian**, Cengage Learning, 2013, Eighth Edition
3. Algebra, **Serge Lang**, Springer, 2002, Revised Third Edition.

| Course Code: MA4104 | Linear Algebra | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Test the consistency of system of linear algebraic equations |
| **CO2** | Verify rank nullity theorem for a given linear transformation |
| **CO3** | Find eigenvalues and canonical forms of a linear operator |
| **CO4** | Identify the importance of orthogonal property in the spectral theory |
| **CO5** | Demonstrate the knowledge of bilinear form and its nature |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | | 2 | 2 | | |
| **CO2** | 2 | | | | | |
| **CO3** | 3 | 2 | 2 | | | |
| **CO4** | 3 | | 3 | | | |
| **CO5** | 3 | | | | | |

Syllabus:

**System of Linear Equations:** Matrices and elementary row operations, Uniqueness of echelon forms, Moore-Penrose Generalized inverse, Solutions of homogeneous and non-homogeneous linear system of equations.

**Vector Spaces and Linear Transformations:** Vector spaces, Subspaces, Bases and dimension, Coordinates, Linear transformations and its algebra and representation by matrices, Algebra of polynomials.

**Diagonalization of Matrices:** Elementary canonical forms, Characteristic values and characteristic vectors, Cayley-Hamilton theorem, Annihilating polynomial, Invariant subspaces. Simultaneous triangularization, Simultaneous diagonalization, Jordan form.

**Inner Product Spaces:** Inner product spaces, Unitary and normal operators, Bilinear forms.

Learning Resources:

Text Books:

1. Linear Algebra, **K.Hoffman and R.Kunze,** Prentice Hall of India, New Delhi, 2003.
2. Linear Algebra Done Right, **Sheldon Axler**, Springer nature, 2015, Third Edition.

Reference Books:

1. First Course in Linear Algebra, **P.G. Bhattacharya, S.K. Jain and S.R. Nagpaul,** Wiley Eastern Ltd., New Delhi, 1991.
2. Matrix and Linear Algebra, **K.B.Datta,** Prentice Hall of India, New Delhi, 2006.

| Course Code: MA4105 | Computer Programming in C++ | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Develop algorithms for mathematical and scientific problems |
| **CO2** | Understand the components of computing systems |
| **CO3** | Choose data types and structures to solve mathematical and scientific problems |
| **CO4** | Develop modular programs using control structures |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 3 | 3 | 3 | 1 | 2 |
| **CO2** | 3 | 2 | 2 | 3 | 2 | |
| **CO3** | 3 | 3 | 3 | 2 | | 1 |
| **CO4** | 2 | 2 | 2 | 1 | 1 | |

Syllabus:

**Introduction:** History of C++, Overview of Procedural Programming and Object-Orientation Programming, Using main () function, Compiling and Executing Simple Programs.

**Expressions and operators:** Tokens, Expressions and Operators, loops and controlling the loop execution, logic, bitwise and arithmetic operators.

**Functions**: Function Declarations, different methods of passing parameters and their purpose, Default Arguments, Structures and unions.

**Pointers**: Arrays Pointers into Arrays, Constants, Pointer to Function, References Pointers to void Structures.

**Strings**: converting values of different types, strings: declarations, initializations, assignments, functions and strings, pointers and strings.

Learning Resources:

Text Books:

1. C++: The Complete Reference, **H. Schildt**, McGraw Hill, 2003, Fourth Edition.
2. Programming with C++, **John R. Hubbard**, McGraw-Hill, 2006, Second edition.

Reference Books:

1. C++ Primer, **Stanley B. Lippman, Josee Lajoie, and Barbara E. Moo**, Pearson Education, 2013, Fifth Edition.
2. Problem solving with C++, Walter Savitch, Pearson Education, 2014, 9th edition.
3. Let Us C++, Yashavant Kanetkar, BPB Publications, 2020.

| Course Code: MA4106 | Numerical Analysis | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to

| | |
|---|---|
| **CO1** | Construct the Polynomial to the given data |
| **CO2** | Evaluate the integrals numerically |
| **CO3** | Find the roots of nonlinear equations |
| **CO4** | Approximate the function by a polynomial |
| **CO5** | Solve Initial value problems numerically |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 2 | | 2 |
| **CO2** | 2 | 2 | 2 | | | 3 |
| **CO3** | 3 | 3 | 3 | 1 | | |
| **CO4** | 3 | 2 | 3 | 1 | 1 | 2 |
| **CO5** | 3 | 3 | 3 | | | 3 |

Syllabus:

**Interpolation**: Existence, Uniqueness of interpolating polynomial, Error of interpolation, Unequally spaced data - Lagrange's and Newton's divided difference formulae, Equally spaced data - finite difference operators and their properties, Inverse interpolation, Hermite interpolation.

**Differentiation**: Finite difference approximations for first and second order derivatives.

**Integration**: Newton-cotes closed type methods - particular cases and error terms; Newton cotes open type methods - Romberg integration, Gaussian quadrature, Legendre, Chebyshev formulae.

**Solution of nonlinear and transcendental equations**: Regula-Falsi method, Newton-Raphson method, Muller's method, System of nonlinear equations.

**Approximation**: Norms, Least square (using monomials and orthogonal polynomials), Uniform and Chebyshev approximations.

**Solution of linear algebraic system of equations**: Gauss-Seidal methods, Solution of tridiagonal system, Ill conditioned equations, Eigen values and eigen vectors using Power method.

**Solution of ordinary differential equations - Initial value problems**: Single step methods; Taylor's, Euler's, Runge-Kutta methods, Error analysis; Multi-step methods: Milne's predictor-corrector methods; System of IVP's and higher orders IVP's.

## Learning Resources:

### Text Books:

1. Numerical Methods for Engineers and Scientists, **MK Jain, SRK Iyengar and RK Jain**, New Age International, 2008.
2. Applied Numerical Analysis, **C.F.Gerald and P.O.Wheatley**, Addison-Wesley, 1984.

### Reference Books:

1. An Introduction to Numerical Analysis, **K. Atkinson, Numerical Analysis**, John Wiley,1989
2. Introduction to Numerical Analysis, **F.B. Hildebrandt**, Courier Coporation,1987.

| Course Code: MA4107 | CPP Lab | Credits 0-0-3: 1.5 |
|---|---|---|

Pre-Requisites: MA4105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Design and test programs to solve mathematical and scientific problems. |
| **CO2** | Develop and test programs using control structures. |
| **CO3** | Implement modular programs using functions. |
| **CO4** | Develop program using pointers and structures. |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 2 | 3 | 3 | 3 |
| **CO2** | 1 | 3 | 3 | 2 | 2 | 2 |
| **CO3** | 1 | 2 | 3 | 3 | 2 | 1 |
| **CO4** | 2 | 2 | 2 | 3 | 1 | 1 |

Syllabus:

Programs using

1. conditional control constructs.
2. loops (while, do-while, for).
3. user defined functions and library functions.
4. arrays, matrices (single and multi-dimensional arrays).
5. pointers (int pointers, char pointers).
6. Programs on structures.

## M.Sc. (Applied Mathematics):: I Year II Semester

| Course Code: MA4151 | Probability & Statistics | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Determine the mean, standard deviation and $m^{th}$ moment of a probability |
| **CO2** | Apply theoretical model to fit the empirical data |
| **CO3** | Differentiate between Large and small sample tests |
| **CO4** | Use the method of testing of hypothesis for examining the validity of a hypothesis |
| **CO5** | Estimate the parameters of a population from knowledge of statistics of a sample |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | 1 | 1 | 2 |
| **CO2** | 2 | 3 | 3 | 1 | 1 | 2 |
| **CO3** | 2 | 3 | 3 | | | 2 |
| **CO4** | 3 | 3 | 2 | | | 1 |
| **CO5** | 3 | 3 | 3 | | | 2 |

Syllabus:

**Random variables:** Review of probability; Probability distributions with discrete and continuous random variables - Joint probability mass function, Marginal distribution function, Joint density function – Independent random variables - Mathematical Expectation - Moment generating function - Chebyshev's inequality - Weak law of large numbers - Bernoulli trials

**Theoretical Probability Distributions:** Binomial, Negative Binomial, Geometric, Poisson, Normal, Rectangular, Exponential, Gaussian, Beta and Gamma distributions and their moment generating functions; Fit of a given theoretical model to an empirical data.

**Sampling and Testing of Hypothesis**: Introduction to testing of hypothesis - Tests of significance for large samples – t, F and Chi-square tests; ANOVA - one-way and two-way classifications.

**Theory of estimation**: Characteristics of estimation - Minimum variance unbiased estimator - Method of maximum likelihood estimation.

**Correlation and Regression:** Scatter diagram - Linear and polynomial fitting by the method of least squares - Linear correlation and linear regression - Rank correlation - Correlation of bivariate frequency distribution.

Learning Resources:

Text Books:

1. Fundamentals of Mathematical Statistics, **S.C. Gupta and V.K. Kapur,** S.Chand & Sons, New Delhi, 2008
2. An Introduction to Probability theory and Mathematical Sciences, **V.K. Rohatgi and A.K. Md. Ehsanes Saleh,** Wiley, 2001

References

1. Miller & Freund's Probability and Statistics for Engineers, **Richard A. Johnson**, Pearson, 2018, Ninth Edition

| Course Code: MA4152 | Partial Differential Equations | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4102

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Solve linear and nonlinear first order partial differential equations |
| **CO2** | Demonstrate the concept of characteristic curves and characteristic strips |
| **CO3** | Solve higher order partial differential equations with constant coefficients |
| **CO4** | Find canonical forms of second order partial differential equations |
| **CO5** | Utilize the knowledge of PDES in solving various physical problems |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 2 |
| **CO2** | 3 | 2 | 2 | | | 1 |
| **CO3** | 3 | 3 | 3 | | | 2 |
| **CO4** | 3 | 1 | 2 | | | |
| **CO5** | 3 | 3 | 3 | | | 1 |

Syllabus:

**Equations of the First Order:** Formulation; Classification of first order partial differential equations (PDEs); Lagrange's method, Cauchy problem, and method of characteristics for linear and quasilinear PDEs; Paffian equation, Condition for integrability; First order non-linear equations, Complete integrals, Envelopes and singular solutions, Method of Charpit and Method of characteristics.

**Equations of higher order:** Method of solution for the case of constant coefficients; Classification of second order equations; Reduction to canonical forms; Method of solution by separation of variables.

**Wave equation:** Derivation of the wave equation; D'Alembert solution of wave equation, Domain of dependence and range of influence; Method of separation of variables; Inhomogeneous wave equation, Duhamel's principle.

**Diffusion equation:** Derivation of the heat equation, Method of separation of variables, Solutions of heat equation with homogeneous and non-homogeneous boundary conditions; Inhomogeneous heat equation, Duhamel's principle.

**Laplace's equation:** Basic concepts; Types of boundary value problems; The maximum and minimum principles; Boundary value problems; Method of separation of variables.

Learning Resources:

Text Books:

1. Elements of Partial Differential Equations, **I. Sneddon,** Dover Publications, 2013.
2. Linear Partial Differential Equations for Scientists and Engineers, **Tyn Myint-U and Lokenath Debnath**, Birkhauser, Bostan, 2007, Fourth Edition.

Reference Books:

1. Partial Differential Equations, **P. Prasad and R. Ravindran,** New Age International (P) Ltd., New Delhi, 2010
2. An Elementary Course in Partial Differential Equations, **T. Amaranath**, Narosa Publishing House, New Delhi, 2003, Second Edition.

| Course Code: MA4153 | Complex Analysis | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4101

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Introduce the analyticity of complex functions and study their applications |
| **CO2** | Evaluate complex integrals and expand complex functions |
| **CO3** | Determine and classify the zeros and singularities of the complex functions |
| **CO4** | Evaluate improper integrals by residue theorem |
| **CO5** | Learn the uniqueness of conformal transformation |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | | | 2 |
| **CO2** | 3 | 1 | 2 | | | 1 |
| **CO3** | 3 | 2 | 1 | | | 2 |
| **CO4** | 3 | 2 | 3 | | | 1 |
| **CO5** | 3 | 3 | 3 | | | 2 |

Syllabus:

**Functions of Complex Variables:** Complex variable - Functions of a complex variable - Continuity - Differentiability – Analytic functions.

**Complex Integration:** Cauchy's theorem - Cauchy's integral formula - Morera's theorem - Cauchy's inequality - Liouville's theorem.

**Series Expansions:** Taylor's theorem - Laurent's theorem - Zeros of an analytic function - Singularities

**Contour Integration:** Residue - Cauchy's residue theorem – contour integration - the fundamental theorem of algebra - Poisson's integral formula. Analytic continuation - branches of a many-valued function - Riemann surface.

**Conformal Mapping:** The maximum modulus theorem - mean values of f(z) - Conformal representation – Bilinear transformation - Transformation by elementary functions - uniqueness of conformal transformation - representation of any region on a circle.

Learning Resources:

Text Books:

1. Complex Variables and Applications, **R.V. Churchill and J.W. Brown,** McGraw Hill, Tokyo, 2009, Eighth Edition.
2. Theory of Complex Variables, E.T. **Copson,** Oxford University Press, New Delhi, 1974.

References

1. Complex Variables with Applications, **S. Ponnusamy & Herb Silverman**, Birkhauser, Boston, 2006, First Edition
2. Complex Variable, **Murray Spiegel, Seymour Lipschutz, John Schiller and Dennis Spellman**, Schaum's Outlines Series, McGraw Hill, 2017, Revised Second Edition.

| Course Code: MA4154 | Topology | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4101

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Compare nature of spaces with different topologies |
| **CO2** | Understand connectedness and compactness in spaces with different topologies |
| **CO3** | Categorize spaces based on countability and separation axioms |
| **CO4** | Combine results in proving results such as Urysohn Lemma and Urysohn metrization theorem |
| **CO5** | Understand the notion of completeness with its importance in Baire's Category theorem |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 3 | 2 | 2 |
| **CO2** | 3 | 1 | 3 | 3 | | 1 |
| **CO3** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | | 2 |
| **CO5** | 3 | | 3 | 3 | | |

Syllabus:

**Topological Spaces and Continuous Functions**: Definition; Basis for a topology; Order topology, Product topology, Subspace topology; Closed sets; $T_1$ axiom and Hausdorff spaces; Continuous functions, Homeomorphisms; Product and box topologies; Metric topology.

**Connectedness and Compactness in Topological Spaces**: Connected spaces, Components of a space, Compact spaces.

**Countability and Separation Axioms**: Countability axioms, Separation axioms, Normal spaces, Urysohn Lemma, Urysohn Metrization Theorem; Brief introduction to: Tietze Extension Theorem, Tychonoff theorem, Stone-Cech Compactification.

**Completeness**: Complete metric spaces, Baire's Category Theorem.

Learning Resources:

Text Books:

1. Topology, **James R. Munkres**, Prentice Hall of India, 2007, Second Edition
2. Introduction to Topology and Modern Analysis, George F. Simmons, McGraw Hill Inc., 2004

Reference Books:

1. Principles of Topology**, Fred H. Croom**, Cengage Learning, 2008
2. General Topology, **John L. Kelley**, Springer, 1991

| Course Code: MA4155 | Mathematical Programming | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4104

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Formulate a LPP and understand graphical solution |
| **CO2** | Determine the solution of a LPP by simplex methods |
| **CO3** | Application of post optimality analysis |
| **CO4** | Solution of transportation and assignment problems |
| **CO5** | Determine the solution of ILPP |
| **CO6** | Determine an optimal solution by dynamic programming |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 3 | | | 2 |
| **CO2** | 2 | 2 | 3 | | | 1 |
| **CO3** | 2 | 2 | 3 | 2 | 2 | 2 |
| **CO4** | 3 | 2 | 2 | 1 | | 1 |
| **CO5** | 3 | 2 | 3 | | | 1 |
| **CO6** | 3 | 2 | 2 | | | 1 |

Syllabus:

**Linear Programming**: Lines and hyperplanes - convex sets, convex hull - Formulation of a Linear Programming Problem - Theorems dealing with vertices of feasible regions and optimality - Graphical solution - Simplex method (including Big-M method and two-phase method) - Revised simplex method - Dual problem - Duality theory - Dual simplex method - Sensitivity analysis.

**Transportation problem:** Existence of solution - Degeneracy - MODI method (including the theory). Assignment problem, Travelling Salesman Problem.

**Integer Programming**: Gomory's cutting plane method for an integer linear programming problem and a mixed integer linear programming problem.

**Dynamic programming**: Multistage decision process - Concept of sub optimization - Principle of optimality - Computational procedure in dynamic programming – Application to problems involving discrete variables, continuous variables and constraints involving equations and inequations.

Learning Resources:

Text Books:

1. Operations Research: An Introduction, **H.A.Taha**, Prentice Hall of India, 2019
2. Operations Research, **Kanti Swarup, Manmohan and P.K.Gupta,** Sultan Chand and Co., 2006
3. Introduction to Operations Research, **J.C.Pant,** Jain Brothers, 2008

Reference Books:

1. Mathematical Programming Techniques, **N.S. Kambo**, East-West Pub., Delhi, 1999.
2. Principles of Operations Research, **H.M.Wagner,** Prentice Hall of India, 1980

| Course Code: MA4160 | Numerical Computing Lab | Credits 0-0-3 : 1.5 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Develop programs for computational problems |
| **CO2** | Write programs for algebraic and transcendental equations |
| **CO3** | Write the programs to solve a system of linear equations |
| **CO4** | Write programs for the numerical approximation of a definite integral |
| **CO5** | Write programs for the solution of initial value problems |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 3 | 2 | 2 | 2 | 2 |
| **CO2** | 2 | 3 | 2 | 3 | 2 | 1 |
| **CO3** | 2 | 3 | 2 | 3 | 2 | |
| **CO4** | 3 | 2 | 2 | 2 | 1 | |
| **CO5** | 2 | 3 | 2 | 3 | 1 | |

Syllabus:

Programs Based on Numerical methods using FORTRAN.

1. Programs for solution of quadratic equation
2. Solution of algebraic and transcendental equations
3. Solution of system of linear equations by Gauss-Seidel method
4. Solution of system of linear equations by Gaussian elimination method
5. Finding the Inverse of a matrix
6. Solution of Tridiagonal system by Thomas algorithm
7. Formulation of finite differences table for a given data
8. Finding the value of a function using Lagrange interpolation
9. Numerical integration
10. Euler's and modified Euler's methods, Runge-Kutta methods.

| MA4198 – Seminar |
|---|
| Every student has to give a seminar and a committee of staff members from the department shall evaluate the same. The DAC (PG & R) of the Department shall constitute this committee. |

## M.Sc. (Applied Mathematics):: II Year I Semester

| Course Code: MA5101 | Mechanics | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Develop equations of motion for a system of particles |
| **CO2** | Analyse the motion of a rigid body under translation |
| **CO3** | Analyse the motion of a rigid body under rotation about a fixed point |
| **CO4** | Develop Lagrange's and Hamiltonian equations for body |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | | | 2 |
| **CO2** | 3 | 2 | 3 | | | 1 |
| **CO3** | 2 | 2 | 2 | | | |
| **CO4** | 2 | 3 | 3 | | | 1 |

Syllabus:

**Systems of Particles**: Linear and angular momentum; Rate of change of angular momentum of a system of particles with respect to the fixed and moving frames of reference; Effect of impulsive forces on the systems of particles.

**Rigid Body**: Moments of inertia; Kinetic energy and angular momentum of a rigid body rotating about a fixed point and about a fixed axis; General motion of a rigid body; Motion of a rigid body parallel to a fixed plane under finite and impulsive forces.

**Rotational Motion:** Euler's motion under no forces, Effects of earth's rotation, Eulerian angles.

**Lagrangian Mechanics:** Generalized coordinates, Velocities and forces; Motion of a top - Lagrange's equations of motion.

Learning Resources:

Text Books:

1. Textbook on Dynamics, **F. Chorlton**, CBS Publication, 2002, Second Edition
2. Principles of Mechanics, **J. L. Synge and B. A. Griffith**, McGraw Hill, 1987

Reference Books:

1. Analytical Mechanics, **G. R. Fowles and G. L. Cassiday**, Cengage Learning, 2004
2. Theory & Problems of Theoretical Mechanics, **Murray R. Spiegel,** Schaum's Outline Series, McGraw Hill, 2017.

| Course Code: MA5102 | Numerical Solution of Differential Equations | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4106

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Apply the explicit and implicit multistep methods to solve the linear and non-linear initial value problems in ordinary differential equations |
| **CO2** | Apply the cubic splines method to solve the two-point boundary value problems in ordinary differential equations |
| **CO3** | Apply the iterative schemes to finite difference equations. |
| **CO4** | Find the numerical solution of the heat equation, wave equation and the Laplace equation in one dimensional and 2-dimensional space using the finite difference |
| **CO5** | Analyse the stability, convergence and the error analysis of the finite difference methods |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 1 |
| **CO2** | 3 | 2 | 3 | | | 2 |
| **CO3** | 3 | 2 | 3 | | | 3 |
| **CO4** | 3 | 3 | 3 | | | 2 |
| **CO5** | 3 | 3 | 3 | | | 2 |

Syllabus:

**Ordinary Differential Equations:** Multistep (explicit and implicit) methods for initial value problems, Linear and nonlinear boundary value problems, Quasilinearization and Shooting methods.

**Finite Difference Methods**: Finite difference approximations for derivatives, Boundary value problems with explicit and implicit boundary conditions, Error analysis, Stability analysis, Convergence analysis.

**Partial Differential Equations**: Finite difference approximations for partial derivatives and finite difference schemes for parabolic equations: Schmidt's two level, Multi-level explicit methods, Crank-Nicolson's two level, Multi-level implicit methods, Dirichlet's problem, Neumann problem, Mixed boundary value problem. Hyperbolic Equations: Explicit methods, Implicit methods, One space dimension. Elliptic equations: Laplace equation, Poisson equation, Iterative schemes, Dirichlet's problem, Neumann problem, Mixed boundary value problem, ADI methods.

Learning Resources:

Text Books:

1. Numerical Solution of Differential Equations, **M. K. Jain,** Wiley Eastern, Delhi, 2018, Fourth Edition.
2. Computational Methods for Partial Differential Equations, **M. K. Jain, S. R. K. Iyengar and R. K. Jain,** Wiley Eastern, 2016.

Reference Books:

1. Numerical Solution of Partial Differential Equations, **G. D. Smith,** Oxford University Press, 2004.
2. Introductory Methods of Numerical Analysis, **S. S. Sastry**, PHI, 2012, Fifth Edition.

| Course Code: MA5103 | Functional Analysis | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4154

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand the nature of Banach spaces |
| **CO2** | Understand the nature of Hilbert spaces |
| **CO3** | Prove the open mapping theorem, closed graph theorem and uniform boundedness principle |
| **CO4** | Apply results of this course in solving operator equations |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | 3 | 2 | 2 |
| **CO2** | 3 | 2 | 3 | 3 | 2 | 2 |
| **CO3** | 3 | 1 | 3 | 3 | 2 | 2 |
| **CO4** | 3 | 2 | 3 | 3 | 2 | 3 |

Syllabus:

**Banach spaces**: Normed linear spaces - Banach spaces, Definition and some examples - Incomplete normed linear spaces - Bounded linear operators - Hahn-Banach theorem.

**Dual Spaces:** Conjugate (or dual) spaces - Natural imbedding of normed linear space N in its second conjugate $N^{**}$ - the open mapping theorem - Closed graph theorem - the conjugate of an operator - The Uniform boundedness principle

**Hilbert spaces**: Definition and basic properties - Orthogonal complements - orthonormal sets - Bessel's inequality - Riesz representation theorem.

**Dual of a Hilbert space:** The dual of a Hilbert space - adjoint of an operator - projections and projection theorem

Learning Resources:

Text Books:

1. Introduction to Topology and Modern Analysis, **George F. Simmons**, McGraw Hill Inc., 2004
2. Introductory Functional Analysis with Applications, **Erwin Kreyszig**, John Wiley and Sons, 2007
3. Functional Analysis, **Balmohan V. Limaye**, New Age International, 2017, Revised Third Edition

Reference Books:

1. A Course in Functional Analysis, **J. Conway**, Springer, 2007, Second Edition
2. A First Course in Functional Analysis, **Casper Goffman and George Pedrick**, AMS Chelsea Publishing, 1983, Second Edition
3. Functional Analysis, **Peter D. Lax**, Wiley-Interscience, 2002

| Course Code: MA5104 | Discrete Mathematics | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Apply Propositional logic and First order logic to determine the validity of the statement |
| **CO2** | Construct induction proofs involving summations, inequalities, and divisibility |
| **CO3** | Implement *the* principles of counting, permutations and combinatory to solve real world problems |
| **CO4** | Formulate and solve recurrence relations |
| **CO5** | Determine whether a given relation is an equivalence relation/poset and will be able to draw a Hasse diagram |
| **CO6** | Develop and analyze the concepts of Boolean algebra |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | | | |
| **CO2** | 3 | 2 | 2 | 2 | 1 | |
| **CO3** | 2 | 2 | 2 | | | |
| **CO4** | 2 | 2 | 2 | | | 1 |
| **CO5** | 2 | 2 | 2 | | | |
| **CO6** | 3 | 2 | 3 | | | 1 |

Syllabus:

**Mathematical Logic:** Connectives, Tautologies, Equivalence of formulas, Duality law, Tautological implications, Normal forms, Theory of inference for statement calculus, Methods of proof, Predicative logic, Statement functions, Variables and quantifiers, Free and bound variables, Inference theory for predicate calculus.

**Counting:** Basics of counting**,** Permutations and combinations - Generalized Permutations and combinations; Pascal's identity, Vandermonde's identity, the Principles of inclusion–exclusion, Pigeonhole principle and its application.

**Recurrence relations:** Generating functions, Generating functions of permutations and combinations, Formulation as recurrence relations, Solving recurrence relations by substitution and generating functions, Method of characteristic roots, Solving inhomogeneous recurrence relations, Applications of recurrence relations.

**Relations:** Binary relations **-** Properties of binary relations, Equivalence relations and partitions, Matrix representation of relations, Adjacency matrices, Incidence matrices, Transitive closure and Warshal's algorithm, Partial and total ordering relations, Lattices.

**Graph Theory:** Basic concepts of graphs, Sub graphs, Matrix representation of graphs: Adjacency matrices, Incidence matrices, Isomorphic graphs, Paths and circuits, Eulerian and Hamiltonian graphs, Multigraphs, Planar graphs, Euler's formula, Graph coloring and covering, Chromatic number, Spanning trees, Algorithms for spanning trees (problems only and theorems without proofs).

Learning Resources:

Text Books:

1. Discrete Mathematics for Computer Scientists, **J. R. Mott, A. Kandel and Baker,** PHI, 2006.
2. Elements of Discrete Mathematics, **C. L. Liu,** McGraw Hill, 1985.

Reference Books:

1. Discrete Mathematics and its Applications with Combinatorics and Graph Theory, **K. H. Rosen,** Tata McGraw Hill, 2015, Seventh Edition.
2. Discrete Mathematical Structures, **Bernand Kolman, Robert C. Busby and Sharon Cutler Ross**, PHI, 2009, Sixth Edition.

| Course Code: MA5113 | Mathematical Programming Laboratory | Credits 0-0-3: 1.5 |
|---|---|---|

Pre-Requisites: MA4153

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Write a program to solve an LPP by simplex method |
| **CO2** | Write a program to solve an LPP by Big-M method |
| **CO3** | Write a program to solve an LPP by two-phase method |
| **CO4** | Write a program to solve an LPP by revised simplex method |
| **CO5** | Write a program to solve a transportation problem |
| **CO6** | Write a program to solve an assignment problem |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO2** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO3** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO4** | 1 | 3 | 2 | 3 | 2 | 2 |
| **C05** | 1 | 3 | 2 | 3 | 2 | 2 |
| **C06** | 1 | 3 | 2 | 3 | 2 | 2 |

Syllabus:

Simple programs dealing with fundamentals of C/C++ language for

1. Simplex method
2. Big-M method
3. Two phase method
4. Revised simplex method
5. Dual simplex method
6. Solution of a transportation problem by north west corner rule
7. Initial basic feasible solution for a transportation problem by Vogel's approximation method
8. Assignment problem

| MA5148 – Seminar |
|---|
| Every student has to give a seminar and a committee of staff members from the department shall evaluate the same. The DAC (PG & R) of the Department shall constitute this committee. |

**M.Sc. (Applied Mathematics):: II Year II Semester**

| Course Code: MA5162 | Numerical Solution of Differential Equations Lab | Credits 0-0-3: 1.5 |
|---|---|---|

Pre-Requisites: MA5102

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Recall the fundamental concepts of C/CPP/Fortran |
| **CO2** | Write a program for second order linear BVP using finite difference schemes |
| **CO3** | Write a program for second order nonlinear BVP using finite difference schemes |
| **CO4** | Adapt the finite difference schemes to write a program for Schmidt's two level, Crank- Nicolson's two level for heat conduction problem |
| **C05** | Develop programs for wave equation using explicit and implicit methods |
| **CO6** | Develop programs for Laplace equation and Poisson equation using explicit and implicit methods |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 2 | 3 | 2 | 1 |
| **CO2** | 2 | 3 | 2 | 3 | 2 | 1 |
| **CO3** | 2 | 3 | 2 | 3 | 2 | 2 |
| **CO4** | 2 | 3 | 2 | 3 | 2 | 1 |
| **CO5** | 2 | 3 | 2 | 3 | 2 | 2 |
| **CO6** | 2 | 3 | 2 | 3 | 2 | 1 |

Syllabus:

**Revision:** Write a program for Tridiagonal Matrix Algorithm (TDMA) - Thomas Algorithm

**Ordinary Differential Equations - Finite Difference Methods:**

(1) Write a program using finite difference schemes for

- Second order linear BVP with both Dirichlet boundary conditions
- Second order linear BVP with both Neumann boundary conditions
- Second order linear BVP with right Neumann and left Dirichlet boundary conditions
- Second order linear BVP with left Neumann and right Dirichlet boundary conditions

(2) Write a program for second order non-linear BVP using finite difference schemes

**Partial Differential Equations - Finite Difference Methods:**

(3) Write a program using finite difference schemes for

- One dimensional heat conduction problem: Schmidt's Scheme (two level)
- One dimensional heat conduction problem: Crank- Nicolson's Scheme (two level)

(4) Write a program using finite difference schemes for

- One-dimensional wave equation
- Laplace equation: Explicit and Implicit Methods
- Poisson equation: Explicit and Implicit Methods

| MA5197 – Comprehensive Viva |
| --- |
| Each student has to appear for comprehensive viva in front of the panel of examiners. |

| MA5199 – Dissertation Work |
| --- |
| Each student will be allotted to a faculty member by DAC (PG & R) for this term project work. It has to be carried out on a topic chosen by the student in consultation with the supervisor. The project supervisor will periodically review the student progress over the semester. The progress of the work will be evaluated in the middle of the semester by DAC (PG & R). Finally, the student has to submit the project report before the end examinations of the IV semester and present the findings for the final evaluation. |

# List of Electives for Applied Mathematics

## M.Sc. (Applied Mathematics):: I Year II Semester

| Course Code: MA4156 | Integral Transforms and Integral Equations | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand the concepts of certain integral transforms |
| **CO2** | Solve differential equations using Laplace transforms |
| **CO3** | Find the solution of BVP's using Fourier transforms |
| **CO4** | Solve finite difference equations by using Z transforms |
| **CO5** | Solve an integral equation |
| **CO6** | Find the Greens function to a differential equation/integral equation |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 2 |
| **CO2** | 3 | 2 | 2 | | | 1 |
| **CO3** | 2 | 2 | 2 | | | |
| **CO4** | 2 | 2 | 3 | | | 1 |
| **CO5** | 3 | 1 | 2 | | | 1 |
| **CO6** | 2 | 1 | 2 | | | |

Syllabus:

**Laplace Transform**: Definition; Functions of exponential order and examples; Transforms of elementary, transcendental and special functions; Transforms of derivatives and integrals; Transforms of periodic, unit-step and impulse functions; The inverse transform –Properties, Partial fraction, Convolution theorem; Solution of differential equations by the use of the transform - Laplace inverse integral, Solution of Laplace equation (in two dimensions), One-dimensional heat and wave equations. Demonstrations with simple examples.

**Fourier Transform**: The Fourier transform, Inverse Fourier transform, Fourier transform properties, Convolution integral, Convolution theorem, Correlation, Correlation theorem, Parseval's theorem, Wave from sampling, Sampling theorem, Frequency sampling theorem. Demonstrations with simple examples.

**Z-transform**: Z-transform, Inverse Z-transform, Z-transform properties, Solution of linear difference equations by using Z-transform. Discrete Fourier Transform - Fourier transform of sequences, Discrete Fourier transform, transfer function.

**Integral equations**: Classification of integral equations, Connection with differential equations, Integral equations of the convolution type, Method of successive approximations, the resolvent, Fredholm theory, Laplace and Fourier transforms with applications to integral equations. Green's functions: Non-homogeneous boundary value problems, one-dimensional Green's function.

## Learning Resources:

### Text Books:

1. Operational Mathematics, **R.V. Churchill,** McGraw Hill, 1972.
2. Methods of Applied Mathematics, **F. B. Hildebrand,** PHI, New Jercy, 1960.
3. Theory and applications of Z-Transform method, **E. I. Jury,** John Wiley, 1964.

### Reference Books

1. The use of Integral Transforms, **I.N. Snedden,** Tata Mc-Grawhill, 1979
2. Mathematical methods in Physics & Engineering, **John W. Dettman,** McGraw Hill, NewYork, 1962

| Course Code: MA4157 | Differential Geometry and Tensor Analysis | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Determine the directions of tangent, normal and binormal at point on the given |
| **CO2** | Find the geodesic curve on a given surface |
| **CO3** | Find surfaces of constant curvature |
| **CO4** | Form tensor quantities and find the corresponding metric tensors |
| **CO5** | Expose students to mathematical applications of tensor algebra to handle diverse |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 3 | | | 1 |
| **CO2** | 3 | 2 | 1 | | | 1 |
| **CO3** | 2 | 1 | 2 | | | |
| **CO4** | 2 | 1 | 2 | | | |
| **CO5** | 2 | 2 | 1 | | | 1 |

Syllabus:

**Differential Geometry**:

**(1) Local curve theory:** Serret-Frenet formulation, Fundamental existence theorem of space curves.

**(2) Plane curves and their global theory:** Rotation index, Convex curves, Isoperimetric inequality, Four vertex theorem.

**(3) Local surface theory:** First fundamental form and arc length, Normal curvature, Geodesic curvature and Gauss formulae, Geodesics, Parallel vector fields along a curve and parallelism, the second fundamental form and the Weingarten map, Principal, Gaussian, Mean and normal curvatures, Riemannian curvature and Gauss's theorem Egregium, Isometrics and fundamental theorem of surfaces.

**(4) Global theory of surfaces:** Geodesic coordinate patches, Gauss-Bonnet formula and Euler characteristic, Index of a vector field, Surfaces of constant curvature.

**Tensor Analysis:** N-dimensional space, Covariant and contravariant vectors, Contraction, Second & higher order tensors, Quotient law, Fundamental tensor, Associate tensor, Angle between the vectors, Principal directions, Christoffel symbols, Covariant and intrinsic derivatives.

Learning Resources:

Text Books:

1. Elements of Differential Geometry, **R. S. Millman and G. D. Parker,** Prentice Hall Inc., 1977.
2. Differential and Riemannian Geometry, **D. Laugwitz,** Academic Press, 2014.
3. Tensor Calculus, **Barry Spain,** Dover Publications, 2003.

Reference Books:

1. A Course in Differential Geometry and Lie Groups, **S. Kumaresan,** Texts and Readings in Mathematics, 22, Hindustan Book Agency, New Delhi, 2002.
2. The Use of Integral Transforms, **I. N. Snedden,** Tata McGraw-Hill, 1974.
3. Mathematical Methods in Physics & Engineering, **John W. Dettman,** Dover Publications, 2013.

| Course Code: MA4158 | Finite Volume Method | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Discretize steady and unsteady convection-diffusion problem |
| **CO2** | Identify the properties of discretisation schemes. |
| **CO3** | Solve convective problems using upwind, QUICK and hybrid schemes |
| **CO4** | Solve the velocity and pressure coupling |
| **CO5** | Solve discretised equations using multigrid methods |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | | | | |
| **CO2** | | | | | | 2 |
| **CO3** | | | 3 | | | |
| **CO4** | | 2 | 3 | | | |
| **CO5** | | | 3 | | | 1 |

Syllabus:

**Convection - Diffusion problems and discretisation:** Steady 1D, 2D and 3D convection and diffusion problems - Discretisation schemes: Central differencing scheme, Upwind differencing scheme, Hybrid differencing scheme, Power-law scheme. Properties of discretisation schemes: Conservativeness - Boundedness – Transportiveness.

**Higher-order differencing schemes:** Quadratic upwind differencing scheme: the QUICK scheme - Stability problems of the QUICK scheme and remedies - Generalisation of upwind-biased discretisation schemes - Total variation and TVD schemes - Criteria for TVD schemes - Flux limiter functions - Implementation and Evaluation of TVD schemes.

**Solution algorithms for pressure—velocity coupling:** The staggered grid - SIMPLE algorithm - SIMPLER algorithm.

**Solution of discretised equations**: Application of the TDMA to 2D and 3D problems - Point-iterative methods: Jacobi iteration method – Gauss-Seidel iteration method - Relaxation methods – Multigrid techniques: Multigrid cycles - Grid generation for the multigrid method.

**Unsteady flows**: Explicit scheme - Crank–Nicolson scheme - Fully implicit scheme - Transient SIMPLE.

Learning Resources:

Text Books:

1. An introduction to CFD: The Finite Volume Method, **H. Versteeg and W. Malalasekera,** Pearson, 2007, Second Edition.
2. Numerical Heat Transfer and Fluid Flow, **S.V. Patankar**, CRC Press, 2009.

Reference Books:

1. Introductory Finite Volume Methods for Partial Differential Equations, **D.M. Causon, C.G. Mingham, & L. Own,** Springer, 2009.

**M.Sc. (Applied Mathematics):: II Year I Semester**

| Course Code: MA5105 | Fluid Dynamics | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Draw stream lines and path lines of a velocity field of a fluid |
| **CO2** | Find complex velocity potential for an incompressible and irrotational flow |
| **CO3** | Set up equations of motion with boundary conditions for problems and solve them |
| **CO4** | Analyse the flow in a tube of uniform cross section and find volumetric flow rate |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 3 | 2 | 3 |
| **CO2** | 3 | 3 | 3 | 2 | 2 | 2 |
| **CO3** | 3 | 2 | 3 | 2 | 3 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 |

Syllabus:

**Kinematics of fluids in motion**: Real fluids and ideal fluids – Velocity of a fluid at a point – Stream lines and path lines – Steady and unsteady flows – The velocity potential – The velocity vector – Local and particle rates of change – The equation of continuity – Acceleration of fluid – Conditions at a rigid boundary.

**Equations of motion of fluid**: Euler's equations of motion – Bernoulli's equation – Some flows involving axial symmetry – Some special two-dimensional flows. Some three-dimensional flows: Introduction – Sources, sinks and doublets – Axisymmetric flows – Stokes' stream function. The Milne-Thomson circle theorem – The theorem of Blasius – Applications.

**Viscous flows**: Stress analysis in fluid motion – Relations between stress and rate of strain – The coefficient of viscosity and laminar flow – the Navier-Stokes' equations of motion of viscous fluid – Steady motion between parallel planes, Through tube of uniform cross section and flow between concentric rotating cylinders. Steady viscous flow in tubes of uniform cross section – A uniqueness theorem – Tube having uniform elliptic cross section – Tube having equilateral triangular cross section – Steady flow past a fixed sphere.

Learning Resources:

Text Books:

1. Fluid Dynamics, **Frank Chorlton**, CBS Publishers, Delhi, 2004
2. Theoretical Hydrodynamics, **L. M. Milne Thomson**, Macmillan Company, New York, 1960

Reference Books:

1. Fluid Mechanics: An Introduction to the Theory of Fluid Flow, **Franz Durst,** Springer-Verlag Berlin Heidelberg, 2008
2. Introduction to Fluid Mechanics, **Stephen Whitaker**, Ed-Tech Press, 2018.

| Course Code: MA5106 | Multivariate Data Analysis | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4151

Course Outcomes:

At the end of the course, the student will be able to

| | |
|---|---|
| **CO1** | Analyse Multivariate Distributions and their characteristics |
| **CO2** | Perform MANOVA |
| **CO3** | Perform Conjoint analysis |
| **CO4** | Analyze Cluster analysis and canonical correlation |
| **CO5** | Interpret Multidimensional scaling |

CO-PO Mapping:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | 1 | | 1 |
| **CO2** | 3 | 2 | 1 | | | |
| **CO3** | 2 | 2 | 1 | | | |
| **CO4** | 3 | 2 | 3 | | | 2 |
| **CO5** | 2 | 2 | 2 | | | 1 |

Syllabus:

**Multivariate analysis of variance**: Introduction -- Differences between MANOVA and discriminant analysis – A hypothetical illustration of MANOVA – A decision process for MANOVA

**Conjoint analysis**: Comparing conjoint analysis with other multivariate methods – Designing a conjoint analysis experiment – Managerial applications of conjoint analysis – Alternate conjoint methodologies – An illustration of conjoint analysis

**Canonical correlation analysis**: Analysing relationships with canonical correlation – interpreting the canonical variate – Validation and diagnosis

**Cluster analysis**: Cluster analysis decision process – Multidimensional scaling – Comparing MDS to other interdependence techniques – A decision framework for perceptual mapping – Correspondence analysis.

Learning Resources:

Text Books:

1. Multivariate Data Analysis, **Joseph F. Hair et al,** CENGAGE, 2018, Eighth Edition.
2. A Course in Multivariate Analysis, **M. G. Kendall,** Charles Griffith, 1968.

Reference Books:

1. An Introduction of Multivariate Data Analysis, **Trever Cox**, Holder Education, 2005
2. Matrix Based Introduction to Multivariate Data Analysis, **Kohei Adachi**, Springer, 2021
3. Exploratory Multivariate Analysis by Example using R, **Francois Husson**, CRC Press, 2020, Second Edition

| Course Code: MA5107 | Lie group Methods for Differential Equations | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4102 & MA4103

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Show competence in the field of ordinary and partial differential equations |
| **CO2** | Show analytic skills and working knowledge in Lie's integration methods |
| **CO3** | Solve linear and non-linear differential equations |
| **CO4** | Reduce a vast amount of nonlinear second-order ordinary equations used in applications to four |
| **CO5** | Know the terminology in group analysis of differential equations |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 2 |
| **CO2** | 3 | 3 | 3 | | | 2 |
| **CO3** | 3 | 2 | 3 | | | 1 |
| **CO4** | 3 | 2 | 2 | | | 2 |
| **CO5** | 3 | 2 | 2 | | | 1 |

Syllabus:

**Introduction to Lie group analysis:** Lie group of transformations – Groups, Group of transformations; One parameter Lie groups of transformations - Infinitesimal transformations - First order theorem of Lie - Infinitesimal generators - Invariant functions - Canonical coordinates - Invariants of points - Curves and surfaces - Extended infinitesimal - Extended transformations (Prolongations) - Symmetry reductions - Multi parameter Lie groups of transformations.

**Group analysis of ordinary differential equations:** Invariance of ordinary differential equations - Prolongation techniques - Calculation of Lie symmetry groups - Differential equations admitting a given group - Invariant solutions - Group classification for ordinary differential equations - Symmetry analysis for systems of ordinary differential equations.

**Group analysis of partial differential equations:** Invariance of partial differential equations -

Prolongation formulae - Determining equations - Infinitesimal of partial differential equations - Invariant solutions - Group classification for partial differential equations - Lie symmetries for systems of partial differential equations.

Learning Resources:

Text Books:

1. Symmetries and Differential Equations, **G.W**. **Bluman, S. Kumei,** Springer-Verlag, New York, 1989, First Edition.
2. Group Analysis of Differential Equations, **L.V. Ovsiannikov,** Academic Press, New York, 1982 (Moscow, Nauka, 1978, in Russian).

Reference Books:

1. Applications of Lie groups to Differential Equations, **P. Olver**, Springer-Verlag, Berlin, 1993, Second Edition.
2. Symmetry Methods for Differential Equations: A Beginner's Guide, **P. E. Hydon,** Cambridge University Press, 2010.
3. Applications of Symmetry Methods to Partial Differential Equations, **G. W. Bluman, A. F. Cheviakov and S. C. Anco,** Springer, 2010, First Edition.

## M.Sc. (Applied Mathematics):: II Year I Semester

| Course Code: MA5108 | Distribution Theory | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4101

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Identify the weak solutions for differential equations |
| **CO2** | Understand support and singular support of distributions |
| **CO3** | Derive fundamental solutions of partial differential equations |
| **CO4** | Prove approximations theorems |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | | | |
| **CO2** | 2 | 1 | 1 | | | 1 |
| **CO3** | 3 | 2 | 1 | | | |
| **CO4** | 3 | 2 | 2 | | | 2 |

Syllabus:

**The calculus of distributions:** Test functions and distributions, Some operations with distributions, Adjoint identities, Consistency of derivatives, Distributional solutions of differential equations. Support and singular support of distributions, Convolution of functions, Convolution of distributions, Fundamental solutions.

**The Fourier transforms:** From Fourier series to Fourier integrals, The Schwartz space, The Fourier inversion formula, Tempered distributions. Convolution with tempered distributions.

**Solving partial differential equations:** The Laplace equation, The heat equation, The wave equation.

**The structure of distributions:** Structure theorems, Distributions with point support, Positive distributions, Continuity of distributions, Approximation theory of distributions, Local theory of distributions, Distributions on spheres.

Learning Resources:

Text Books:

1. Topics in Functional Analysis and Applications, **S. Kesavan**, New Age International Publishers, 2015.
2. A Guide to Distribution Theory and Fourier Transforms, **R. S. Strichartz**, World Scientific, 2008, Third Edition

Reference Books:

1. Generalized Functions, **I. M. Gelfand** and **G. E. Shilov**, Academic Press, 1964, Vol.1.
2. Introduction to Partial Differential Equations, **Gerald B. Folland**, Princeton University Press, 1995

| Course Code: MA5109 | Finite Element Method | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Determine an extremum by calculus of variations approach |
| **CO2** | Formulate a variational problem for a boundary value problem |
| **CO3** | Find the solution of solution of one-dimensional problems |
| **CO4** | Find the solution of two-dimensional problems by rectangular elements |
| **CO5** | Find the solution of two-dimensional problems by triangular elements |
| **CO6** | Solve the time dependent problems |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 1 |
| **CO2** | 3 | 2 | 2 | | | 2 |
| **CO3** | 3 | 3 | 3 | | | 2 |
| **CO4** | 3 | 2 | 3 | | | 2 |
| **CO5** | 3 | 3 | 3 | | | 2 |
| **CO6** | 3 | 3 | 3 | | | 2 |

Syllabus:

**Calculus of Variations**: Introduction, Euler's Equation, Euler Lagrange Equations, Ostrogradsky equation.

**Variational formulation**: Variational Formulation for a boundary value problem with homogeneous and non-homogeneous boundary conditions, Rayleigh- Ritz minimization, Weighted residuals - Collocation, Least squares method, Galerkin, Petrov-Galerkin methods for boundary value problems.

**One dimensional problem**: Solution of one-dimensional boundary value problems by linear, quadratic and cubic shape functions.

**Two dimensional problems:** Solution of two-dimensional boundary value problems by linear, quadratic and cubic rectangular, serendipity and triangular shape functions.

**Time Dependent Problems**: One-dimensional heat and wave equations.

Learning Resources:

Text Books:

1. An introduction to the Finite Element Method, **J. N. Reddy**, McGraw Hill, 4th Edition, 2020
2. Finite Element Analysis in Fluid Dynamics, **I. J. Chung**, McGraw-Hill International Book Company, 2007, Digitized Version.

Reference Books:

1. Finite Elements and Approximation, **O. C. Zienkiewiez and K. Morgan**, John Wiley, 1983

The Finite Element Method – Principles and Applications, **P. E. Lewis and J. P. Ward**, Addison Wesley, 1991.

| Course Code: MA5110 | Dynamical Systems | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4103 & MA4106

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Identify Autonomous and Nonautonomous Systems |
| **CO2** | Understand Limit Cycle Motion and Periodic Attractor |
| **CO3** | Differentiate Dissipative and Conservative Systems |
| **CO4** | Understand different types of bifurcations |
| **CO5** | Apply Poincare Bendixson Theory. |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 3 | 2 | 1 | 1 |
| **CO2** | 2 | 2 | 2 | 1 | 1 | 1 |
| **CO3** | 2 | 1 | 2 | | | |
| **CO4** | 2 | 2 | 1 | | | |
| **CO5** | 3 | 2 | | | | |

Syllabus:

**Qualitative Features:** Autonomous and nonautonomous Systems- Equilibrium Points - Phase space/phase plane and phase trajectories: Stability, Attractors and Repellers; Classification of equilibrium points- Limit cycle motion - Periodic attractor – Poincare - Bendixson theorem - Higher dimensional systems: Lorenz equations - Quasiperiodic attractor - Poincare map - Chaotic attractor - Dissipative and conservative systems - Hamiltonian systems.

**Bifurcations and Onset of Chaos in Dissipative Systems:** Saddle-node bifurcation - Pitchfork bifurcation - Transcritical bifurcation - Hopf bifurcation - Discrete dynamical systems - Logistic map - Equilibrium points and their stability- Periodic solutions or cycles - Period doubling phenomenon- Onset of chaos: Sensitive dependence on initial conditions - Lyapunov exponent- Bifurcation diagram - Logistic map- Strange attractor in the Henon map - The period doubling phenomenon - Self-similar structure - Route to chaos.

**Chaos in Conservative Systems:** Poincare cross section - Orbits in conservative systems - Regular and irregular trajectories - Canonical perturbation theory: Overlapping resonances and chaos - Periodically driven undamped duffing oscillator - The standard map - Linear stability and invariant curves - Numerical analysis: Regular and chaotic motions.

**Characterization of Regular and Chaotic Motions:** Lyapunov exponents - Numerical computation of Lyapunov exponents - One-dimensional map - Computation of Lyapunov exponents for continuous time dynamical systems- Power spectrum and dynamical motion - Autocorrelation - Criteria for chaotic motion.

Learning Resources:

Text Books:

1. Nonlinear Dynamics: Integrability, Chaos and Patterns, **M. Lakshmanan, S. Rajasekar**, Springer, First edition, 2010.
2. Differential Equations with Applications and Historical Notes, **George F. Simmons**, McGraw-Hill, Second Edition, 2003.

Reference Books:

1. Differential Equations, Dynamical Systems, and an Introduction to Chaos, **Hirsch, Smale and Devaney,** Elsevier Academic Press, USA, 2004.
2. Differential Equations and Dynamical Systems, **Lawrence Perko,** Third Edition, Springer-Verlag, 2010.

**M.Sc. (Applied Mathematics):: II Year I Semester**

| Course Code: MA5111 | Iterative Methods | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Solve differential equations using ADM. |
| **CO2** | Get solutions of differential equations by HPM. |
| **CO3** | Find solutions of fluid dynamics problems using HAM. |
| **CO4** | Apply VIM for ODEs. |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | | 3 | | 2 | |
| **CO2** | 2 | | 3 | | 2 | |
| **CO3** | 2 | | 3 | | 2 | |
| **CO4** | 2 | | 3 | | 2 | |

## Detailed Syllabus:

**Adomian Decomposition Method (ADM):** The ADM for solving differential equations, Convergence of ADM, ADM in several dimensions, Solving boundary value problems using ADM, Modified ADM, Mathematica code of ADM.

**Homotopy Perturbation Method (HPM):** The HPM algorithm, Convergence analysis, Applications.

**Homotopy Analysis Method (HAM):** The HAM algorithm, Convergence analysis, The role of auxiliary parameter, Control of convergence, Relation to ADM and HPM, Applications of HAM to solve nonlinear equations.

**Variational Iteration Method (VIM):** The VIM algorithm, Convergence of VIM, Applications to solve ordinary differential equations**,** Solving system of fractional differential equations using ADM**.**

Learning Resources:

Text Books:

1. Solving frontier problems in Physics: The decomposition method, **G. Adomian**, Kluwer Academic Publishers, London, 1994.
2. Beyond perturbation: introduction to the homotopy analysis method, **S. Liao**, CRC press, 2003.
3. Variational Iteration Method and its applications, **Belal Batiha**, LAP Lambert Academic Publishing, 2012.

| Course Code: MA5112 | Spectral Methods | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4106

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand the basics of MATLAB |
| **CO2** | Understand the basics of spectral methods |
| **CO3** | Evaluate Fourier and Chebyshev spectral differentiation using differentiation matrices and FFT's |
| **CO4** | Solve IVP's and BVP's using spectral methods |
| **CO5** | Determine stability, convergence criterions and stiffness |
| **CO6** | Understand the mathematical concepts of spectral element methods |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 2 |
| **CO2** | 3 | 2 | 3 | | | 1 |
| **CO3** | 3 | 2 | 3 | | | 2 |
| **CO4** | 3 | 2 | 3 | | | 2 |
| **CO5** | 3 | 2 | 3 | | | 2 |
| **C06** | 2 | 1 | 1 | | | |

Syllabus:

**Basics of Matlab:** Introduction to Matlab, Programming in Matlab, Branching and looping, Built-in functions and user defined functions.

**Spectral Methods:** Historical background, Introduction to spectral methods via orthogonal functions, some examples of spectral methods, Spectral differentiation versus Finite differences, MATLAB as a tool in problem solving, Basic layout of spectral methods.

**Fourier Spectral Differentiation:** Fourier approximation, Fourier spectral differentiation via differentiation matrices, Smoothness and accuracy, Aliasing and aliasing removal, MATLAB demonstrations.

**Chebyshev Spectral Differentiation:** Polynomial approximation, Jacobi polynomials, Chebyshev spectral differentiation via Differentiation matrices, Smoothness and accuracy, MATLAB demonstrations.

**Initial Value Problems:** Spectral method treatment of problems with mixed initial/boundary conditions, Semi-implicit methods, Case studies and MATLAB demonstrations.

**Boundary Value Problems:** Spectral method treatment of problems Dirichlet/Neumann/Robin type boundary conditions, Eigen boundary value problems, Boundary value problems in Polar coordinates, Differential eigen problems, Case studies and MATLAB demonstrations.

## Learning Resources:

### Text Books:

1. Numerical Computing with MATLAB, **Cleve Moler,** SIAM, 2004.
2. Spectral Methods in Matlab, **L. N. Trefethen,** SIAM, 2000.
3. Spectral Methods: Fundamentals in Single Domain, C. **Canuto, M.Y. Hussaini, A. Quarteroni and T. A. Zang,** Springer Verlag, 2006, First Edition.

### Reference Books:

1. Numerical Analysis of Spectral Methods: Theory and Applications, **D. Gottlieb and S. A. Orszag,** CBMS-NSF 26, Philadelphia: SIAM, 1987.
2. Spectral Methods in Fluid Dynamics, **C. Canuto, M.Y. Hussaini, A. Quarteroni and T.A. Zang,** Springer-Verlag Berlin Heidelberg, 1988, First Edition.

**M.Sc. (Applied Mathematics):: II Year II Semester**

| Course Code: MA5151 | Measure and Integration | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4101

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Identify the class of measurable sets |
| **CO2** | Derive properties of Lebesgue measurable sets and functions |
| **CO3** | Determine whether the given function is Lebesgue integrable or not |
| **CO4** | Prove Fatou's Lemma, Lebesgue's Monotone convergence theorem and Lebesgue dominated convergence theorem |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | | | |
| **CO2** | 2 | 1 | 2 | | | |
| **CO3** | 3 | 1 | 2 | | | |
| **CO4** | 3 | 1 | 1 | | | |

Syllabus:

**Lebesgue Measure:** Outer measure, Measurable sets, A non-measurable set, Example of measurable set which is not a Borel set, Lebesgue measure and its properties, Measurable functions.

**Abstract Integration:** The concept of measurability, Simple functions, Elementary properties of measures, Arithmetic in [0, ∞], integration of positive functions, Lebesgue's monotone convergence theorem, Fatou's lemma, Lebesgue's dominated convergence theorem, Integration of complex functions, the role played by sets of measure zero.

**Product measures:** Integration on cartesian products, Product measures, The Fubini's theorem.

Learning Resources:

Text Books:


3. Real Analysis, **H. L. Royden**, Pearson, 2003, Third Edition.
4. Real and Complex Analysis, **W. Rudin**, Tata McGraw-Hill Edition, 2006, Third edition


Reference Books:


1. Measure and Integration, **G. de Barra**, Wiley Eastern, 1981.
2. An Introduction to Measure Theory, **Terence Tao**, Graduate Studies in Mathematics, AMS, 2011.
3. Real Analysis: Modern Techniques and Their Applications, **G.B. Folland**, John wiley and sons inc. 1999, Second Edition.
4. Measure Theory, **Paul R. Halmos**, Springer New York, 2014, Illustrated Edition.

| Course Code: MA5152 | Non-Newtonian Fluids | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA5105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Classify the fluids and their characteristics |
| **CO2** | Perceive the knowledge of nanofluids, couple stress fluids, micropolar fluids. |
| **CO3** | Formulate the governing equations with respect to various geometric situations |
| **CO4** | Solve fluid flow problems with diverse working fluids |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | | 1 | | |
| **CO2** | 1 | 2 | 3 | | 1 | |
| **CO3** | 3 | 3 | 3 | 3 | | 3 |
| **CO4** | 3 | 3 | 3 | 3 | | 3 |

Syllabus:

**Non-Newtonian Fluids**: Non-Newtonian fluid behavior - Introduction, Classification of fluid behavior, Time-independent fluid behavior, Time-dependent fluid behavior, Visco-elastic fluid behavior, Modeling the flow of fluids, Generalized Newtonian fluids, Power-law fluid, Viscoelastic fluids, Nanofluids, Couple stress fluids, Micropolar fluids, Basic problems.

**Nanofluids**: Thermal physical properties of nanofluids, Conduction heat transfer in nanofluids, Constitutive equations of nanofluids using (a) Tiwari and Das approach, (b) Buongiorno approach. Steady flow between parallel plates, Steady flow between two coaxial cylinders, Poiseuille flow through circular pipes.

**Couple stress fluids**: Governing equations, Boundary conditions, Steady flow between parallel plates, Steady flow between two coaxial cylinders, Poiseuille flow through circular pipes, creeping flow past a sphere.

**Micropolar fluids**: Skew-symmetry of the gyration tensor and micro-isotropy, Micropolar fluids, Governing equations, Boundary conditions, Steady flow between parallel plates, Steady flow between two coaxial cylinders, Poiseuille flow through circular pipes, creeping flow past a sphere.

Learning Resources:

Text Books:

1. Non-Newtonian Flow and Applied Rheology, **R. P. Chhabra and J. F. Richardson, Butterworth-Heinemann**, Oxford, U. K., 2008, Scond Edition.
2. Nanofluids: Science and Technology, **Sarit K. Das, Stephen U. S. Choi, Wenhua Yu and T. Pradeep**, Wiley-Interscience, 2008, First Edition.
3. Theories of Fluids with Microstructure, **V.K. Stokes**, Springer, New York 1984.

Reference Books:

1. Microcontinnum Field Theories-II: Fluent Media, **A. C. Eringen**, Springer, New York, 2001.
2. Rheology and Non-Newtonian Fluids, **Fridtjov Irgens**, Springer, 2014.

| Course Code: MA5153 | Computational Fluid Dynamics | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA5105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Classification of physical behaviours of governing equations |
| **CO2** | Understand the effect of turbulent fluctuations on properties of the mean flow |
| **CO3** | Handle the errors and uncertainty in CFD modelling |
| **CO4** | Differentiate DNS, LES, subgrid scale models in turbulence flow |
| **CO5** | Simulate the flow in complex geometries using unstructured grids |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | | | |
| **CO2** | 3 | 2 | 3 | | | 2 |
| **CO3** | 3 | 1 | 2 | | | 2 |
| **CO4** | 2 | 1 | 2 | | | 1 |
| **CO5** | 2 | 1 | 3 | | | 1 |

Syllabus:

**Basics of computational fluid dynamics:** Governing equations of fluid dynamics – Continuity, Momentum and Energy equations – Chemical species transport – Physical boundary conditions – Time-averaged equations for Turbulent Flow – Turbulent–Kinetic Energy Equations – Mathematical behaviour of PDEs on CFD – Elliptic, Parabolic and Hyperbolic equations.

**Finite difference methods:** Mixed derivatives – Accuracy - Finite difference formulation – Explicit and Implicit schemes – von Neumann stability analysis – schemes for Parabolic, Elliptic and Hyperbolic equations – Schemes for Burger's equation.

**Coordinate transformation and boundary conditions:** Arbitrary geometries, Determination of Jacobians and Transformed equations – Applications of Neumann Boundary Conditions. Artificial compressibility method – Pressure Correction method (Self-Implicit method).

**Nonlinear Equations:** Euler equations - Quasilinearization–eigenvalues and compatibility relations – Characteristic variables – Central schemes with combined space and time discretization, Nonlinear problems - convection dominated flows, Linearized Burger's equations.

Learning Resources:

Text Books:

1. Computational Fluid Dynamics, **T. J. Chung**, Cambridge Univ. Press, 2003.
2. Computational Techniques for Fluid Dynamics, **C.A.J. Fletcher,** Springer-Verlag, Berlin, 1991, Volumes: I and II.

Reference:

1. Computational Fluid Flow and Heat Transfer, **K. Muralidhar and T. Sundarajan,** Narosa Publishing House, 2003.
2. Numerical Method for Partial Differential Equation, **W.F.Ames.** Academic Press, 2014.

| Course Code: MA5154 | Dynamo Theory | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA5105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand astro- and geophysical problems |
| **CO2** | Solve the complex physical problems by applying numerical as well as analytic and asymptotic methods |
| **CO3** | Understand and the ability to predict the time behaviour of the magnetic field generation of cosmic bodies |
| **CO4** | Apply mathematical approaches with convenient approximations based on physical understanding of details in Dynamo mechanisms |
| **CO5** | Tract the hydrodynamic Stability of rotating fluids permeated by magnetic field (Rotating Magnetoconvection) and Kinematic Dynamos |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | | | | | |
| **CO2** | | 1 | | | | |
| **CO3** | 2 | | | | | |
| **CO4** | | | 2 | | | |
| **CO5** | | 3 | | 3 | | 2 |

Syllabus:

**Foundations of Magnetohydrodynamics (MHD):** Introduction and basic equations of MHD - Nondimensional numbers, e.g. magnetic Reynolds number (Rm); Induction equation analysis, Case Rm << 1with negligible induction effect - Frozen flux approximation, Case Rm >> 1.

**Dynamics of Rotating Fluids and Rotating Magnetoconvection (RMC):** Significant effects of Coriolis force in astro-physical bodies and in the Earth's outer core - Boundary layers effects- Geostrophic and quasigeostrophic approximation - Basic equations for the RMC and nondimensional numbers; Magnetostrophic and quasigeostrophic approximation.

**Linear and Nonlinear Models of the RMC -** Geometry simplifications: the RMC in planar layer, The Cartesian box, Busse cylindrical annulus; Various complexities, e.g. Anisotropic diffusive coefficients. Weakly nonlinear analysis in various approximations - The Nusselt number computation.

**Waves in Rotating MHD Systems:** Dynamics of various waves **-** Dispersion equations of inertial, Alfvén, Lehnert (MC), MAC waves (their mostly asymptotic analysis) - Rossby waves modified by magnetic fields and/or by buoyancy.

**Numerical modelling in RMC:** Introduction to Numerical Methods and Approaches (NMA)**-** NMA due to the (complex) spherical shell geometry **-** NMA due to more complex basic fields and quantities.

**Dynamo Theory and Numerical simulation:** Kinematic dynamos, toroidal and poloidal fields - Mean field dynamo theory, alpha and omega effects - Convection driven dynamos - Numerical methods, Pseudo-spectral methods **-** Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) approaches - Planetary dynamos scaling laws- Internal structure and magnetic fields of cosmic objects (planets, stars, galaxies) - the Geodynamo; planetary, Solar, stellar and galactic dynamos - Conclusion on Natural Dynamos.

Learning Resources:

Text Books:

1. Introduction to Modeling Convection in Planets and Stars: Magnetic Field, Density Stratification, Rotation, **Gary A. Glatzmaier**, Princeton University Press, 2013.
2. Encyclopedia of Geomagnetism and Paleomagnetism, **Editors: David Gubbins, Emilio Herrero-Bervera,** Springer, 2007.

Reference Books:

1. The Magnetic Universe: Geophysical and Astrophysical Dynamo Theory, **Günther Rüdiger, Rainer Hollerbach,** Wilely, 2006.

| Course Code: MA5155 | Sobolev Spaces | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4101

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Identify the weak solutions for differential equations |
| **CO2** | Understand basic properties of Sobolev spaces |
| **CO3** | Derive general Sobolev inequalities |
| **CO4** | Prove interior and global approximation theorems |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | | | |
| **CO2** | 2 | 1 | 1 | | | 1 |
| **CO3** | 3 | 2 | 1 | | | |
| **CO4** | 2 | 1 | 2 | | | 1 |

Syllabus:

**Sobolev spaces:** Weak derivatives, Definition of Sobolev spaces, Elementary properties of Sobolev spaces.

**Approximations:** Interior approximation by smooth functions, Approximation by smooth functions, Global approximation by smooth functions, Extension theorems, Trace theorems.

**Sobolev Inequalities:** Gagliardo- Nirenberg-Sobolev inequality, Morrey's inequality, General sobolev inequalities, Compactness, Poincare inequalities, Difference quotients, Differentiability a.e., Fourier transform methods.

**Other spaces of functions:** The space $H^{-1}$, Spaces involving time.

Learning Resources:

Text Books:

1. Partial Differential Equations, **Lawrence C. Evans**, American mathematical Society, 2000.
2. Topics in Functional Analysis and Applications**, S. Kesavan**, New Age International Publishers, 2015.

Reference Books:

1. Sobolev Spaces, **R. A. Adams** and **J. F. Fournier**, Academic Press, 2003.
2. Functional Analysis, Sobolev Spaces and Partial Differential Equations, **H. Brezis**, Springer, 2011.

| Course Code: MA5156 | Inventory, Queueing Theory and Non-Linear Programming | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA4155

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| CO1 | Determine the characteristics of a queuing model |
| CO2 | Determine the EOQ for a deterministic inventory model |
| CO3 | Determine the EOQ for a stochastic inventory model |
| CO4 | Determine the solution of a CNLPP |
| CO5 | Determine the solution of a QPP |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 2 | | | 1 |
| **CO2** | 3 | 1 | 2 | | | 1 |
| **CO3** | 2 | 1 | 2 | | | 1 |
| **CO4** | 3 | 2 | 2 | | | |
| **CO5** | 3 | 1 | 2 | | | |

Syllabus:

**Queuing theory:** Characteristics of queueing systems - The birth and death process - Steady state solutions - Single server model (finite and infinite capacities) - Single server model (with SIRO) - Models with state dependent arrival and service rates- Waiting time distributions.

**Inventory control:** Inventory control for single commodity - Deterministic inventory models (without and with shortages) - Probabilistic inventory (both discrete and continuous) control models.

**Nonlinear programming problem:** Constrained NLPP - Lagrange's multipliers method - Convex NLPP, Kuhn-Tucker conditions (including the proof) - Quadratic programming problem (Wolfe's method).

Learning Resources:

Text Books:

1. Operations Research: An Introduction, **H.A.Taha** , PHI, Delhi, 2014
2. Principles of Operations Research, **H.M.Wagner**, PHI, Delhi, 2010.

Reference Books:

1. Introduction to Optimization: Operations Research, **J.C.Pant,** Jain Brothers, Delhi, 2015.
2. Operations Research - Introduction to Management Science, **Kanti Swarup, P.K. Gupta, Man Mohan**, Sultan Chand and Sons, 2019.

| Course Code: MA5157 | Heat and Mass Transfer | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA5105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Understand the boundary layer concepts. |
| **CO2** | Compute temperature distribution in steady-state and unsteady-state heat conduction. |
| **CO3** | Interpret free and mixed convection heat and mass transfer |
| **CO4** | Analyse the heat and mass transfer past vertical and horizontal bodies |
| **CO5** | Apply the concepts of industrial problems. |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 2 |
| **CO2** | 3 | 2 | 3 | | | 1 |
| **CO3** | 3 | 2 | 3 | | | |
| **CO4** | 3 | 2 | 3 | | | 2 |
| **CO5** | 3 | 2 | 3 | 1 | 1 | 1 |

Syllabus:

**Laminar boundary layer flow:** Concept of boundary layer, Velocity and thermal boundary layer, Derivation of boundary layer equations for two-dimensional incompressible flow, Similarity solutions, Dimensional analysis, Wall heating conditions and uniform wall heat flux boundary layer over a flat plate (Blasius Equations).

**Heat transfer:** Free convection, Mixed convection, Free and mixed convection on a vertical flat plate with a constant wall temperature, Constant heat flow, Variable surface temperature, Variable heat flux on a surface, Free convection on a vertical surface in stratified media. Free and mixed convection on a vertical cylinder, Horizontal cylinder, Inclined cylinder and cone.

**Mass transfer:** Properties of mixtures, Mass conversation, Mass diffusivities, and Boundary conditions, Laminar forced convection, Impermeable surface model, Other external forced convection configurations, Internal forced convection, Natural convection, Mass function and mass line, Effect of chemical reaction.

**Convection in porous media:** Mass conservation, Darcy flow model and the Forchheimer modification, First law of thermodynamics, Second law of thermodynamics, Forced and natural convection boundary layers, Enclosed porous media heated from the side, Penetrative convection, Enclosed porous media heated from below, Multiple flow scales distributed non-uniformly**.**

Learning Resources:

Text Books:

1. Boundary Layer Theory, **H. Schlichting and K. Gersten,** Springer, 2017, Ninth Edition.
2. Fluid Mechanics (An introduction to the theory of fluid flows), **F. Durst,** Springer, 2008.

First Edition.
3. Convection Heat Transfer, **A. Bejan,** Wiley-India, 2013, Fourth Edition.

Reference Books:

1. Convection in Porous Media, **D. A. Nield and A. Bejan,** Springer, 2013, Fourth Edition.

**M.Sc. (Applied Mathematics):: II Year II Semester**

| Course Code: MA5158 | Bio-Fluid Mechanics | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA5105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Estimate volumetric flow rate of blood in blood vessels |
| **CO2** | Analyse pressure in stenotic regions in blood vessels |
| **CO3** | Simplify governing equations for blood flow by taking small amplitude and long wave length |
| **CO4** | Analyse filtration process of the blood flow in Renal tubes |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 3 | | | 2 |
| **CO2** | 2 | 1 | 2 | | | 2 |
| **CO3** | 3 | 2 | 3 | | | 1 |
| **CO4** | 3 | 2 | 3 | | | 2 |

Syllabus:

**Fundamental concepts of Biomechanics**: Introduction

**Cardiovascular System**: Basic concepts about blood, Blood vessels, Governing equations, Models on blood flow, Flow in large blood vessels, Microcirculation, Pulsatile flow, Stenotic region flow.

**Peristalsis**: Basic concepts, Governing equations, Peristaltic transport under long wave length approximation, Peristaltic flow for small amplitudes and small Reynold's number.

**Flow in Renal Tubules**: Basic concepts, Governing equations, Ultra-filtration, Flow through proximal tubules, Flow through tubes with varying cross section.

Learning Resources:

Text Books:

1. Mathematical Models in Biology and Medicine, **J. N. Kapur**, Affiliated East West Press, 1992
2. Biodynamics: Circulation, **Y. C. Fung**, Springer-Verlag New York, 2010, Second Edition

Reference Books:

1. Mechanics of Circulation, **C. G. Caro, T. J. Pedley, R. C. Schroter, and W. A. Seed**, Oxford University Press, 2011

| Course Code: MA5159 | Electro-kinetic Transport Phenomena | Credits 3-0-0: 3 |
|---|---|---|

Prerequisite: MA5105

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Perceive the concepts of electrostatics and its applications |
| **CO2** | Explain the concepts of electric double layer, electric potential distribution and zeta potential |
| **CO3** | Develop the fundamental transport equations of electro-osmostic flow |
| **CO4** | Analyze the flow characteristics of electro-osmostic fluid flow in a microchannel |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | | | | | |
| **CO2** | 1 | 2 | 2 | 1 | | |
| **CO3** | 2 | 3 | 3 | 2 | 1 | 1 |
| **CO4** | 3 | 3 | 3 | 2 | 1 | 3 |

Syllabus:

**Electro-statics:** Basic electro-statics in free space, Electro-static classification of materials, Basic electro-statics in dielectrics, Maxwell's equations of electro-magnetism.

**Applications of Electro-statics:** Two-dimensional dielectric slab in an external electric field, A dielectric sphere in an external electric field, A conducting sphere in an external electric field.

**Basics of Electric Double Layer:** Electric double layers at charged interfaces, Potential for planar electric double layer, Potential for curved electric double layer, Electro-static interaction between two planar surfaces, Electro-static potential energy, Electro-static interactions between curved geometries, Models of Surface potentials, Zeta potential.

**Fundamental Transport Equations:** Single-component system, Multicomponent systems, Hydrodynamics of colloidal systems.

**Electro-kinetic Phenomena:** Electro-osmosis, Streaming potential, Electro-phoresis, Sedimentation potential.

**Flow in Microchannels:** Electro-osmotic flow in a slit charged microchannel, Electric current in electro-osmotic flow in slit channels, Electro-viscous flow in slit microchannels, Electro-osmotic flow in a circular charged capillary, Transient electro-osmotic flow in cylindrical microchannels, AC electro-osmotic flows in a rectangular microchannel, High surface potential, Solute dispersion in microchannels.

## Learning Resources:

### Text Books:

1. Microflows and Nanoflows: Fundamental and Simulation, **G. Karniadakis, A. Beskok, and N. Aluru**, Springer Publication, 2008, First Edition.
2. Introduction to Microfluidics, **P. Tabeling**, Oxford University Press, 2010.

### Reference Books:

1. Fundamentals and Applications of Microfluidics, **Nam-Trung Nguyen, Steven T. Wereley, Seyed Ali Mousavi Shaegh**, Artech House Publishers, 2019, Third Edition.
2. Electrokinetics in Microfluidics, **Dongqing Li**, Academic Press, 2004, First Edition.

| Course Code: MA5160 | Variational Methods and Splines | Credits 3-0-0: 3 |
|---|---|---|

Pre-Requisites: MA5109

Course Outcomes:

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Formulate a variational form for a boundary value problem |
| **CO2** | Solve a boundary value problem using Cubic splines |
| **CO3** | Solve a boundary value problem using Quintic splines |
| **CO4** | Solve a boundary value problem by Orthogonal Collocation Method |

Course Articulation Matrix:

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 3 | | 2 | 2 |
| **CO2** | 2 | 1 | 3 | | 2 | 1 |
| **CO3** | 2 | 2 | 3 | | 2 | 1 |
| **CO4** | 2 | 2 | 3 | | 2 | 2 |

Syllabus:

**Variational Methods:** Introduction.

**Cubic Splines:** Cubic spline interpolation and use of cubic splines to solve boundary value problems. Derivation of cubic B-splines and its application to solve boundary value problems. Collocation and Galerkin methods with cubic B-splines to solve boundary value problems.

**Quintic Splines:** Quintic spline interpolation and use of quintic splines to solve boundary value problems. Derivation of quintic B-splines and its application to solve boundary value problems. Collocation and Galerkin methods with quintic B-splines to solve boundary value problems.

**Orthogonal Collocation Method:** Orthogonal collocation method to solve boundary value problems.

Learning Resources:

Text Books:

1. Splines and Variational Methods, **P. M. Prenter**, John Wiley & Sons, 2009
2. A practical Guide to Splines, **Carl de Boor**, Springer-Verlag, 2001

Reference Books:

1. Handbook of splines, **Gheorghe Micula and Sanda Micula**, Springer Verlag, 1999.
2. The Theory of Splines and Their Applications, **J. Harold Ahlberg, Edwin Norman Nilson, Joseph Leonard Walsh**, Elsevier, 2016.