## Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad
### Department of Mathematics and Statistics

## Revised Syllabus of M.Sc. (Mathematics)

**Semester I**

| S. No. | Course code | Course Name | Credits |
|---|---|---|---|
| 1. | MAS - 706 | Complex Analysis | 4(3-1-0) |
| 2. | MAS – 707 | Topology | 4(3-1-0) |
| 3. | MAS – 708 | Algebra | 4(3-1-0) |
| 4. | MAS – 709 | Measure and Integration | 4(3-1-0) |
| 5. | MAS – 710 | Mechanics | 4(3-1-0) |
| | | Total Credits | 20 |

**Semester II**

| S. No. | Course code | Course Name | Credits |
|---|---|---|---|
| 1. | MAS - 756 | Discrete Mathematics | 4(3-1-0) |
| 2. | MAS – 757 | Mathematical Methods | 4(3-1-0) |
| 3. | MAS – 758 | Functional Analysis | 4(3-1-0) |
| 4. | MAS – 759 | Differential Geometry | 4(3-1-0) |
| 5. | MAS – 760 | Group Theory | 4(3-1-0) |
| | | Total Credits | 20 |

**Semester III**

| S. No. | Course code | Course Name | Credits |
|---|---|---|---|
| 1. | MAS - 806 | Operations Research | 4(3-1-0) |
| 2. | MAS – 807 | Numerical Analysis | 4(3-1-0) |
| 3. | MAS – 808 | Galois Theory | 4(3-1-0) |
| 4. | MAS – 809 | Number Theory | 4(3-1-0) |
| 5. | MAS – 810 | Fluid Dynamics | 4(3-1-0) |
| | | Total Credits | 20 |

**Semester IV**

| S. No. | Course code | Course Name | Credits |
|---|---|---|---|
| 1. | MAS - 856 | Differential Equations | 4(3-1-0) |
| 2. | MAS – 899 | Dissertation | 30 |

**Total credits: 94 (Course work - 64 + Research work – 30)**

## Syllabus for M.Sc. (Mathematics)

Basic Features:

Full time M.Sc. in Mathematics will be of four semesters. From I Semester to III Semester, each semester will have 5 Courses of 4 Credits each and in IV semester there is one course with 4 credits and a dissertation of 30 credits.
4 Credit = 3(Theory )+ 1 (Tutorial) classes per week.

## Semester I

### MAS 706. Complex Analysis

Recall of algebra and geometry of **C**, Stereographic correspondence, complex differentiable functions, analytic functions, Cauchy- Riemann equations, necessary and sufficient conditions for analyticity, chain rule, power series and its radius of convergence, analytic function represented by power series, complex exponential, trigonometric and hyperbolic functions, a branch of logarithmic and its analyticity, branches of $z^b$ (b belongs to **C**) conjugate functions, construction of analytic functions(elementary method).

Complex line integral over a piecewise smooth paths and its elementary properties, length of a curve, necessary and sufficient condition for independent of the line integral, Cauchy's theorem for disc, Cauchy-Goursat theorem (statement only), winding number, higher derivatives, Cauchy's integral formula for derivatives.

Morera's theorem, Cauchy's estimate, Liouville's theorem, zeros of an analytic function, Fundamental theorem of algebra, Cauchy's theorem in homotopy form(statement only) Cauchy's theorem for simply connected domains, Weierstrass theorem for a uniform convergent sequence of analytic functions, Taylor series, isolated singularities(removable singularities, poles and isolated essential singularities), Laurent series expansion theorem, singularity at infinity, Casorati-Weierstrass theorem.

Open mapping theorem (statement only), Maximum modulus theorem, Residue and singularity, residue at infinity, Cauchy theorem for residue, meromorphic function, argument principle, Rouche's theorem and its application.
Evaluation of Contour integrals of the type

$$\int_0^{2\pi} f(\cos\theta, \sin\theta), \int_0^{\infty} f(x)dx, \int_{-\infty}^{\infty} f(x)dx,$$

$$\int_0^{\infty} f(x)\cos mx, \int_0^{\infty} f(x)\sin mx$$

Schwarz lemma, Moebius transformations ,fixed points of a Moebious transformation, cross ratio and its invariance under Moebius transformation , Moebius transformation as mappings, determination of all Moebius transformations which map (i) **R** onto **R** (ii)Im (z)>0 onto $\{z \in C : |z| < \delta\}$ and (iii) $\{z \in C : |z| < \delta\}$ onto $\{z \in C : |z| < r\}$ .

**References:**


1. L. V. Ahlfors, Complex Analysis, McGraw Hill International Ed.
2. J. B. Conway, Functions of Complex variable, Narosa publication, 1973.
3. S. Ponnusamy, Foundation of Complex analysis, Narosa publication, 1995.
4. A.R. Sastri, An introduction to Complex analysis, Macmillan Publication.

**MAS 707. Topology**

Definition and examples of topological spaces (including metric spaces), Open and closed sets, Subspaces and relative topology, Closure and interior, Accumulation points and derived sets, Dense sets, Neighbourhoods, Boundary, Bases and sub-bases. Alternative methods of defining a topology in terms of the Kuratowski closure operator and neighbourhood systems. Continuous functions and homeomorphism, Quotient topology, First and second countability and separability, Lindelöf spaces.

The separation axioms $T_0$, $T_1$, $T_2$, $T_3$, $T_{3½}$, and $T_4$; their characterizations and basic properties, Urysohn's lemma, Tietze's extension theorem.

Compactness. Basic properties of compactness, Compactness and the finite intersection property, Local compactness, One-point compactification,

Connected spaces and their basic properties, Connectedness of the real line, Components, Locally connected spaces

(Tychonoff) Product topology in terms of the standard sub-base and its characterizations, Product topology and separation axioms, connectedness, countability properties and compactness (incl. the Tychonoff's theorem)

***References:***

1. J. L. Kelley, *General Topology*, Van Nostrand, 1995.
2. K. D. Joshi, *Introduction to General Topology*, Wiley Eastern, 1983.
3. James R. Munkres, *Topology,* 2nd Edition, Pearson International, 2000.
4. J. Dugundji, *Topology*, Prentice-Hall of India, 1966.
5. George F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.
6. S. Willard, *General Topology,* Addison-Wesley, 1970.

**MAS 708. Algebra**

A brief review of groups, their elementary properties and examples, subgroups, cyclic groups, homomorphism of groups and Lagrange's theorem; permutation groups, permutations as products of cycles, even and odd permutations, normal subgroups, quotient groups; isomorphism theorems, correspondence theorem.

Normal and subnormal series, composition series, Jordan-Holder theorem, solvable groups.

Group action; Cayley's theorem, group of symmetries, dihedral groups and their elementary properties; orbit decomposition; counting formula; class equation, consequences for p-groups; Sylow's theorems (proofs using group actions). Applications of Sylow's theorems, conjugacy classes in $S_n$ and $A_n$, simplicity of $A_n$. Direct product; structure theorem for finite abelian groups; invariants of a finite abelian group (Statements only)

Basic properties and examples of ring, domain, division ring and field; direct products of rings; characteristic of a domain; field of fractions of an integral domain; ring homomorphisms (always unitary); ideals; factor rings; prime and maximal ideals, principal ideal domain; Euclidean domain; unique factorization domain.

A brief review of polynomial rings over a field; reducible and irreducible polynomials, Gauss' theorem for reducibility of *f*(x) Ͼ **Z**[x]; Eisenstein's criterion for irreducibility of *f*(x) Ͼ**Z**[x] over **Q**, roots of polynomials; finite fields of orders 4, 8, 9 and 27 using irreducible polynomials over $\mathbf{Z}_2$ and $\mathbf{Z}_3$ .

**References:**

1. N. Jacobson, Basic Algebra I, 3rd edition, Hindustan Publishing corporation, New Delhi, 2002.
2. I. N. Herstein, Topics in Algebra, 4th edition, Wiley Eastern Limited, New Delhi, 2003.
3. J. B. Fraleigh, A First Course in Abstract Algebra, Narosa Publishing House, New Delhi, 2002.
4. Lal, Ramji, Algebra Volume 1. & 2, Shail Publication, 2002.
5. M. Artin, Algebra, Prentice Hall of India, 1994.
6. P.B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra, Cambridge University Press, 2000.

**MAS 709. Measure and Integration**

Review of Riemann Integral, Its drawbacks and Lebesgue's recipe to extend it. Extension of length function, Semi-algebra and algebra of sets, Lebesgue outer measure, Measurable sets, Measure space, Complete measure space.

The Lebesgue measure on **R**, Properties of Lebesgue measure, Uniqueness of Lebesgue Measure, Construction of non-measurable subsets of **R**

Lebesgue Integration: The integration of non-negative functions, Measurable functions, Fatou's Lemma, Integrable functions and their properties, Lebesgue's dominated convergence theorem.

Absolutely continuous function, Lebesgue-Young theorem (without proof), Fundamental theorem of Integral calculus and its applications. Product of two measure spaces, Fubini's theorem. $L_p$-spaces, Holder's inequality, Minkowski's inequality, Completion of $L_p$-spaces.

**References:**


1. Inder K. Rana, An introduction to Measure and Integration, Narosa, 1997.
2. G. de Barra, Measure Theory and Integration, John Wiley & Sons, 1981.
3. J.L. Kelly, T. P. Srinivasan, Measure and Integration, Springer, 1988.


**MAS 710. Mechanics**

Moment of Inertia, Motion of system of particles, D'Alembert's Principle and motion about a fixed axis, Lagrangian Dynamics, Generalized coordinates, Velocities and Momenta, Holonomic and non-holonomic systems, Lagrange's equations ,Theory of small Oscillations of conservative holonomic dynamical system, Lagrange's equations for non-holonomic system with moving constraints, First Integrals of motion,

Motion of a Rigid Body, Eulerian angles.Hamilton's equations of motion, Variational Principle and Principle of Least Action, Infinitesimal Contact transformations, and Generators, Poisson's Brackets, Hamilton Jacobi equation.

**References:**


1. H. Goldstein, Classical Mechanics, Narosa Publishing House, 1980.
2. F. Charlton, Text book of Dynamics, 2nd edition, CBS Publishers, 1985.
3. R.G. Takwale& P.S. Puranik, Introduction to Classical Mechanics, Tata McGraw Hill Publishing Co., New Delhi.

## Semester II

### MAS 756. Discrete Mathematics

Mathematical Logic and Relations**:** Statements, Logical connectives, Truth tables, Equivalence, Inference and deduction, Predicates, Quantifiers. Relations and their compositions, Equivalence relations, Closures of relations, Transitive closure and the Warshall's algorithm, Partial ordering relation, Hasse diagram, Recursive functions.

Semigroups & Monoids: Semigroups, Monoids, Subsemigroups/monoids, Congruence and quotient semigroups/monoids, Homomorphism, isomorphism and the basic isomorphism theorem.

Boolean Algebra: Boolean algebra and their various identities, Homomorphisms and isomorphisms, Atoms and the Stone's theorem (finite case), Boolean functions, their simplification and their applications to combinational circuits.

Combinatorics & Recurrence Relations: Permutation, Combination, Principle of inclusion and exclusion, Recurrence relations, Generating functions

Graph Theory: Basic concepts of graphs, directed graphs and trees, Adjacency and incidence matrices, Spanning tree, Kruskal's and Prim's algorithms, Shortest Path, Dijkstra's algorithm, Planar Graphs, Graph Coloring, Eulerian and Hamiltonian graphs.

**References:**


1. J.P. Trembley and R.P. Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw Hill.
2. L. L. Dornhoff and E. F. Hohn, Applied Modern Algebra, McMillan Publishing Co., 1978.
3. N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall of India, 1980.
4. I. Rosen, Discrete Mathematics, Tata McGraw Hill.
5. B. Kolman, R. Busby, S.C. Ross, Discrete Mathematical Structures, Prentice Hall of India, 2008


### MAS 757. Mathematical Methods

Classification of second order P.D.E.'s, Reduction to canonical forms, Linear equations with constant coefficients, Separation of variables, Laplace, Diffusion and wave equation in various coordinate systems (particularly in Cartesian, cylindrical and spherical coordinate systems), Boundary value problems on transverse vibrations of strings and heat diffusion in rods.

Fourier Analysis: Periodic functions, trigonometric series, Fourier series, Euler formulas, Functions having arbitrary periods, Even and odd functions, Half range expansions, Approximation by Trigonometric Polynomials, Fourier Integral, Fourier Transform (including cosine and sine transforms) & Laplace transformations

Series solutions, Bessel's functions, Legendre functions and Hypergeometric series

**Reference:**


1. I.N. Sneddon, Elements of Partial Differential Equations, McGraw Hill Publications.
2. T. Amaranath, Partial Differential Equations, Narosa Publication
3. E. Kreyszig, Advanced Engineering Mathematics, Wiley Eastern Ltd.


### MAS 758. Functional Analysis

Normed linear spaces, Quotient norm, Banach spaces and examples, $l^p$ spaces as Banach spaces, Bounded linear transformations on normed linear spaces, B($X,Y$) as a normed linear spaces, Open mapping and closed graph theorems, Uniform boundedness principle, Hahn-Banach theorem and its applications, Dual space, Separability, Reflexivity, Weak and weak* convergence of operators, Compact operators and their basic properties.

Inner product spaces, Hilbert spaces, Orthogonal sets, Bessel's inequality, Complete orthonormal sets and Parseval's identity, Structure of Hilbert spaces, Projection theorem, Riesz representation theorem, Riesz-

Fischer theorem, Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert spaces. Self-adjoint operators, Positive, projection, normal and unitary operators and their basic properties.

**References:**


1. G. Bachman and L. Narici, Functional Analysis, Academic Press, 1966.
2. J. B. Conway, A First Course in Functional Analysis, Springer, 2000.
3. C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice-Hall of India, 1987
4. B. V. Limaye, Functional Analysis, New Age International, 1996.
5. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.


**MAS 759. Differential Geometry**

Graph and level sets, vector fields, the tangent space, surfaces, orientation, the Gauss map, geodesics, parallel transport, the Weingarten map, curvature of plane curves, arc length and line integrals, curvature of surfaces, parametrized surfaces, surface area and volume, surfaces with boundary, the Gauss-Bonnet Theorem.

Riemannian Geometry of surfaces, Parallel translation and connections, structural equations and curvature, interpretation of curvature, Geodesic coordinate systems, isometries and spaces of constant curvature.

**References:**


1. W. Kuhnel, Differential Geometry-curves-surfaces-Manifolds, AMS 2006
2. Mishchenko and A. Formentko, A course of Differential Geometry and Topology, Mir Publishers Moscow, 1988.
3. Pressley, Elementary Differential Geometry, SUMS, Springer, 2004.
4. I.A. Thorpe, Elementary Topics in Differential Geometry. Springer, 2004


**MAS 760. Group Theory**

**(Prerequisites:** Linear Algebra and Algebra )

Solvable groups, Nilpotent groups, p-groups.

Free groups, Generators and relations, The Todd Coxeter Algorithm, Semidirect product, Free product of Groups, Generalized Free products.

Structure of groups of order pq where p and q are primes, Classification of groups up to order 16, Dedekind groups and their classification, Extra-special p-groups. Finite cyclic groups and their automorphism groups.

Basic structure of General Linear group, Special Linear Group and Projective Special Linear group, Bruhat Decomposition in General Linear group.

**References:**


1. Michael Artin, Algebra, Prentice- Hall of India, 1991.
2. J.J. Rotman, Theory of Groups: An Introduction, Allyn and Bacon, 1973.
3. D.J.S. Robinson, A course in theory of groups, Springer, 1996.
4. J.L. Alperin, R.B. Bell, Groups and Representations, Springer, 1995.
5. Lal, Ramji, Algebra Volume 1. & 2, Shail Publication, 2002

## Semester III

### MAS 806. Operations Research
**(Prerequisite:** Linear Algebra)

Linear Programming: Convex sets, hyperplanes and half spaces, vertices of a convex set, polyhedron and polytopes, separating and supporting hyperplanes, basic definitions and theorems for a general linear programming problems using convex sets theory, A simple LPP model and its graphical solution, standard form of a general LPP, basic feasible solutions, Simplex method and algorithm, M-Technique, Two-phase Technique, Duality.

Mathematical formulation of transportation and assignment problems, balanced and unbalanced transportation problems, Initial basic feasible solutions of a T.P.using North-west corner rule, the Least Cost method and Vogel's approximation method (VAM), the optimum solution of a T.P. using u-v Method., Hungarian method for solving an assignment problem, Salesman routing problems. Problems of maximization.

Game Theory: Basic concepts, pure and mixed strategies, Two Person Zero sum matrix game, saddle point and maximin minimax principle, reduction of size of pay off matrix by dominance rules, mixed strategies for games without saddle point, 2 x 2 games, 2 x n & n x 2 games, graphical method, subgames method, Matrix method for n x n games, ($n \geq 3$), solution of a game by linear programming method.

Sequencing problems with n jobs on 2 machines, Problems of n jobs on more than 2 machines, Johnson's method.

Dynamic Programming: Bellman Principle of optimality, dynamic programming algorithm, Solution of LPP by dynamic programming.

Non-Linear Programming: Kuhu-Tucker conditions, Quadratic programming and its solution by Wolfe's Method and Beale's Method.

Construction of network, time calculations in network by CPM and PERT, Critical activities and slack times. Elements of a queueing model, role of Exponential and
Poisson distributions., Kendall's Notation for representing Queueing Models, Single-Channel Queueing Theory, Single-channel Poisson Arrivals with Exponential Service Times, Infinite- Population (M/M/1) (FCFS/ $\infty$ ) and (M/M/1) (SIRO/ $\infty$ ).

**References:**


1. H.A.Taha, Operations Research An Introduction, $7^{th}$ edition, Pearson Education.
2. K. Murty, Linear and combinatorial programming , John Wiley, Newyork
3. S. S. Rao, Optimization Theory and Applications, Wiley Eastern Limited
4. Swapnil Srivastava, A Fundamental approach to Operations Research, Shail Publication, Alld.


### MAS 807. Numerical Analysis

General Theory of Approximations and Errors, Scientific notation for representing decimal numbers, Floating point arithmetic, Valid significant digits, Absolute and Relative errors and error bounds, Errors of sum, difference, product, quotient, power and root, General formula for Errors.

Solutions of arbitrary equations, Methods of Bisection, Fixed point iteration, Regula- falsi,and Newton-Raphson together with their convergence and error bounds.

Interpolation, Lagrangian and Divided difference interpolation formulas along with error estimates, Calculus of operators $\Delta,\delta,\mu,E,D$ etc. Gregory-Newton forward and backward interpolation formulas with error estimates, Central difference interpolation formulas of Gauss (forward and backward), Stirling, Bessel and Everett. Inverse interpolation, Spline interpolation, Numerical Differentiation.

Numerical Integration,Newton-Cotes Formulas,Trapezoidal, Simpson's 1/3 and 3/8- rules along with error estimates, Euler-Maclaurin formula. Numerical techniques for solution of Ordinary differential equations, Incremental methods, Euler's and Improved Euler's methods, Fourth order Runge-Kutta method along with error bounds, Predictor-Corrector methods of Adams-Bashforth-Moulton and Milne's types with error estimates.

Numerical Linear Algebra, Gaussian elimination and Gauss-Jordan methods for solving systems of linear equations, LU and Cholesky decomposition and solutions of linear systems and matrix inversion using these decompositions, Gauss-Jacobi and Gauss-Seidel Iterative methods and their convergence, Estimation of eigenvalues and eigenvectors, Gerschgorin's circles, Power method for the first and second dominant eigenvalues along with convergence criteria.

**References:**


1. D. Prasad, Introduction to Numerical Analysis. Narosa Publishing House.
2. S. S. Sastry, Introduction to Numerical Methods, Prentice Hall of India.
3. K.Sankar Rao, Numerical Methods for Scientists and Engineers, Prentice Hall of India.
4. S.D.Conte and C.de Boor, Elementary Numerical Analysis; an Algorithmic Approach. Tata McGraw-Hill.
5. F.B. Hildebrandt, Introduction to Numerical Analysis, Dover.
6. H.M. Antia, Numerical Methods for Scientists and Engineers, Hindustan Book Agency.


**MAS 808. Galois Theory**
**(Prerequisites:** Algebra)

Extension fields, finite extensions; algebraic and transcendental elements, adjunction of algebraic elements, Kronecker theorem, algebraic extensions, splitting fields– existence and uniqueness; extension of base field isomorphism to splitting fields.

Simple and multiple roots of polynomials, criterion for simple roots, separable and inseparable polynomials; perfect fields; separable and inseparable extensions, finite fields; prime fields and their relation to splitting fields; Frobenius endomorphisms; roots of unity and cyclotomic polynomials.

Algebraically closed fields and algebraic closures, primitive element theorem; normal extensions; automorphism groups and fixed fields; Galois pairing; determination of Galois groups, Fundamental theorem of Galois theory, abelian and cyclic extensions.

Sovability by radicals; solvability of algebraic equations; symmetric functions; ruler and compass constructions, Fundamental theorem of algebra.

**References:**


1. N. Jacobson , Basic Algebra I, 3rd edition, Hindustan Publishing corporation, New Delhi, 2002.
2. I. N. Herstein, Topics in Algebra, 4th edition, Wiley Eastern Limited, New Delhi, 2003.
3. J. B. Fraleigh, A First Course in Abstract Algebra, 4th edition , Narosa Publishing House, New Delhi, 2002.
4. D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
5. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra, 3rd edition, Cambridge University Press, 2000.


**MAS 809. Number Theory**

Divisibility in integers, Division Algorithm in integers, Well ordering property in the set of positive integers, Greatest common divisor and least common multiple and algorithms to find them. Primes, Fundamental Theorem of Arithmetic, Euclid's theorem, Fermat and Mersenne primes, Infinitude of primes of certain types. Congruences, Euler's phi function, Euler-Fermat theorem, Fermat's little theorem, Wilson's theorem.

Linear congruence equations, Chinese Remainder theorem, Multiplicativity and expression for $\varphi(n)$, Congruence equations of higher degree, Prime power congruences, Power residues.

Quadratic Residues, Legendre symbols, Gauss' lemma, Quadratic Reciprocity Law and applications, Jacobi symbol, Tests of primality, Factors of Mersenne numbers.

Multiplicative functions, Functions $\tau$, $\sigma$, and $\mu$ and their multiplicativity, Moebius inversion formula and its converse, Group structure under convolution product and relations between various standard functions, Diophantine equations: $ax + by = c$, $x^2 + y^2 = z^2$, $x^4 + y^4 = z^2$, Sums of squares, Waring's problem, Binary quadratic forms over integers. Farey sequences, Rational approximations, Hurwitz'Theorem.

Simple continued fractions, Infinite continued fractions and irrational numbers, Periodicity, Pell's equation. Distribution of primes, Function $\pi(x)$, Tschebyschef 's theorem, Bertrand's postulate. Partition function, Ferrer's Graph, Formal power series, Euler's identity, Euler's formula for $\varphi(n)$, Jacobi's formula.

**References:**


1. Niven and T. Zuckermann, An Introduction to the Theory of Numbers, Wiley Eastern.
2. G.H. Hardy and E.M. Wright, Theory of Numbers, Oxford University Press & E.L.B.S.
3. D.E. Burton, Elementary Number Theory, Tata McGraw-Hill.
4. S.G. Telang, M. Nadkarni & J.Dani, Number Theory, Tata McGraw-Hill.


**MAS 810. Fluid Dynamics**

Kinematics, Equation of continuity: Eulerian and Lagrangian equations, Equations of Motions: Euler, Bernoulli, Lamb, Lagrange equations and Helmholtz equation of motion, Kinematics of vorticity and circulation.

Motion in two dimensions :Stream function, Irrotational motion, Velocity and Complex potentials, Cauchy-Riemann's equations, Sources and Sinks, Doublets; Image system of a simple source and a doublet with respect to a plane and a circle, Milne-Thomson Circle Theorem, Blasius Theorem. Motion of circular cylinders and sphere, Vortex motion,

Kinematics of Deformation: Newton's Law of viscosity, Newtonian and non Newtonian fluids, Theory of stress and Rate of strain , Body and Surface forces.

Navier-Stokes equations and energy equations, Laminar flow of viscous incompressible fluid, Similarity of flows: Reynolds and other numbers.

Boundary layer concept, 2-dimensional boundary layer equations, separation phenomena; boundary layer on a semi-infinite plane, Blasius solution; boundary layer thickness, Karman's Integral method

Elementary concept on conformal Representation.

**References:**


1. F. Charlton, Text book of Fluid Dynamics, CBS Publishers.
2. W.H. Besant and A.S. Ramsey, A Treatise on Hydrodynamics, CBS Publishers..
3. Z.U.A. Warsi, Fluid Dynamics, CRC Press, 1999

## Semester IV

### MAS 856. Differential Equations

Ordinary Differential Equations in more than two variables: Surface and curves in three Dimensions, Simultaneous Differential Equations of the First order and the first degree in three variables, methods of solution of $dx/P = dy/Q = dz/R$, Orthogonal Trajectories of a system of curves on a surface, Pfaffian Differential forms and equations, solution of Pfaffian differential equation in three variables, Caratheodory's theorem, application to Thermodynamics.

Partial Differential Equations of the Second Order: The origin of Second order equatios, second order equation in Physics, Higher order equation in Physics, characteristic curves of second order equations, characteristics of equations in three variables, the solution of linear hyperbolic equations, the method of integral transform, nonlinear equation of the second order.

Laplace's Equation: The Occurence of Laplace equation in Physics, families of Equipotential Surfaces, Boundary vale problem, separation of variables, problems with axial symmetry, Kelvin's Inversion Theorem, The theory of Green function for Laplace equation, The two dimensional Laplace equation, relation of the Logarithmic Potential to the theory of functions, Green's function for the two dimensional equation.

The wave Equation: The occurrence of wave equation in Physics, Elementary solutions of the one dimensional wave equation, The Riemann- Volterra solution of the one dimensional wave equation, three dimensional problems, general solutions of the wave equation, Green's function for the wave equation, the nonhomogeneous wave equation, Riesz's Integrals, The propagation of sound waves of finite amplitude.

**References:**

1. Ian Sneddon, Elements of Partial Differential Equations, McGraw- Hill Int. Book Comp.

### MAS 899. Dissertation