M.Sc. Syllabus of Mathematics
For
Diamond Harbour Women's University.

Total Marks 1000.
4 semesters, 5 units in each semester, each unit of 50 marks.

1st Semester : Unit 1. Real Analysis
Unit 2. Complex Analysis
Unit 3. Abstract Algebra
Unit 4. Linear Algebra
Unit 5. Classical Mechanics.

2nd Semester : Unit 6. Topology
Unit 7. Functional Analysis
Unit 8. Ordinary Differential Equations
Unit 9. Partial Differential Equations & Calculus of Variations
Unit 10. Integral Equations & Integral Transforms

3rd Semester : Unit 11. Numerical Analysis and Laboratory
Unit 12. Discrete Mathematical Structure
Unit 13. Continuum Mechanics
Unit 14. Differential Geometry
Unit 15. Optional.

4th Semester : Unit 16 to Unit 19 Optional
Unit 20. Project & Viva

Optional Units:

Advanced Complex Analysis 1, Advanced Complex Analysis 2, Advanced Topology, Algebraic Topology, Differential Topology, Field theory, Semigroup theory, Advanced Topology, Algebraic Topology, Differential Topology, Advanced Functional Analysis, Operator theory 1, Operator theory 2, Operations Research, Soft Computing, Design and Analysis of Algorithms, Theory of Computation, Electro Magnetic theory and Special Theory of Relativity, Computational Fluid Dynamics 1, Computational Fluid Dynamics 2, Dynamical Oceanography, Dynamical Meteorology, Solid Mechanics, Fluid Dynamics 1, Fluid Dynamics 2, Boundary layer theory and Viscous Flow, Quantum Mechanics 1, Quantum Mechanics 2, Bio Mathematics 1, Bio Mathematics 2,

For each unit of theoretical classes, 3 classes of one hour each per week and total 45 hours for a semester and for numerical practical 2 classes of one hour each and total of 30 hours for a semester would be needed.

Unit 1 : Real Analysis

Fourier Series and Fourier Transformation .

Bounded Variation .

Functions of Bounded Variation and their properties, Differentiation of a function of bounded variation, Absolutely Continuous Function, Representation of an absolutely continuous function by an integral.

The Theory of Measure .

Semiring and ring of sets, σ-ring and σ-algebra, Ring and σ-ring generated by a class of sets, Monotone class of sets, Monotone class generated by a ring, Borel Sets. Measures on semirings and their properties, Outer Measure and Measurable Sets, Caratheodory Extension : Outer measure
generated by a measure, Lebesgue measure on R^n, Measure space, Finite and σ-finite measure spaces. Measurable Functions, Sequence of measurable functions, Egorov's Theorem, Convergence in Measure.

The Lebesgue Integral .

Simple and Step Functions, Lebesgue integral of step functions, Upper Functions, Lebesgue integral of upper functions, Lebesgue Integrable functions, Fatou's Lemma, Dominated Convergence Theorem, Monotone Convergence Theorem, Riemann integral as a Lebesgue integral, Lebesgue-Vitali Theorem, Application of the Lebesgue Integral.

References :

1. Aliprantis, C.D., Burkinshaw, O., *Principles of Real Analysis*, 3rd Edition, Harcourt Asia Pte Ltd., 1998.

2. Royden, H.L., *Real Analysis*, 3rd Edition, Macmillan, New York & London, 1988.

3. Halmos, P.R., *Measure Theory*, Van Nostrand, New York, 1950.

4. Rudin, W., *Real and Complex Analysis*, McGraw-Hill Book Co., 1966.

5. Kolmogorov, A.N., Fomin, S.V., *Measures, Lebesgue Integrals, and Hilbert Space*, Academic Press, New York & London, 1961.

Note : This course is based on book (1), Chapters 3, 4.

Unit 2 : Complex Analysis

Complex Numbers :
Complex Plane, Lines and Half Planes in the complex plane, Extended plane and its Spherical Representation, Stereographic Projection.

Complex Differentiation :
Derivative of a complex function, Comparison between differentiability in the real and complex senses, Cauchy-Riemann Equations, Necessary and Sufficient Criterion for complex differentiability, Analytic functions, Entire functions, Harmonic functions and Harmonic conjugates.

Complex Functions and Conformality :
Polynomial functions, Rational functions, Power series, Exponential, Logarithmic, Trigonometric and Hyperbolic functions, Branch of a logarithm, Analytic functions as mappings, Conformal maps, Möbius Transformations.

Complex Integration :
The complex integral (over piecewise C^1 curves), Cauchy's Theorem and Integral Formula, Power series representation of analytic functions, Morera's Theorem, Goursat's Theorem, Liouville's Theorem, Fundamental Theorem of Algebra, Zeros of analytic functions, Identity Theorem, Weierstrass Convergence Theorem, Maximum Modulus Principle and its applications, Schwarz's Lemma, Index of a closed curve, Contour, Index of a contour, Simply connected domains, Cauchy's Theorem for simply connected domains.

Singularities :
Definitions and Classification of singularities of complex functions, Isolated singularities, Laurent series, Casorati-Weierstrass Theorem, Poles, Residues, Residue Theorem and its applications to contour integrals, Meromorphic functions, Argument Principle, Rouche's Theorem.

Analytic Continuation :
Schwarz Reflection Principle, Analytic Continuation along a path, Monodromy Theorem.

References :

1. Conway, J.B., *Functions of one complex variable*, Second Edition, Narosa Publishing House.

2. Sarason, D., *Complex Function Theory*, Hindustan Book Agency, Delhi, 1994.

3. Ahlfors, L.V., *Complex Analysis*, McGraw-Hill, 1979. Rudin, W., *Real and Complex Analysis*, McGraw-Hill Book Co., 1966.

4. Hille, E., *Analytic Function Theory* (2 vols.), Gonn & Co., 1959. Titchmarsh, E.C., *The Theory of Functions*, Oxford University Press, London.

5. Ponnusamy, S., *Foundations of Complex Analysis*, Narosa Publishing House, 1997.

Note : This course is based on the books (1) and (2), as described below:
Section (i) : Books (1) & (2), Chapter I. Section (ii) : Book (2), Chapter II.
Section (iii) : Book (1), Chapter III. Section (iv) : Book (2), Chapters VI, VII, IX.
Section (v) : Book (1), Chapter V & Book (2), Chapter VIII. Section (vi) : Book (1), Chapter IX.

Unit 3 : Abstract Algebra

Groups (20 Marks)
Homomorphism of groups, Normal Subgroups, Quotient Groups, Isomorphism Theorems, Cayley's Theorem, Generalized Cayley's Theorem, Automorphisms, Inner Automorphisms and Automorphism Groups, Cauchy's Theorem, Sylow Theorems and their applications.

Rings (20 Marks)
Ideals and Homomorphisms, Quotient Rings, Prime and Maximal Ideals, Quotient Field of an Integral Domain, Divisibility Theory : Euclidean Domain, Principal Ideal Domain, Unique Factorization Domain, Gauss' Theorem, Polynomial Rings, Irreducibility of Polynomials.

Number Theory (10 Marks) :
Algebraic approach to Fermat's Theorem, Euler's Theorem, Wilson's Theorem, Arithmetic Functions, Definitions and Examples, Perfect Numbers, Chinese Remainder Theorem, Primitive Roots.

References :

1. Artin, M., Algebra.
2. P. B. Bhattacharya, S.K.Jain & S.R.Nagpaul – Basic Abstract Algebra (Cambridge).
3. Dummit, D.S., Foote, R.M., Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.
4. Goldhaber, J.K., Ehrlich, G., Algebra, The Macmillan Company, Collier-Macmillan Limited, London.
5. Herstein, I.N., Topics in Abastract Algebra, Wiley Eastern Limited, Hungerford, T.W., Algebra, Springer.
6. Hungerford, T.W., Algebra, Springer.
7. Jacobson, N., Basic Algebra, I & II, Hindusthan Publishing Corporation, India.
8. Lang, S., Algebra.

9. Malik, D.S., Mordesen, J.M., Sen, M.K., Fundamentals of Abstract Algebra, The McGraw-Hill Companies, Inc.
10. Rotman, J.J., The Theory of Groups: An Introduction, Allyn and Bacon, Inc., Boston.
11. Sen, M.K., Ghosh, S. and Mukhopadhyay, P., Topics in Abstract Algebra, Universities Press, 2006.
12. Gareth A Jones and J. Mary Jones : Elementary Number Theory, Springer International Edition.
13. Neal Koblitz, A Course in Number Theory and Cryptography, Springer-Verlag, 2nd Edition.
14. D. M. Burton : Elementary Number Theory, Wim C. Brown Publishers Duireque, Lowa, 1989.

Unit 4 : Linear Algebra

Vector spaces of finite and infinite dimensions over a field, existence of basis, finite and infinite dimensional subspaces, sum and direct sum of subspaces, dimension, complementary subspace, quotient space, matrices and linear transformations, change of basis and similarity, algebra of linear transformations, rank-nullity theorem. Dual space, Adjoints of Linear Transformations, Dual Basis.

Eigen Values and Eigen Vectors, Characteristic and Minimal Polynomials, Cayley-Hamilton theorem.

Inner product space, Cauchy-Schwartz inequality, orthogonal vectors and orthogonal complements, orthonormal sets and orthonormal basis, Bessel's inequality, Gram-Schmidt orthogonalization method. Spectral Theorem.

Canonical forms : similarity of linear transformations, Diagonalization, invariant subspaces, reduction to triangular forms, Nilpotent transformations, Hermitian, Self-adjoint, unitary and orthogonal transformations, Jordan blocks and Jordan forms, Rational Canonical forms, The primary decomposition theorem, cyclic subspaces of annihilators, cyclic decomposition. Billinear and Quadratic forms.

References :

1. Artin, M., Algebra.
2. Friedberg, Insel and Spence, Linear Algebra.
3. Halmos, Finite Dimensional Vector Spaces.
4. Hoffman and Kunze, Linear Algebra, Prentice Hall.
5. Hungerford, T.W., Algebra, Springer.

6. Kumerason, S., Linear Algebra.
7. Lang, S., Linear Algebra.
8. Rao and Bhimsankaran, Linear Algebra.
9. Jin Ho Kwak and Sungpyo Hong, Linear Algebra, Birkhauser.

Unit 5: Classical Mechanics

Classical Mechanics

Laws of Motion: Moving axes. Particle Motion Relative to the Rotating Earth. Foucault's Pendulum. Coriolis Force. Virial Theorem. Two- and Three-Body Motions.

Generalised Co-ordinates. Unilateral and Bilateral Constraints. Principle of Virtual Work. D'Alembert's Principle. Holonomic and Nonholonomic Systems. Scleronomic and Rheonomic Systems. Lagrange's Equation of Motion. Applications. Energy Equation for Conservative Fields. Cyclic or Ignorable Co-ordinates. Routh's Equations. Dynamical Systems of Liouville's Type Hamilton's Equations of Motion. Calculus of Variations. Hamilton's Principle. Lagrange's Equations of Motion form Hamilton's Principle. Principle of Least Action. Constants of Motion. Noether's Theorem. Conservation Laws. Infinitesimal transformations.

Motion of a Rigid Body about a Fixed Point in it. Euler's Dynamical Equations. Eulerian angles. Gyroscope and nonholonomic Problems. Motion of a Symmetrical Spinning Top on a perfectly Rough Floor. Stability of Steady Precession.

(9)

Canonical Transformations. Generating Functions. Poisson's Bracket. Jacobi's Identity. Poisson's Theorem. Jacobi-Poisson Theorem.

Hamilton-Jacobi Equation. Jacobi's Theorem. Hamilton's Principle Function. Hamilton's Characteristic Function. Action-Angle Variables. Adiabatic Invariance.

Theory of Small Oscillations (Conservative System). Normal Co-ordinates. Oscillations under Constraints. Stationary Character of Normal Modes. Elements of Non-linear Oscillations.

Newtonian potential function. Formulation of potential and attraction for volume, surface and linear distributions of matter. Potential of a body at a distant point. Examples. Equipotential sufaces. Potential function at points in free space. Potential and attraction at a point within matter, existence, continuity and differentiability. Behaviour of the first partial derivatives and of logarithmic potential at large distances.

An introduction to Quantum Mechanics.

Books Recommended:

1. H.Goldstein, Classical Mechanics. Narosa Publishing House, New Delhi, (1980).
2. F.Gantmacher, Lectures in Analytical Mechanics, MIR Publishers, Moscow 1975)
3. J.L.Synge and B.A. Griffith, Principles of Mechanics, McGraw-Hill, N.Y. (1970)
4. N.C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw Hill Pub. Company Ltd., New Delhi (1998)
5. N.H. Louis and Janet D.Finch, Analytical Mechanics, C.U.P. (1998)
6. E.T. Whittaker, A Treatise of Analytical Dynamics of Particle and Rigid Bodies, C.U.P. (1977)
7. S.W. McCusky, An Introduction to Advanced Dynamics, Addison-Wesley Publ. Co. Inc. Massachusetts (1953)
8. A. S. Ramsey, Dynamics Part-II, C.U.P. (1972)
9. L. Elsgolts, Differential Equations and the Calculus of Variations, MIR Publishers Moscow (1973)
10. R.H. Dicke and J.P. Wittke, Introduction to Quantum Mechanics, Addison Wesley, (1960)
11. Rydnik, ABC of Quantum Mechanics, Peace Publisher, Moscow.
12. F.Chorlton, Textbook of Fluid Dynamics, CBS Publications, Delhi, 1985.
13. A.S. Ramsey - Newtonian Attractions. (Cambridge)
14. O.D. Kellog – Foundations of Potential Theory, Dover (1963).

Unit 6: Topology

Set Theory :
Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem, Cardinal Numbers and Cardinal Arithmetic, Continuum Hypothesis, Zorn's Lemma, Axiom of Choice, Well-Ordered Sets, Maximum Principle, Ordinal Numbers.

Topological Spaces and Continuous Functions :
Topological spaces, Basis and Subbasis for a topology, Order Topology, Product topology on X × Y, subspace Topology, Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set, Kuratowski closure operator and the generated topology, Continuous Functions, Open maps, Closed maps and Homeomorphisms, Product Topology, Quotient Topology, Metric Topology, Complete Metric Spaces, Baire Category Theorem.

Connectedness and Compactness :
Connected and Path Connected Spaces, Connected Sets in R, Components and Path Components, Local Connectedness. Compact Spaces, Compact Sets in R, Compactness in Metric Spaces, Totally Bounded Spaces, Ascoli-Arzelà Theorem, The Lebesgue Number Lemma, Local Compactness.

References :

1. Munkres, J.R., *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.

2. Dugundji, J., *Topology*, Allyn and Bacon, 1966.

3. Simmons, G.F., *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.

4. Kelley, J.L., *General Topology*, Van Nostrand Reinhold Co., New York, 1995.

5. Hocking, J., Young, G., *Topology*, Addison-Wesley Reading, 1961.

6. Steen, L., Seebach, J., *Counter Examples in Topology*, Holt, Reinhart and Winston, New York, 1970.

Note : This course is based on the book (1), Chapters 1 - 5. 0.5in

Unit 7: Functional Analysis

Banach Spaces :
Normed Linear Spaces, Banach Spaces, Equivalent Norms, Finite dimensional normed linear spaces and local compactness, Quotient Space of normed linear spaces and its completeness, Riesz Lemma, Fixed Point Theorems and its applications.
Bounded Linear Transformations, Normed linear spaces of bounded linear transformations, Uniform Boundedness Theorem, Principle of Condensation of Singularities, Open Mapping Theorem, Closed Graph Theorem, Linear Functionals, Hahn-Banach Theorem, Dual Space, Reflexivity of Banach Spaces.

Hilbert Spaces :
Real Inner Product Spaces and its Complexification, Cauchy-Schwarz Inequality, Parallelogram law, Pythagorean Theorem, Bessel's Inequality, Gram-Schmidt Orthogonalization Process, Hilbert Spaces, Orthonormal Sets, Complete Orthonormal Sets and Parseval's Identity, Structure of Hilbert Spaces, Orthogonal Complement and Projection Theorem. Riesz Representation Theorem, Adjoint of an Operator on a Hilbert Space, Reflexivity of Hilbert Spaces, Self-adjoint Operators, Positive Operators, Projection Operators, Normal Operators, Unitary Operators. Introduction to Spectral Properties of Bounded Linear Operators.

References :

1. Aliprantis, C.D., Burkinshaw, O., *Principles of Real Analysis*, 3rd Edition, Harcourt Asia Pte Ltd., 1998.

2. Goffman, C., Pedrick, G., *First Course in Functional Analysis*, Prentice Hall of India, New Delhi, 1987.

3. Bachman, G., Narici, L., *Functional Analysis*, Academic Press, 1966.

4. Taylor, A.E., *Introduction to Functional Analysis*, John Wiley and Sons, New York, 1958.

5. Simmons, G.F., *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.

6. Limaye, B.V., *Functional Analysis*, Wiley Eastern Ltd.

7. Conway, J.B., *A Course in Functional Analysis*, Springer Verlag, New York, 1990.

8. Kreyszig, E., *Introductory Functional Analysis and its Applications*, John Wiley and Sons, New York, 1978.

Unit 8: Ordinary Differential Equations

Ordinary Differential Equations
First order system of equations: Well-posed problems, existence and uniqueness of the solution, simple illustrations. Peano's and Picard's theorems (statements only),
Linear systems, non-linear autonomous system, phase plane analysis, critical points, stability, Linearization, Liapunov stability, undamped pendulum, Applications to biological system and ecological system.

Special Functions
Series Solution : Ordinary point and singularity of a second order linear differential equation in the complex plane; Fuch's theorem, solution about an ordinary point, solution of Hermite equation as an example; Regular singularity, Frobenius' method – solution about a regular singularity, solutions of hypergeometric, Legendre, Laguerre and Bessel's equation as examples
Legendre polynomial : its generating function; Rodrigue's formula, recurrence relations and differential equations satisfied by it; Its orthogonality, expansion of a function in a series of Legendre Polynomials
Adjoint equation of n-the order: Lagrange's identity, solution of equation from the solution of its adjoint equation, self-adjoint equation, Green's function

References :

1. Codington ,E.A and Levinson , N ., Theory of ordinary differential equation , Mcgraw Hill .
2. Estham , Ordinary differential equation .
3. Hartman , P , Ordinary differential equation , John wiley and sons
4. Reid , W.T . Ordinary differential equation , John wiley and sons .
5. Burkhill , J .C ., Theory of ordinary differential equation
6. Ince , E .L . Ordinary differential equation , Dover

Unit 9: Partial Differential Equations and Calculus of Variations

Theory of Partial Differential Equations (30 marks)
Introduction, Cauchy-kowalewski's theorem (statement only) classification of second order partial differential equations to Hyperbolic,. Elliptic and Parabolic types. Reduction of linear and quasilinear equations in two independent variables to their canonical forms, characteristic curves. Well-posed and ill-posed problems.

(i) Hyperbolic Equations:
The equation of vibration of s string. Formulation of mixed initial and boundary value problem. Existence, uniqueness and continuous dependence of the solution to the initial conditions. D'Alembert's formula for the vibration of an infinite string. The domain of dependence, the domain of influence use of the method of separation of variables for the solution of the problem of vibration of a string. Investigation of the conditions under which the infinite series solution convergence and represents the solution. Riemann method of solution, Problems, Transmere of vibration of membrances. Rectangular and circular membranes problems.

(ii) **Elliptic Equations :**

Occurrence of Laplace's equation. Fundamental solutions of laplace's equation in two and three independent variables. Laplace equation in polar, Spherical polar and in cylindrical polar coordinates, Minimum – Maximum theorem and its consequences. Boundary value problems, Dirichlets and Neumann's interior and exterior problems uniqueness and continuous dependence of the solution on the boundary conditions. Use of the separation of variables method for the solution of Laplace's equations in two and three dimensions interior and exterior Dirichlet's problem for a circle, and a semi circle, steady-state heat flow equation Problems, Higher dimensional problems, Dirichlet's problem for a cube, cylinder and sphere, Green's function for the Laplace equation, in two and three dimensions.

Calculus of variations. (20 marks)

Variational problems with fixed boundaries - Euler's equation for functionals containing first-order derivative and one independent variable. Extremals. Functionals dependent on higher order derivatives. Functionals dependent on more than one independent variable. Variational problems in parametric form. Invariance of Euler's equation under coordinate transformation.
Variational problems with moving boundaries. Functionals dependent on one and two functions. One sided variations.
Sufficient conditions for an extremum — Jacobi and Legendre conditions. Second variation. Variational principle of least action. Applications.

References:

1. Elements of Partial Differential Equations – Ian N. Sneddon (McGraw Hill).

2. An Elementary Course in Partial Differential Equations – T. Amarnath (Narosa).

3. Partial Differential Equations, Graduate Series in Mathematics, Vol.19 - L. C. Evans (1998, AMS)

4. Partial Differential Equations - Miller.

5. Partial Differential Equations – F. John

6. Phoolan Prasad, Renuka Ravindran: Partial Differential Equations.

7. John David Logan: Applied Partial Differential Equations.

8. Emmanuele Di Benedetto: Partial Differential Equations.

9. Andrei Dmitrievich Polianin, Vadim Fedorovich Zaitsev, Alan Moussiaux: Handbook of first Order Partial Differential Equations.

10. Tyn Myint U., Lokenath Debnath: Linear Partial Differential Equations for Scientists and Engineers.

11. M. Gelfand and S.V. Fomin - Calculus of Variations (Prentice Hall 1963)

12. A.S. Gupta - Calculus of Variations with Applications {Prentice Hall 1997)

Unit 10: Integral Equations & Integral Transforms

Integral Equations – 25 marks

1. Linear integral equations of 1st and 2nd kinds – Fredholm and Volterra types. Relation between integral equations and initial boundary value problems .

2. Existence and uniqueness of continuous solutions of Fredholm and Volterra's integral equations of second kind. Solution by the method of successive approximations. Iterated kernels.
3. Fredholm theory for the solution of fredholm's integral equation. Fredholm's determinant D(lamda). Fredholm's first minor D(x,y,lamda) Fredholm's first and second fundamental relations. Fredholm's p-th minor. Fredholm's first , second and third fundamental theorems. Fredholm's alternatives.

4. Hilbert-Schmidt theory of symmetric kernels. Properties of symmetric kernels. Existence of characteristic constants. Complete set of characteristic constants and complete orthonoralmised system of fundamental functions. Expansion of iterated kernel $k_c(x,t)$, in terms of fundamental functions. Schmidt's solution of Fredholm's integral equations.
5. Applications

Integral Transforms – 25 marks
1. Fourier Transforms: Fourier integral Theorem. Definition and properties.
Fourier transform of the derivative. Derivative of Fourier transform. Fourier transforms of some useful functions. Fourier cosine and sine transforms. Inverse of Fourier transforms. Convolution. Properties of convolution function. Convolution theorem. Applications.
2. Laplace transforms: Definition and properties. Sufficient conditions for the existence of Laplace Transform. Laplace Transform of some elementary functions. Laplace transform of the derivatives. Inverse of Laplace transform. Bromwich Integral Theorem. Initial and final value theorems. Convolution theorem. Applications.
Books:

1. S. G. Mikhlin – *Integral Equation* (Pergamon Press).

2. F. G. Tricomi – *Integral Equation* (Interscience Publishers) .

3. A.Chakrabarti,- Applied Integral Equation (Vijay Nicole Imprints Pvt Ltd).

4. I.N. Sneddon Use of Integral transform (McGraw -Hill).

5. I.N. Sneddon - Fourier Transforms (McGraw -Hill).

Unit 11: Numerical Analysis and Laboratory

Numerical Analysis (35 marks)

Numerical Methods : Algorithm and Numerical stability. Graffae's root squaring method and Bairstow's method for the determination of the roots of a real polynomial equation.

Polynomial Approximation : Polynomial interpolation; Errors and minimizing errors; Tchebyshev polynomials; Piece-wise polynomial approximation. Cubic splines; Best uniform approximations, simple examples.

Richardson extrapolation and Romberg's integration method; Gauss' theory of quadrature. Evaluation of singular integral.

Operators and their inter-relationships : Shift, Forward, Backward, Central differences; Averaging operators, Differential operators and differential coefficients

Initial Value Problems for First and Second order O.D.E. by

(i) 4th order R – K method

(ii) RKF_4- method

(iii) Predictor – Corrector method by Adam-Bashforth, Adam-Moulton and Milne's method.

Boundary value and Eigen-value problems for second order O.D.E. by finite difference method and shooting method.

Elliptic, parabolic and hyperbolic P.D.E. (for two independent variables) by finite difference method; Concept of error, convergence & numerical stability.

References :

1. F. B. Hildebrand – Introduction to Numerical Analysis
2. Demidovitch and Maron – Computational Mathematics
3. F. Scheid – Computers and Programming (Schaum's series)
4. G. D. Smith – Numerical Solution of Partial Differential Equations (Oxford)
5. Jain, Iyengar and Jain – Numerical Methods for Scientific and Engineering Computation
6. A. Gupta and S. C. Basu – Numerical Analysis
7. Scarborough – Numerical Analysis
8. Atkinson – Numerical Analysis
9. A. Ralston-A First Couse in Numerical Analysis, McGraw-Hill, N.Y.(1965)

Laboratory: (15 marks)

1. Inversion of a non-singular square matrix.
2. Solution of a system of linear equations by Gauss – Seidel method.
3. Integration by Romberg's method.
4. Initial Value problems for first and second order O.D.E. by
   (i) Milne's method (First order)
   (ii) 4th order Runge – Kutta method (Second order)
5. Dominant Eigen – pair of a real matrix by power method (largest and least).
6. B.V.P. for second order O.D.E. by finite difference method and Shooting method.
7. Parabolic equation (in two variables) by two layer explicit formula and Crank– Nickolson – implicit formula.
8. Solution of one dimensional wave equation by finite difference method.

References:

1. Xavier, C. – *C Language and Numerical Methods*, (New Age International (P) Ltd. Pub.)
2. *Gottfried, B. S. – Programming with C* (TMH).
3. Balaguruswamy, E. – *Programming in ANSI C* (TMH).

Unit 12: Discrete Mathematical Structure

Partial and linear orderings.Chains and antichains. Lattices. Distributive lattices. Complementation.Boolean algebras.Duality.Boolean functions.Normal forms.Karnaugh maps.Truth functional logic and prepositional connectives.Switching circuits.

Graphs, Vertex degrees, Walks, Paths, Trails, Cycles, Circuits, Subgraphs, Induced subgraph, Cliques, Components, Complete Graphs. Bipartite Graphs.Connected Graphs, Trees, Eulerian Graphs, Hamiltonian Graphs,Traveling Salesman Problem, Planar Graphs, Vertex coloring, Chromatic number.

Automata Theory: Alphabets and strings. Formal languages and grammars. Finite state machines.Nondeterministic finite automata.Regular languages.Context-free languages, Push-down automata. Regular expressions. Pumping lemma.

References

1. Introduction to Graph Theory, Douglas B. West, Prentice-Hall of India Pvt. Ltd., New Delhi 2003.
2. Graph Theory, F. Harary, Addison-Wesley, 1969.
3. Basic Graph Theory, K.R. Parthasarathi, Tata McGraw-Hill Publ. Co. Ltd., New Delhi, 1994.
4. Graph Theory Applications, L.R. Foulds, Narosa Publishing House, New Delhi,1993.
5. Graph Theory with Applications, J.A. Bondy and U.S.R. Murty, Elsevier science, 1976.
6. Graphs and Digraphs, G. Chartrand and L. Lesniak, Chapman & Hall, 1996.
7. Graph Theory with Applications to Engineering and Computer Science, NarsinghDeo, Prentice-Hall of India Pvt.Ltd., New Delhi, 1997.
8.Rayward-Smith, V. J., *A First Course in Formal Language Theory.*
9.Davis, M., and Weyuker, E. J., *Computability, Complexity, and Languages***.**
10. Hopcroft, and Ullman, *Introduction to Automata Theory, Languages, and Computation.*

Unit 13 : Mechanics of Continua

Principles of continuum mechanics, axioms. Forces in a continuum. The idea of internal stress. Stress tensor. Equations of equilibrium. Symmetry of stress tensor. Stress transformation laws. Principal stresses and principal axes of stresses. Stress invariants. Stress quadric of Cauchy. Shearing stresses. Mohr's stress circles.

Deformation. Strain tensor. Finite strain components in rectangular Cartesian coordinates. Infinitesimal strain components. Geometrical interpretation of infinitesimal strain components. Principal strain and principal axes of strain. Strain invariants. The compatiability conditions. Compatibility of strain components in three dimensions.

Constitutive equations. Inviscid fluid. Circulation. Kelvins energy theorem. Constitutive equation for elastic material and viscous fluid. Navier Stokes equations of motion.

Motion of deformable bodies. Lagrangian and Eulerian approaches to the study of motion of continua. Material derivative of a volume integral. Equation of continuity. Equations of motion. Equation of angular momentum. Equation of Energy. Strain energy density function.

References :

1. Y.C. Fung : A first course in continuum mechanics.
2. A.C. Eringen : Mechanics of continua.
3. L.I. Sedov : A course in continuum mechanics. Vol – I.
4. W. Prager : Mechanics of continuous media.

Unit 14: Differential Geometry

Tensors:
Tensor and their transformation laws, Tensor algebra, Contraction,
Quotient law, Reciprocal tensors, Kronecker delta, Symmetric and skew- symmetric tensors, Metric tensor, Riemannian space, Christoffel symbols and their transformation laws, Covariant differentiation of a tensor, Riemannian curvature tensor and its properties, Bianchi identities, Ricci-tensor, Scalar curvature, Einstein space.

Curves in Space:
Parametric representation of curves, Helix , Curvilinear coordinates in E_3. Tangent and first curvature vector, Frenet formulas for curves in space, Frenet formulas for curve in E_n. Intrinsic differentiation, Parallel vector fields,Geodesic.

Surfaces :
Parametric representation of a surface, Tangent and Normal vector field on a surface, The first and second fundamental tensor, Geodesic curvature of a surface curve, The third fundamental form, Gaussian curvature , Isometry of surfaces, Developable surfaces, Weingarten formula, Equation of Gauss and Codazzi , Principal curvature, Normal curvature, Meusnier's theorem.

References :

1. Tensor Calculas and Application to Geometry and Mechanics :

(chapter-II and III) – I.S.SOKOLNIKOFF.

2. An Introduction to Differential Geometry: (chapter – I,II,III,V and VI)

- T.T.WILMORE.

3. Differential Geometry:- BARY SPAIN.

Optional Units:

Advanced Complex Analysis I

The Functions *M(r), A(r)*, Hadamard Theorem on Growth of log *M(r)*, Schwarz Inequality, Borel-Caratheodory Inequality.
Entire Functions, Growth of an Entire Function, Order and Type and their Representations in terms of the Taylor Coefficients, Distribution of Zeros, Schottky's Theorem (no proof), Picard's Little Theorem, Weierstrass Factor Theorem, The Exponent of Convergence of Zeros, Hadamard Factorization Theorem, Canonical Product, Borel's First Theorem, Borel's Second Theorem (statement only).
Analytic Continuation, Natural Boundary, Analytic Element, Global Analytic Function, Concept of Analytic Manifolds, Multiple Valued Conditions, Branch Points and Branch Cut, Riemann Surfaces.

References :

1. Conway, J.B., *Functions of one complex variable*, Second Edition, Narosa Publishing House.

2. Ahlfors, L.V., *Complex Analysis*, McGraw-Hill, 1979.

3. Rudin, W., *Real and Complex Analysis*, McGraw-Hill Book Co., 1966.

4. Hille, E., *Analytic Function Theory* (2 vols.), Gonn & Co., 1959.

5. Titchmarsh, E.C., *The Theory of Functions*, Oxford University Press, London.
Markusevich, A.I., *Theory of Functions of a Complex Variable*, Vol. I, II, III.

6. Copson, E.T., *An Introduction to the Theory of Functions of a Complex Variable*.

7. Hayman, W.K., *Meromorphic Functions*. Kaplan, W., *An Introduction to Analytic Functions*.

Advanced Complex Analysis II

Harmonic Functions, Characterization of Harmonic Functions by Mean-Value Property, Poisson's Integral Formula, Dirichlet Problem for a Disc.
Doubly Periodic Functions, Weierstrass Elliptic Functions.
Meromorphic Functions, Expnasions, Definition of the functions $m(r,a)$, $N(r,a)$ and $T(r)$.
Nevanlinna's First Fundamental Theorem, Cartan's Identity and Convexity Theorems, Order of Growth, Order of a Meromorphic Function, Comparative Growth of log $M(r)$ and $T(r)$, Nevanlinna's Second Fundamental Theorem, Estimation of $S(r)$ (statement only), Nevanlinna's Theory of Deficient Values, Upper Bound of the Sum of Deficiencies.

References :

1. Conway, J.B., *Functions of one complex variable*, Second Edition, Narosa Publishing House.

2. Ahlfors, L.V., *Complex Analysis*, McGraw-Hill, 1979.

3. Rudin, W., *Real and Complex Analysis*, McGraw-Hill Book Co., 1966. Hille, E., *Analytic Function Theory* (2 vols.), Gonn & Co., 1959.

4. Titchmarsh, E.C., *The Theory of Functions*, Oxford University Press, London. Markusevich, A.I., *Theory of Functions of a Complex Variable*, Vol. I, II, III.

5. Copson, E.T., *An Introduction to the Theory of Functions of a Complex Variable*.

6. Hayman, W.K., *Meromorphic Functions*.

7. Kaplan, W., *An Introduction to Analytic Functions*.

Advanced Topology

Countability and Separation Axioms :
Countability Axioms, The Separation Axioms, Equation spaces, Lindelöf spaces, Regular spaces, Normal spaces, Urysohn Lemma, Tietze Extension Theorem.

Nets and Filters :

Directed Sets, Nets and Subnets, Convergence of a net, Ultranets, Partially Ordered Sets and Filters, Convergence of a filter, Ultrafilters, Basis and Subbase of a filter, Nets and Filters in Topology.

Tychonoff Theorem & Compactification :
Tychonoff Theorem, Completely Regular spaces, Local Compactness, One-point compactification, Stone-Cech Compactification.

Metrization: Urysohn Metrization Theorem, Topological Imbedding, Imbedding Theorem of a regular space with countable base in R^n, Partitions of Unity, Topological *m*-Manifolds, Imbedding Theorem of a compact *m*-manifold in R^n.
Local Finiteness, Nagata-Smirnov Metrization Theorem, Paracompactness, Stone's Theorem, Local Metrizability, Smirnov Metrization Theorem. Uniform Spaces.

Complete Metric Spaces & Function Spaces:
Complete Metric Spaces, The Peano Space-Filling Curve, Hahn-Mazurkiewicz Theorem (statement only).
Compactness in Metric Spaces, Equicontinuity, Pointwise and Compact Convergence, The Compact-Open Topology, Stone-Weierstrass Theorem, Ascoli's Theorem, Baire Spaces, A Nowhere Differentiable Function.
An Introduction to Dimension Theory, Topological notion of (Lebesgue)dimension.

References :

1. Munkres, J.R., *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.

2. Dugundji, J., *Topology*, Allyn and Bacon, 1966.

3. Simmons, G.F., *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.

4. Kelley, J.L., *General Topology*, Van Nostrand Reinhold Co., New York, 1995.

5. Bourbaki, N., *Topologie Générale*.

6. Hocking, J., Young, G., *Topology*, Addison-Wesley Reading, 1961.

7. Steen, L., Seebach, J., *Counter Examples in Topology*,

8. Holt, Reinhart and Winston, New York, 1970.

Algebraic Topology

Geometric Complexes and Polyhedra, Orientation of Geometric Complexes. Chains, Cycles, Boundaries and Homology Groups, Examples of Homology Groups, The Structure of Homology Groups, Euler - Poincaré Theorem, Pseudomanifolds and the Homology Groups of S^n`. Simplicial Approximation, Induced Homomorphisms on the Homology Groups, Brouwer Fixed Point Theorem and Related Results.

Note : This course is based on the book [2]; Chapters 1 - 3.

Geometric Complexes and Polyhedra, Orientation of Geometric Complexes. Chains, Cycles, Boundaries and Homology Groups, Examples of Homology Groups, The Structure of Homology Groups, Euler - Poincaré Theorem, Pseudomanifolds and the Homology Groups of S^n`. Simplicial Approximation, Induced Homomorphisms on the Homology Groups, Brouwer Fixed Point Theorem and Related Results.

Note : This course is based on the book [2]; Chapters 1 - 3.

References :

1. Munkres, J.R., *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.

2. Croom, F.H., *Basic Concepts of Algebraic Topology*, Springer, NY, 1978.

3. Bredon, G.E., *Topology and Geometry*, Springer, India, 2005.

4. Spanier, E.H., *Algebraic Topology*, McGraw-Hill, 1966. Singer, I.M.,

5. Thorpe, J.A., *Lecture Notes on Elementary Topology and Geometry*, Springer, India, 2003 .

6. Hatcher, A., *Algebraic Topology*, Cambridge University Press, 2003.

7. Dieudonné, J., *A History of Algebraic and Differential Topology, 1900 - 1960*, Birkhäuser, 1989

Differential Topology

Smooth Mappings: Inverse Function Theorem, Local Submersion Theorem (Implicit Function Theorem).

Differentiable manifolds: Differentiable manifolds and submanifolds, examples, including surfaces, $S^{n,}$ RP^n,CP^n and lens spaces, tangent bundles; Sard,s theorem and its applications. Differentiable transversality, orientation,. Whitney,s embedding theorems. Pontryagin-Thom construction, Fruedenthal suspension theorem.

Vector fields and differential forms : Integrating vector fields, degree of a map, Brouwer Fixed Point Theorem, Poincare-Hopf Theorem, differential forms, deRham's theorem.

References :

Text : Hirsch, Moris W. " Differential Topology" Graduate Texts in Mathematics. Vol.33, Reprint edition. New York, Springer-Verlag, 1988.
Spivak : Calculus on Manifolds, Benjamin, 1965 (differentiation, Inverse Function Theorem, Stokes Theorem)
Milnor : Topology from the Differentiable viewpoint, University of Virginia Press, 1965
James R Munkres : Elementary Differentail Toplogy, 1966
J.W.Milnor : Differential Topology.
Guillemen Pollack : Differential Toplogy, Prentice-Hall, 1974 (basic reference)

Abraham, Ralph., Jerrold E. Marsden and Tudor Ratiu : Manifolds, Tensor Analysis and Applications, Applied Mathematical Sciences, Vol. 75, New York, Springer-Verlag, 1998.
Bott, Raoul, R. Bott and Loring W.Tu. : Differential Forms in Algebraic Topology, Graduate Texts in Mathematics. Vol.82, Reprint edition. New York, Springer-Verlag, 1995.
For the examples we refer to the books of
Greenberg : Lectures on Algebraic Topology, W.A. Benjamin, 1967.
Munkres : Elements of Algebraic Topology, Addison-Wesley, 1984.
Hirsch : Differential Topology, Springer, 1976.

Field Theory

Field Extensions : Algebraic and Transcendental Extensions, Finite Extension, Algebraic Closure of a field, Algebraically Closed Field, Splitting Field of a polynomial, Normal Extension, Separable Extension, Impossibility of some constructions by straightedge and compass.

Finite Fields and their properties, Galois Group of Automorphisms and Galois Theory, Solution of polynomial equations by radicals, Insolvability of the general equation of degree 5(or more) by radicals.

References

1. Dummit, D.S., Foote, R.M., *Abstract Algebra*, Second Edition, John Wiley & Sons, Inc., 1999.
2. Goldhaber, J.K., Ehrlich, G., *Algebra*, The Macmillan Company, Collier-Macmillan Limited, London.
3. Herstein, I.N., *Topics in Abstract Algebra*, Wiley Eastern Limited.
4. Hungerford, T.W., *Algebra*, Springer.
5. Jacobson, N., *Basic Algebra, I & II*, Hindusthan Publishing Corporation, India.
6. Malik, D.S., Mordesen, J.M., Sen, M.K., *Fundamentals of Abstract Algebra*, The McGraw-Hill Companies, Inc.

Semigroup Theory

Introduction:Basic Definitions. Monogenic semigroups, Periodic semigroups.Ordered sets, Semilattices.Bands, Binary relations, equivalences.Congruences.Ideals and Rees congruences.Green's equivalence relations.Regular semigroups.

Completely regular semigroups:Characterization of completely regular semigroups as union of groups, Semilattices of groups, Clifford semigroups, Orthodox semigroups.

Simple and 0-simple semigroups.Completely simple, Completely 0-simple semigroups. Rees' theorem.

Inverse semigroups:Definitions and elementary properties, Congruences on inverse semigroups, Fundamental inverse semigroups.

References

1.Fundamentals of semigroup theory, J. M. Howie, Clarendon Press, oxford, 1995.

2.An introduction to semigroup theory, J. M. Howie, Academic Press, London, 1976.

3.The algebraic theory of semigroups, Amer. Math. Soc., Math Surveys No. 7, Providence, Vol I, 1961, Vol II, 1967.

4.Completely Regular Semigroups, M. Petrich and N. R. Reilly, John Wiley & Sons.

5. Introduction to semigroups, M. Petrich, Merrill, Columbus, 1973.

6.Structure of regular semigroups, M. Petrich, Univ. de Montpellier, 1977.

7.Lectures in semigroups, M. Petrich,

8.Semigroups and combinatorial applications, G. Lallement,

9.Completely 0-simple semigroups: an abstract treatment of the lattice of congruences, Benjamin, New York, 1969.

Advanced Functional Analysis

Examples of Banach Spaces, Stone-Weierstrass Theorem, Ascoli-Arzela Theorem. L^p-spaces, Completeness and other Properties. Linear Topological Spaces, Locally Convex Spaces and their Characterization in terms of a family of Seminorms, Hahn-Banach Theorem, Separation Theorem, Open Mapping Theorem, Closed Graph Theorem, Weak Topology and Duality Theorem for Normed Linear Spaces, Krein-Milman Theorem and its Applications, Uniform Convexity, Strict Convexity and their Applications. 0.25in

References:

Kelley, J.L., Namioka, I., *Linear Topological Spaces*, D.Van Nostrand Company, 1963. Rudin, W., *Functional Analysis*, Tata McGraw-Hill Publishing Corpn. Ltd., 1979. Aliprantis, C.D., Burkinshaw, O., *Principles of Real Analysis*, 3rd Edition, Harcourt Asia Pte Ltd., 1998. Goffman, C., Pedrick, G., *First Course in Functional Analysis*, Prentice Hall of India, New Delhi, 1987. Taylor, A.E., *Introduction to Functional Analysis*, John Wiley and Sons, New York, 1958. Conway, J.B., *A Course in Functional Analysis*, Springer Verlag, New York, 1990.

Operator Theory I

Unit 3.3 Bounded linear Operators :

Resolvent set, Spectrum, Point spectrum, Continuous spectrum, Residual spectrum, Approximate point spectrum, Spectral radius, Specrtral properties of a bounded linear operator, Spectral mapping theorem for polynomials. Numerical range, Numerical radius, Convexity of numerical range, Closure of numerical range contains the spectrum, Relation between the numerical radius and norm of abounded linear operator A()

Banach Algebra:
Definition of normed and Banach Algebra and examples, Singular and Non-singular elements, The spectrum of an element, The spectral radius.

Compact linear operators:
Spectral properties of compact linear operators on a normed linear space, Operator equations involving compact linear operators, Fredholm alternative theorem, Fredholm alternative for integral equations. Specrtral theorem for compact normal operators.

References:

1. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and sons.
2. G. Bachman and L. Narici, Functional Analysis, Dover Publications.
3. A . Taylor and D. Lay, Introduction to Functional Analysis, John Wiley and Sons.
4. N. Dunford and J.T. Schwarts, Linear Operators – 3, John Wiley and Sons.
5. P.R. Halmos, Introduction to Hilbert space and the theory of Spectral Multiplicity, Chelsea Publishing Co., N.Y.

Operator Theory II

Selfadjoint operators: Spectral properties of bounded selfadjoint linear operators on a complex Hilbert space, Positive operators, Square root of a positive operator, Projection operators, Spectral family of a bounded selfadjoint linear operator and its properties, Spectral theorem for a bounded selfadjoint linear operator.

Normal Operators:
Spectral properties for bounded normal operators, Spectral theorem for bounded normal operators.

Unbounded linear operators in Hilbert space:
Hellinger-Toeplitz theorem, Symmetric and selfadjoint operators, Closed linear operators, Spectrum of an unbounded selfadjoint linear operator, Cayley Transformation U = (T-i I) (T + i I)-1 of an operator T, Spectral theorem for unitary and selfadjoint operators, Multiplication operator and differentiation operator, Application to Quantum Mechanics.

References:

1 Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and sons.
2. G. Bachman and L. Narici, Functional Analysis, Dover Publications.

3. A . Taylor and D. Lay, Introduction to Functional Analysis, John Wiley and Sons.
4. N. Dunford and J.T. Schwarts, Linear Operators – 3, John Wiley and Sons.
5. P.R. Halmos, Introduction to Hilbert space and the theory of Spectral Multiplicity, Chelsea Publishing Co., N.Y.

Operations Research

Operations Research --- an overview. Revised Simplex Method --- minimization and maximization problem.
Sensitivity Analysis --- Change in profit (or cost) contribution coefficients, change in availability of resources. change in input-output coefficients.

Integer Linear Programming --- Branch and Bound algorithm, Cutting plane algorithm.

Non-linear Programming --- Formulation of Non-linear programming problem --- Graphical method of solution. Unconstrained optimization. Optimization with equality constraints. Kuhn-Tucker conditions for constrained optimization. Convex programming. Quadratic programming Problems by (i) Wolfe's method and (ii) Beale's method.

Dynamic Programming --- Deterministic and probabilistic models.

Inventory --- Introduction, Features of inventory system, Inventory model building. Deterministic models with (i) No Shortage, (ii) Shortage. Multi item inventory models with constraints. Probabilistic models --- Single period probabilistic models (i) without set up cost, (ii) with set up cost.
Queuing Theory --- Introduction. Essential features of Queuing system. Probability distribution in Queuing Models. Classification of Queue models. Solution of Queuing models: [1] {(M/M/1):(infinity/FCFS)}, [2]{(M/M/1):(n/FCFS)} [3] {(M/M/s):(infinity/FCFS)} [4] {(M/M/s):(n/FCFS).

References:

1. H. A. Taha---Operations Research-An Introduction. Macmillan Pub. Co., Inc., New York.
2. G. Hadley ---Nonlinear and Dynamic Programming, Addition-Wesley.
3. S. S. Rao --- Optimization Theory and Application, Wiley Eastern.
4. Kanti Sarup, P. K. Gupta and Man Mohan --- Operation Research, Sultan Chand & Sons.
5. J. K. Sharma Operation Research, Mcmillan India.
6. S. D. Sharma Operation Research, Kedarnath & Ramnath, Meerat.
7. O. L. Mangasarian Non linear Programming, McGraw Hill.
8. Peressini, Sullivan and Uhl The mathematics of Nonlinear programming, Springer-Verlog.
9. Rabindran, Phillips, Solberg Operation Research, John Wiley & Sons.

Soft Computing

Introduction;overview;Fuzzy Sets-Crisp Sets,Membership Functions, Operations ,Fuzzy Relations,Extension Principle,Fuzzy Logic,Fuzzy Rules, Fuzzy Reasoning, Applications of Fuzzy operators, Inference systems, Rough Sets, Indiscernibility, Approximations, Reducts, Probabilistic reasoning, Introduction to Neural Networks, Evolutionary Search strategies ,Genetic Algorithms, Simulated annealing

References:

1. Klir ,G and Yuan, B Fuzzy Sets and Fuzzy logic :Theory and applications(PHI)
2. Klir G and others –Fuzzy sets ,uncertainty and information (Englewood Cliffs, PH)
3. Terano and others - Applied fuzzy systems (Academic Press)
4. Pawlak,Z -Rough Sets Academic publishers
5. Goldberg D.E. Genetic Algorithms in search ,optimization and machine learning (Addision Wesley)
6. Davis L Genetic Algorithms and Simulated Annealing ,PItmann
7. Roy and Chakraborty Soft Computing (Pearson)

Design and Analysis of Algorithms

Algorithms: Overview, Mathematical Preliminaries : Mathematical Induction, Recurrence Relation, Generating Functions,Efficiency, Complexity : Bounds , Different Notations , Properties Divide and Conquer approach: Strassen's Matrix Multiplication , Dynamic Programming :Travelling Salesman problem, Chained Matrix Multiplication, Greedy Approach: Shortest paths, Prim's ,Kruskal's , Dijkstra's algorithms. Branch and Bound, Backtracking. Computational complexity

References:

1. Rosen,K - Discrete Mathematics and its applications (TMH)
2. Liu ,C -Elements of Discrete Mathematics (McGrawhill)
3. Saara Baase - Computer Algorithms (Pearson)
4. Design and analysius of algorithms S K Basu (PHI)
5. Neapoliton,R and K. Naimipour –Foundations of Algorithms(D.C. Heath and company)

Theory of Computation

Introduction; Regular Languages and Finite Automata. Regular Expressions, DFA, NFA, Closure, Conversion, Context-free grammars, Pushdown automata, Types, NPDA
Turing Machines, Church Hypothesis, Recursively Enumerable Languages
Context-sensitive grammars, Chomsky Hierarchy, Decidable and Undecidable problems, PCP
Tractability, Decision problems

References:

1. Hopcroft J and Ullmann -Introduction to Automata Theory,languages and Computation
   (Pearson)

2. Mishra K and Chandrasekharan,N Theory of Computer Science,automata (PHI)
3. Peter Linz - An introduction to formal languages and automata (Narosa)
4. Henne – Introduction to Computabilty (Addision Wesley)
5. Sivanandan and others - Theory of Computation(I.K.International)

Electromagnetic Theory and Special Theory of Relativity

Electrostatics: Coulomb's law, Electrostatic potential, Gauss' law, field equations of electrostatics, Electric dipole, Dielectric media, Polarizations, Electrostatic energy, Simple electrostatic boundary value problems.

Electrodynamics: Steady current, Equation of continuity, Biot-Savart's law, Magnetic vector potential, Ampere's law, Faraday's law, Maxwell's equations for electromagnetic field and their empirical basis, Electromagnetic potential, Electromagnetic energy, Pointing theorem. Plane electromagnetic waves in dielectric and conducting medium, Field of a point charge in uniform motion.

Special theory of relativity: Galilean transformation, Einstein's postulates on special theory of relativity, Lorentz transformation, Consequences, Relativistic mass and energy, Force and acceleration in relativity, Transformations of electric and magnetic fields and invariance of Maxwell's equations.

References:

1. Introduction to Electrodynamics- David J. Griffiths (Prentice Hall)

2. Classical Electrodynamics- J. D. Jackson (John Wiley and Sons)
3. Electricity and magnetism- Chattopadhyay and Rakshit (New Central)
4. Basic laws of Electromagnetism – I. E. Irodov (CBS)
5. Electromagnetism – B. B. Laud (New Age International)
6. Reitz, J.R., Milford F.J., Christy R.W. : Foundations *of* Electromagnetic theory, Addison Wesley, 1966

Computational Fluid Dynamics-I

Finite difference method: Treatment of model equations of parabolic, hyperbolic, elliptic types. Explicit and implicit schemes. Truncation error, consistency, convergence, stability (Von Neumann stability analysis only) of model equations with appropriate initial and boundary conditions. Thomas algorithm. ADI method for 2-D heat conduction problem. Splitting and approximate factorization for 2-D Laplace equation. Multigrid method. First- order wave equation. Upwind scheme, consistency, CFL stability condition. First order hyperbolic system Hyperbolic conservation laws. Lax- Wendorf and McCormack schemes. Convection- diffusion equation . Stability. Finite - Volume method: Preliminary concepts, Flux computation across quadrilateral cells. Reduction of a boundary value problem to algebraic equations. Illustrative example, like solution of Dirichlet problem for 2-D Laplace equation by finite volume method

Books Recommended:

1. P. Niyogi, S.K. Chakraborty and M.K. Laha - Introduction to Computational Fluid Dynamics, Pearson education, Delhi 2005
2. C.A.J. Fletcher- Computational Techniques for Fluid Dynamices, Vol-I and Vol-II, Springer 1988
3. R. Peyret and T.D. Taylor – Computational Methods for Fluid Flow, Springer 1983
4. J.F. Thompson, Z.U.A. Warsi and C.W. Martin- Numerical Grid Generation, Foundations and Applications, North Holland 1985
5. L.D. Landau and E.M. Lifshitz, Fluid Mechanics, Trans, Pergamon Press 1989.
6. H. Schlichting and K. Gersten- Boundary – Layer Theory, 8th Ed., Springer 2000

Computational Fluid Dynamics-II

Conservation principles of fluid dynamics. Basic equations of viscous and inviscid flow. Basic equations in conservation form. Associated typical boundary conditions for Euler and N-S equations. Lax-Wendorf and McCormack schemes for 2-D unsteady Euler equations. Grid generation using elliptic partial differential equations. Boundary-layer equations. Incompressible viscous flow field computation: Stream- function vorticity and MAC method. Turbulance modeling, Viscous compressible flow computation based on RANS using simple turbulence modeling.

Books Recommended:

1. P. Niyogi, S.K. Chakraborty and M.K. Laha- Introduction to Computational Fluid Dynamics, Pearson education, Delhi 2005
2. C.A.J. Fletcher- Computational Techniques for Fluid Dynamices, Vol-I and Vol-II, Springer 1988
3. R. Peyret and T.D. Taylor – Computational Methods for Fluid Flow, Springer 1983
4. J.F. Thompson, Z.U.A. Warsi and C.W. Martin- Numerical Grid Generation, Foundations and Applications, North Holland 1985
5. L.D. Landau and E.M. Lifshitz, Fluid Mechanics, Trans, Pergamon Press 1989.
6. H. Schlichting and K. Gersten- Boundary – Layer Theory, 8th Ed., Springer 2000

Dynamical Meteorology

Thermodynamics of dry and wet air. Eulerian equations of continuity and of motion for atmospheric motion and their forms in spherical coordinates rotating with the Earth. Circulation and vorticity theorems. Energy and entropy equations. Scale analysis of basic equations for mid-latitude synoptic systems. Quasi-static equations for adiabatic frictionless motions. Geostrophic wind, . thermal wind equation, inertial, cyclostrophic and gradient motions. Basic equations for mean with Reynolds' stresses, The mixing length theory, Ekman layer equation. Richardson's Criterion for persistence of turbulence. Static stability on a resting earth. Dry and wet adiabatic lapse rate. Oscillations and waves in a compressible atmosphere under gravity. Application to Lee waves. Stability of zonal currents for horizontal non-divergent motion. Rossby wave in barotropic and baroclinic currents. Numerical Forecasting. Quasi-geostrophic equations. Applications to one parameter and two-parameter atmospheric models. Cyclones end anticyclones. The general circulation. Tropical motion systems. Monsoons.

Books Recommended:

1. James R. Holton, An introduction to Dynamic Meteorology Academic Press, New York, 1992.
2. George J. Haltiner, Frank L. Martin --- Dynamical and Physical Meteorology, McGraw Hill, 1957.
3. I.P.Bazarov, Thermodynamics, Pragman Press, Oxford, 1964.
4. V.M. Kamenkovich, Fundamentals of Ocean Dynamics Elsevier Scientific Publ. Company, 1977.
5. Adrian E.Gill, Atmosphere -Ocean Dynamics, Academic Press, London, 1982

Dynamical Oceanography

Thermodynamics of sea water as a two-component system. Gibbs relation. Gibbs-Duhem relation. Conditions of thermodynamic equilibrium of finite volume of sea water, Vaisala frequency, Equations of conservation of mass, Boundary conditions at the ocean surface. Equation of motion of sea water. Equation of energy and entropy transfer. Linearised equations for small amplitude wave motion in spherical coordinates. Boussinesq approximation. f3 -plane equations for motion of seawater. Equation of energy for linear wave motion. Eigen value problems for determination of free linear waves on a sphere. Gravity waves in an exponentially stratified fluid. Planetary waves. Theory of tides. Reynolds' equation of mean motion and boundary conditions at the mean ocean surface. Quasi- static approximation. Geostrophic motion. Pure Drift current. Ekman's theory of wind-driven current in homogeneous ocean. Ekman boundary layer. Western boundary flow. Two-dimensional and three-dimensional models of ocean currents. Simple linear model of a thermocline.

Books Recommended:

1. James R. Holton, An introduction to Dynamic Meteorology Academic Press, New York, 1992.
2. George J. Haltiner, Frank L. Martin --- Dynamical and Physical Meteorology, McGraw Hill, 1957.
3. I.P.Bazarov, Thermodynamics, Prgaman Press, Oxford, 1964.
4. V.M. Kamenkovich, Fundamentals of Ocean Dynamics Elsevier Scientific Publ. Company, 1977.
5. Adrian E.Gill, Atmosphere -Ocean Dynamics, Academic Press, London, 1982

Quantum Mechanics -I

Old Quantum Theory: (a) Black body radiation-Planck's Hypothesis, (b) Electromagnetic radiation --- the photoelectric effect and the Compton effect (c) De Broglie's waves, (d) Bohr's postulates and discrete levels. Dynamical variables and observable: (a) Linear operators, (b) Eigenvalues and eigenfunctions (c) Commutation relations, (d) Angular momentum operators - the eigenvalue equation for L^2, (e) Observable - the general physical interpretation (f) Dirac's bra and ket notation. The Physical Postulates: (a) The correspondence

principle (b) The complementary principle, (c) The uncertainty principle- limitations on experiment, (e) Packets in space and time.
Schrodinger's wave equation: (a) The fundamental properties - statistical interpretation, normalization, (b) The current density, (c) Energy eigenfunctions. Discrete Eigenvalues: Bound states = (a) One dimensional motion well potential, Linear harmonic oscillator, (b) The hydrogen atom - (i) Separation in spherical polar coordinates reduced mass, asymptotic behaviour, energy levels, wavefunctions.

Approximate Method for Bound States: (a) Stationary Perturbation Theory

Books Recommended:

1. Quantum Mechanics - L I Schiff, 3rd edition, McGraw Hill, 1968.

2. The Principles of Quantum Mechanics - P.A.M. Dirac, 4th edition. Clarendon, Oxford, 1958.
3. Introduction to Quantum Mechanics - L. Pauling and E.B. Wilson, Jr. Mc Graw Hill (Dover) 1985
4. Quantum Mechanics - E. Merzbacher, 2nd edition, Wiley, 1970.
5. Quantum Mechanics - L. E. Ballentine, Prentice Hall 1990
6. Atomic and Molecular Physics – B. H. Bransden and C. J. Joachain
7. The Theory of Atomic Collisions – N. F. Mott and H. S. W. Massey (Oxford)

Quantum Mechanics -II

Continuous Eigen values: Collision Theory - (a) One dimensional square potential barrier-asymptotic behaviour, scattering coefficients, (b) Scattering by spherically symmetric potentials -asymptotic behaviour, scattering cross section, method of partial waves.

Identity of Particles and spin: (a) The spin operators, Pauli spin matrices, spin and Statistiics (b) The Exclusion principle.
Approximate Methods for Bound States: (a) The Variation method, (b) Ground state energy of helium.
Approximate Methods in collision Theory : (a) Born approximation, (b) Partial-wave method.

Relativistic Wave Equation: (a) Derivation of the Dirac equation - Dirac matrices, charge and current densities. (b) Theory of positrons.

Books Recommended:

1. Quantum Mechanics - L I Schiff, 3rd edition, McGraw Hill, 1968.
2. The Principles of Quantum Mechanics - P.A.M. Dirac, 4th edition. Clarendon, Oxford, 1958.
3. Introduction to Quantum Mechanics - L. Pauling and E.B. Wilson, Jr. Mc Graw Hill (Dover) 1985
4. Quantum Mechanics - E. Merzbacher, 2nd edition, Wiley, 1970.
5. Quantum Mechanics - L. E. Ballentine, Prentice Hall 1990
6. Atomic and Molecular Physics – B. H. Bransden and C. J. Joachain
7. The Theory of Atomic Collisions – N. F. Mott and H. S. W. Massey (Oxford)

Biomathematics -I

Mathematical Models of Population Biology or Ecology
Mathematical models: Deterministic and Stochastic. Single species population models. Population growth - An age structure model

Interactions between two species: Host-Parasite type of interactions, Competitive type of interactions. Trajectories of interactions of H-P and competitive types between two species. Effect of migration on H-P interactions. Some consequences of Lotka-Volterra equations.

Generalized L-V equations. Pure birth process, Pure death process, Birth and death process.

The logistic models with the effect of time-delay. Stability of equilibrium position for the logistic model with general delay function. Stability of logistic model for discrete time lag.

Linear birth-death-immigration- emigration processes.

Host-Parasite models with time delays.

Mathematical Theory of Epidemics

Introduction; Some basic definitions. Simple epidemic, General epidemic. Kermack-McKendrik threshold theorem. Recurring epidemic.

Control of an epidemic. Stochastic epidemic model without removal

Epidemic model with multiple infections. Stochastic epidemic model with removal. Stochastic epidemic model
with removal, immigration and emigration. Special discussion on the stochastic epidemic model with carriers.

References:

1. J. N. Kapur ---Mathematical Models in Biology and Medicine, East West Press Pvt Ltd (1985)
2. D. A. MacDonald ----Blood Flow in Arteries,The Williams and Wilkins Company, Baltimore (1974)
3. Y. C. Fung ---Biomechanics of Soft Biological Tissues, Springer Verlag
4. R. Habermann--- Mathematical Models , Prentice Hall
5. R. W. Poole -----An Introduction to Quantitative Ecology, McGraw- Hill
6 E. C. Pielou ---An Introduction to Mathematical Ecology, Wiley, New York
7 R. Rosen ----Foundation of Mathematical Biology (vol. I& II), Academic Press

Biomathematics -II

Some Mathematical Aspects of Oscillations of the Biological Systems
Introduction; Biological Clock; Model for the circadian oscillator. Mathematical models in Pharmacokinetics - Compartmental Analysis Technique. Two-compartment model -- Clinical Bromsulphalein Test.

Basic equations for an n-compartment system. Distributions of drugs in n- compartment model for (i) given initial dose, (ii) repeated medication, (iii) constant rate of infusion and (iv) truncated infusion.

Compartment model for diabetes mellitus.

Stochastic compartment models. Drug action. Some general principles for real biological oscillations.

Arterial Biomechanics

Importance of studies on the mechanics of blood vessels. Structure and functions of blood vessels; Mechanical properties.

Viscoelasticity; Linear discrete viscoelastic (spring-dashpot) models: Maxwell Fluid, Kelvin Solid, Kelvin Chains and Maxwell models. Creep Compliance, Relaxation Modulus. Hereditary Integrals, Stieltjes Integrals.

Constituents of blood. Structure and functions of the constituents of blood. Mechanical properties of blood. Equations of motion applicable to blood flow. Non-Newtonian fluids - Power law, Bingham Plastic, Herschel-Bulkley and Casson fluids. Steady non- Newtonian fluid flow in a rigid circular tube. Fahraeus-Lindqvist effect. Pulsatile flow in both rigid and elastic tubes. Blood flow through arteries with mild stenosis.

Large deformation theory. Various forms of strain energy functions. The base vectors and metric tensors; Green's deformation and Lagrangian strain tensors. Cylindrical model; Constitutive equations for blood vessels; equations of motion for the vascular wall.

Cranial Biomechanics

Importance of studying head-injury problems. Structure and different components of human head. Mechanical properties of the different components of head.

Geometrical shape of head. Hypotheses on brain damage.

Head-injury mechanics - different types of head injury. Formulation of the problems: (i) when head is subjected to an impact, (ii) when head is subjected to rotational acceleration.

References:

1. J. N. Kapur ---Mathematical Models in Biology and Medicine, East West Press Pvt Ltd (1985)
2. D. A. MacDonald ----Blood Flow in Arteries,The Williams and Wilkins Company, Baltimore (1974)

3. Y. C. Fung ---Biomechanics of Soft Biological Tissues, Springer Verlag
4. R. Habermann--- Mathematical Models , Prentice Hall
5. R. W. Poole -----An Introduction to Quantitative Ecology, McGraw- Hill
6 E. C. Pielou ---An Introduction to Mathematical Ecology, Wiley, New York
7 R. Rosen ----Foundation of Mathematical Biology (vol. I& II), Academic Press

Solid Mechanics

Notion of a Continuum and of Deformable Bodies. Linear Elastic Solid (or Hookean Solid).

Analysis of Stress: Body and surface forces. Vector stress(or stress vetor) and Notation for its Components. Specification of stress at a point. Stress Tensor. Equations of Equilibrium. Symmetry of Stress Tensor. Surface Boundary Conditions. Rule of Transformation of Stress Components. Principal Stresses and Stress Invariants. Stress quadric of Cauchy. Maximum normal and Shearing Stresses. Mohr's Diagram. Problems

Analysis of Strain: Deformation. Affine Transformation. Infinitesimal Affine Transformation. Strain Tensor. Finite Strain Components. Infinitesimal Strain and Rotation Components. Geometrical Interpretation of Infinitesimal Strain Components. Transformation of Infinitesimal Strain Components. The Strain Quadric. Principal Strains and Principal Axis of Strain. Rate of Deformation Tensor. Problems.

Motion of Deformable Bodies: Lagrangian and Eulerian Descriptions. Path line and Stream line. Material Derivative, Condition on a Boundary Surface. Conservation of Mass. The Continuity Equation. Momentum Principles. Equation of Motion. Energy Balance. Laws of Thermodynamics, Equation of State. Dissipation Function.
Constitutive Equations: Ideal Materials.Classical Elasticity. Generalised Hooke's law. Isotropy. Elastic Moduli.

Linearised Elasticity: Equations of Motion and Equilibrium in Terms of Displacement Components. Beltrami-Michell Compatibility Equations. Strain Energy Density Function. Saint-Venant's principle. Boundary Value Problems of Static and Dynamic Elasticity. Uniqueness of Solutions.

Two-dimensional problems: Plane stress. Generalized plane stress. Airy stress function. General solution of biharmonic equation. Stresses and displacements in terms of complex potentials. Simple problems. Stress function approach to problems of plane stress.

Waves: Propoagation of waves in an isotropic elastic solid medium. Waves of dilation and distortion. Plane waves. Elastic surface waves such as Rayleigh and Love waves.

Problems on Isotropic Elastic Materials. Axial Extension of an Elastic Beam. Bending of a Beam by Terminal Couples. Torsion of Circular Beam. Plane Waves in Unbounded Elastic Bodies. Simple Problems.

Books Recommended:

1. I. S. Sokolnikoff, Mathematical Theory of Elasticity (McGraw Hill, 1956)
2. T. J. Chung, Continuum Mechanics (Prentice Hall, 1988)
3. S. C. Hunter, Mechanics of Continuous Medisa (Ellis Horwood Ltd., England, 1983)
4. A. J. M. Spencer, Continuum Mechanics (Longman, 1980)
5. A. C. Eringen, Mechanics of Continua (John Wiley and Sons, 1967)
6. R. N. Chatterjee, Mathematical Theory of Continuum Mechanics (Narosa, 1999)
7. A. E. H. Love, A Treatise on the Mathematical Theory of Elasticity (Dover)

Fluid Mechanics I (Theory of Incompressible flow)(50 marks)

Lagrange’s and Euler’s methods in fluid motion. Equation of motion and equation of continuity, Boundary conditions and boundary surface stream lines and paths of particles. Irrotational and rotational flows, velocity potential. Bernoulli”s equation. Impulsive action equations of motion and equation of continuity in orthogonal curvilinear co-ordinate. Euler’s momemtum theorem and D’Alemberts paradox.

Theory of irrotational motion flow and circulation. Permanence irrotational motion. Connectivity of regions of space. Cyclic constant and acyclic and cyclic motion. Kinetic energy. Kelvin’s minimum. Energy theorem. Uniqueness theorem.

Dimensional irrotational motion.

Function. Complex potential, sources. sinks, doublets and their images circle theorem. Theorem of Blasius. Motion of circular and elliptic cylinders. Circulation about circular and elliptic cylinder. Steady streaming with circulation. Rotation of elliptic cylinder. Theorem of Kutta and Juokowski. Conformal transformation. Juokowski transformation. Schwartz-chirstoffel theorem. Motion of a sphere. Stoke’s stream function. Source, sinks, doublets and their images with regards to a plane and sphere.

Vortex motion. Vortex line and filament equation of surface formed by stream lines and vortex lines in case of steady motion. Strength of a filament. Velocity field and kinetic energy of a vortex system. Uniqueness theorem rectilinear vortices. Vortex pair. Vortex doublet. Images of a vortex with regards to plane and a circular cylinder. Angle infinite row of vortices. Karman’s vortex street. Waves: Surface waves. Paths of particles. Energy of waves. Group velocity. Energy of a long wave.

Reference Books:

1. Hydrodynamics –A.S.Ramsay(Bell) .
2. Hydrodynamics – H. Lamb(Cambridge).
3. Fluid mechanics – L.D.Landau and E.M.Lifchiz(Pergamon),1959.

4. Theoritical Hydrodynamics –I.M.Milne-Thomson;Macmillan, 1958.

Fluid Mechanics II (Gas Dynamics) (50 marks)

Basic thermodynamics of compressible fluids:

Field equations of fluid motion, crocco-vazsonyl equation. Propagation of small disturbances in a gas. Dynamics similarity of two flows..Plane rotational and irrotational motion with supersonic velocity. Steady flow through a De Level nozzle. Normal and oblique shock wave shock polar diagram .

Chracteristics and their use for solution of plane irrotational problem. Prandtl-Mayer flow past a convex corner.

Steady linearised subsonic and supersonic flows. Prandtl-Glauert transformation. Flow along a wavy boundary. flow past a slight corner. Jangen-rayleigh method of approximation. Ackeret's formula.

Legendre and molenbroek transformations Chaplygin's equation for stream function. Solution of chaplygin's equation. Subsonic gas jet problem, limiting line. Motion due to a two dimensional source and a vortex. Karman-Tsien approximation. Transonic flow. Euler's-Tricomi equation and its fundamental solution. Hypersonic flow.

Reference Books:

1. Compressible fluid dynamics - P.A. Thompson.
2. Compressible fluid flow – A.H.Shaproo.
3. Aspects of subsonic and transonic flows – Lipman Bers.
4. Introduction to the theory of compressible flow –Shih-I.Pai; Van Nostrand, 1959
5. Inviscid gas dynamics – P.Niyogi, Mcmillan, 1975(india)
6. Gas dynamics – K.Oswatitsch(english tr.) acade

Mechanics of Viscous fluids and Boundary layer Theory I (50 Marks)

Mechanics of viscous fluids –

Viscous fluids, velocity strain – tensor and stress-strain relations for viscous fluids (statement of relations only). The Navier – Stokes equations of motion in Cartesian Co-ordinates and statements of its equivalent forms in spherical, polar and cylindrical Co-ordinates. Dissipation of energy due to viscosity, steady motion between parallel planes, Theory of lubrication, steady motion in a tube of different cross-sections. Vorticity in viscous fluids, Circulation in viscous fluids. Diffusion of vorticity, steady flow past a fixed sphere, Dimensional Analysis, Reynolds number, steady motion of a viscous fluid dueto a slowly rotating sphere.

Two Dimensional Motion
Equation satisfied by the stream function for a motion under conservative field of external forces, Hamel's equation, Logarithmic spirals.

Three Dimensional Motion
Stokes' solution for a slow steady parallel flow past a sphere, stream function and the flow pattern, Oseen's criticism, Oseen's solution for slow steady parallel flow past a sphere and past a circular cylinder.

References :
1. Theoretical Hydrodynamics --- Milne – Thomson
2. Viscous flow Theory --- S.I. Pai
3. Hydrodynamics --- H. Lamb
4. A Treatise on Hydrodynamics Part II -- W.H. Besant & A.S. Ramsay
5. Text book of Fluid Dynamics --- F. Chorlton.

Mechanics of Viscous fluids and Boundary layer Theory II (50 Maks)

Fundamental concept of boundary layer when the Reynolds number is moderately large. Prandtl's equation of the boundary layer. Expressions of displacement thickness and momentum thickness of the boundary layer. Vorticity and stress components within the boundary layer in two dimensional motion. Separation of boundary layer from an obstacle.
Blasius equation for steady two dimensional motion past a flat plate and its solution in the form of an infinite series. Boundary layer for two dimensional steady converging radial flow between two non parallel walls. Boundary layer for two dimensional jet. Flow symmetrical about a free stream lines. Problem of steady three dimensional jet. Karman's integral equation of the boundary layer ; interpretation of its terms. Alternative form of integral equation in term of displacement, thickness and momentum thickness. Application of Karman's integral equation in the study of the approximate solutions of steady two dimensional flow past a flat plate and comparison with the corresponding exact solutions; calculations of frictional resistance on both sides of the plate and checking of errors. Application of this method by assuming liner, quadratic, cubic, and biquadratic distribution of velocity. Lamb's Trigonometric solution. Mises' Transformation of boundary layer equation into an equation of the conduction of heat with variable coefficient of conduction.
Non steady boundary layers, method of successive approximation and its application in the case of a flat plate impulsively set in motion. Unsteady motion of oscillatory cylinder and deduction of oscillatory motion of a piston.

References :
1. Viscous flow theory, Vol.I --- S.I. Pai
2. Hydrodynamics --- H. Lamb
3. New methods in laminar boundary layer theory --- D. Meksyn.
4. Elementary treatise on hydrodynamics and sound --- A.B. Besset.
5. Modern developments in fluid dynamics --- S. Goldstein
6. Boundary layer theory --- H. Schlichting.

7. Laminar boundary layers --- L. Rosenhead.