

RAJA NARENDRA LAL KHAN WOMEN'S COLLEGE (AUTONOMOUS)

Gope Palace, Midnapore 721 102 West Bengal



Post Graduate Syllabus in  
***Applied Mathematics with  
Oceanology and Computer Programming***

Under Choice Based Credit System (CBCS)

[w.e.f. : 2018-19]

## COURSE STRUCTURE

### M.Sc. IN APPLIED MATHEMATICS WITH OCEANOLOGY AND COMPUTER PROGRAMMING

SEMESTER	COURSE NO.	COURSE TITLES	Full Marks	Credit	
I	MTM 101	REAL ANALYSIS	50	4	
	MTM 102	COMPLEX ANALYSIS	50	4	
	MTM 103	ORDINARY DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS	50	4	
	MTM 104	ADVANCED PROGRAMMING IN C AND MATLAB	50	4	
	MTM 105	CLASSICAL MECHANICS AND NON-LINEAR DYNAMICS	50	4	
	MTM 106	GRAPH THEORY	25	2	
	MTM 197	COMPUTATIONAL METHODS : USING MATLAB (practical)	25	2	
<b>TOTAL</b>			<b>300</b>	<b>24</b>	
II	MTM 201	FLUID MECHANICS	50	4	
	MTM 202	NUMERICAL ANALYSIS	50	4	
	MTM 203	MTM 203.1	ABSTRACT ALGEBRA	25	2
		MTM 203.2	LINEAR ALGEBRA	25	2
	ELECTIVE(CBCS) (any one)				
	C-MTM 204	C-MTM 204A	<i>STATISTICAL AND NUMERICAL METHODS</i>	50	4
		C-MTM 204B	<i>HISTORY OF MATHEMATICS</i>		
	MTM 205	GENERAL THEORY OF CONTINUUM MECHANICS		50	4
	MTM 206	GENERAL TOPOLOGY		25	2
	MTM 297	C PROGRAMMING WITH NUMERICAL AND STATISTICAL METHODS		25	2
<b>TOTAL</b>			<b>300</b>	<b>24</b>	
III	MTM 301	PARTIAL DIFFERENTIAL EQUATIONS AND GENERALIZED FUNCTIONS	50	4	
	MTM 302	TRANSFORMS AND INTEGRAL EQUATIONS	50	4	
	MTM 303	MTM 303.1	DYNAMICAL OCEANOLOGY AND METEOROLOGY	25	2
		MTM 303.2	OPERATIONS RESEARCH	25	2
	C-MTM 304	DISCRETE MATHEMATICS		50	4
	SPECIAL PAPER (A or B)				
	MTM 305	MTM 305A	DYNAMICAL OCEANOLOGY	50	4
		MTM 305B	ADVANCED OPTIMIZATION AND OPERATIONS RESEARCH		
	MTM 306	MTM 306A	DYNAMICAL METEOROLOGY-I	50	4
		MTM 306B	OPERATIONAL RESEARCH MODELLING-I		
<b>TOTAL</b>			<b>300</b>	<b>24</b>	
IV	MTM 401	FUNCTIONAL ANALYSIS	50	4	
	MTM 402	MTM 402.1	FUZZY MATHEMATICS WITH APPLICATIONS	25	2
		MTM 402.2	SOFT COMPUTING	25	2
	MTM 403	MTM 403.1	MAGNETO HYDRO-DYNAMICS	25	2
		MTM 403.2	STOCHASTIC PROCESS AND REGRESSION	25	2
	SPECIAL PAPER (A or B)				
	MTM 404	MTM 404A	COMPUTATIONAL OCEANOLOGY	50	4
		MTM 404B	NONLINEAR OPTIMIZATION		
	MTM 405	MTM 405A	DYNAMICAL METEOROLOGY - II	25	2
		MTM 405B	OPERATIONAL RESEARCH MODELLING - II		
	MTM 495	MTM 495A	DYNAMICAL METEOROLOGY (practical)	25	2
		MTM 495B	O.R. METHOD USING MATLAB AND LINGO (practical)		
	MTM 406	DISSERTATION PROJECT WORK		50	6
<b>TOTAL</b>			<b>300</b>	<b>26</b>	
<b>GRAND TOTAL</b>			<b>1200</b>	<b>98</b>	

Full Marks, 50 = END SEMESTER EXAMINATION (40) + INTERNAL ASSESSMENT (10)  
 25 = END SEMESTER EXAMINATION (20) + INTERNAL ASSESSMENT (5)

### ***Semester-I***

<i>Course No.</i>	<i>Topics</i>	<i>Marks</i>	<i>No. of Lectures (Hours)</i>	<i>Credit</i>
MTM-101	Real Analysis	50	40	4
MTM-102	Complex Analysis	50	40	4
MTM-103	Ordinary Differential Equations And Special Functions	50	40	4
MTM-104	Advanced Programming in C and MATLAB	50	40	4
MTM-105	Classical Mechanics and Non – linear Dynamics	50	40	4
MTM-106	Graph Theory	25	20	2
MTM-197	Lab.1:(Computational Methods: Using MATLAB)	25	40	2

### ***Semester-II***

<i>Course No.</i>	<i>Topics</i>	<i>Marks</i>	<i>No. of Lectures (Hours)</i>	<i>Credit</i>
MTM-201	Fluid Mechanics	50	40	4
MTM-202	Numerical Analysis	50	40	4
MTM-203	Unit-1: Abstract Algebra	25	20	2
	Unit-2: Linear Algebra	25	20	2
C-MTM-204A	Statistical and Numerical Methods	50	40	4
C-MTM-204B	History of Mathematics	50	40	4
MTM-205	General Theory of Continuum Mechanics	50	40	4
MTM-206	General Topology	25	20	2
MTM-297	Lab. 2: (Language: C- Programming with Numerical Methods)	25	40	2

### ***Semester-III***

<i>Course No.</i>	<i>Topics</i>	<i>Marks</i>	<i>No. of Lectures (Hours)</i>	<i>Credit</i>
MTM-301	Partial Differential Equations and Generalized Functions	50	40	4
MTM-302	Transforms and Integral Equations	50	40	4
MTM-303	Unit-1: Dynamical Oceanology and Meteorology	25	20	2
	Unit-2: Operations Research	25	20	2
C-MTM-304	Discrete Mathematics	50	40	4

MTM-305A	Special Paper-OM:Dynamical Oceanology	50	40	4
MTM-306A	Special Paper-OM:Dynamical Meteorology -I	50	40	4
MTM-305B	Special Paper-OR: Advanced Optimization and Operations Research	50	40	4
MTM-306B	Special Paper-OR:Operational Research Modelling-I	50	40	4

***Semester-IV***

<i>Course No.</i>	<i>Topics</i>	<i>Marks</i>	<i>No. of Lectures (Hours)</i>	<i>Credit</i>
MTM-401	Functional Analysis	50	40	4
MTM-402	Unit-1: Fuzzy Mathematics with Applications	25	20	2
	Unit-2: Soft Computing	25	20	2
MTM-403	Unit-1: Magneto Hydro-Dynamics	25	20	2
	Unit-2: Stochastic Process and Regression	25	20	2
MTM-404A	Special Paper-OM: Computational Oceanology	50	40	4
MTM-405A	Special Paper-OM: Dynamical Meteorology –II	25	20	2
MTM-495A	Special Paper-OM: Lab.: Dynamical Meteorology	25	40	2
MTM-404B	Special Paper-OR: Nonlinear Optimization	50	40	4
MTM-405B	Special Paper-OR: Operational Research Modelling-II	25	20	2
MTM-495B	Special Paper-OR: Lab. OR methods using MATLAB and LINGO	25	40	2
MTM-406	Dissertation Project Work	50	60	6

**Note:**

1. There will be two examinations for each paper:
  - (i) End semester examination having 40 marks and
  - (ii) Internal assessment (IA) examination having 10 marks. Marks from IA will be evaluated by averaging two marks obtained in two IA.
2. Dept. Offers two special papers: Dynamical Oceanology and Meteorology (MTM-305A,-306A, -404A, -405A and -495A) and Operations Research (MTM-305B,-306B, -404B, -405B and -495B). Each student has to take either of these two.
3. Courses C-MTM-204A, C-MTM-204B and C-MTM-304 are open elective papers for PG students other than students of Applied Mathematics.

## Outcome of the Programme(s)

- Skills to analyze problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions thereof.
- Development of critical thinking for carrying out scientific investigations.
- Development of the effective scientific and technical communications in both oral and written forms.
- Ability to pursue research or build careers in industry in mathematical sciences and allied fields.

## Programme Specific Outcomes

- Development of mathematical reasoning and an understanding of the underlying unifying structures of mathematics (i.e., sets, relations and functions, logical structure) and the relationships among them.
- Understanding about the fundamental axioms in mathematics and capability of developing ideas based on them.
- Advanced knowledge in mathematical sciences.
- Knowledge in a wide range of mathematical techniques and application of mathematical methods/tools in other scientific and engineering domains.
- Motivation for research studies in mathematics and related fields with real life applications.
- Preparing for competitive examinations, like NET, SET, GATE, etc.

### *Semester-I*

**MTM-101**

**Real Analysis**

**50**

**Total Lecture 40H**

Complete Metric spaces, compactness, connectedness (with emphasis on  $\mathbb{R}^n$ ), Heine-Borel Theorem, Separable and non-separable metric spaces. [ 4H]

Functions of bounded variation, R-S Integral. [6H]

Measurable sets. Concept of Lebesgue function. Inner and outer measure. It's simple properties. Set of measure zero. Cantor set, Borel set and their measurability, Non-measurable sets. [ 8H]

Measurable function: Definition and it's simple properties, Borel measurable functions, sequence of measurable functions, Statement of Lusin's theorem, Egoroff's theorem. Simple functions and it's properties. [ 10H]

Lebesgue integral on a measurable set: Definition. Basic simple properties. Lebesgue integral of a bounded function over a set of finite measure. Simple properties. Integral of non-negative measurable functions, General Lebesgue integral. Bounded convergence theorem for a sequence of Lebesgue integrable function, Fatou's lemma. Classical Lebesgue dominated convergence theorem. Monotone convergence theorem, Relation between Lebesgue integral and Riemann integral [ 12H]

## Learning outcomes

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the functions of bounded variation and its characterization, Riemann-Stieltjes integral as a generalization of Riemann integral, Lebesgue measure, measurable sets, measurable functions and Lebesgue integral and its relationship with Riemann integral.
- ii) The students would be able to characterize functions which are of bounded variation, find Lebesgue measure of various subsets of  $\mathbb{R}$ , determine functions which are Lebesgue measurable and calculate Lebesgue integral of measurable functions and calculate Fourier series of suitable functions.

**References:**

1. W. Rudin, Principles of Mathematical Analysis, 3<sup>rd</sup> Edition, McGraw-Hill, 2013.
2. W. Rudin, Real and Complex Analysis, International Student Edition, McGraw-Hill, 1987.
3. S. Kumaresan, Topology of Metric Spaces, 2<sup>nd</sup> Edition, Narosa Publishers, 2011.
4. Inder K. Rana, An Introduction to Measure and Integration, 2<sup>nd</sup> Edition, Narosa Publishing House, New Delhi, 2002.

**MTM-102**

**Complex Analysis**

**50**

Total Lecture 40H

The definition of an analytic function. Cauchy- Riemann differential equation. Construction of analytic function. Jordan arc. Contour. Rectifiable arcs. Cauchy's theorem. Cauchy's integral formula. Morer's theorem. Liouville's theorem. Taylor's and Laurent's series. Maximum modulus principle. [4H]

Residues and Poles: Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points, Residues at Poles, Zeros of Analytic Functions, Zeros and Poles, Behaviour of Functions Near Isolated Singular [6H]

Application of Residues: Evaluation of Improper Integrals, Improper Integrals from Fourier Analysis, Jordan's Lemma, Indented Paths, An Indentation Around a Branch Point, Integration Along a Branch Cut, Definite Integrals Involving Sines and Cosines, Argument Principle, Rouch'e's Theorem, Inverse Laplace Transforms [8H]

Mapping by Elementary Functions: Linear Transformations, Mappings by  $1/z$ , Linear Fractional Transformations, An Implicit Form, Mappings of the Upper Half Plane, The Transformation  $w = \sin z$ , Mappings by  $z^2$  and Branches of  $z^{1/2}$ , Square Roots of Polynomials, Riemann Surfaces [10H]

Conformal Mapping: Preservation of Angles, Scale Factors, Local Inverses, Harmonic Conjugates, Transformations of Harmonic Functions, Transformations of Boundary Conditions, [8H]

The Schwarz-Christoffel Transformation: Mapping the Real Axis Onto a Polygon, Schwarz-Christoffel Transformation, Triangles and Rectangles, Degenerate Polygons. [4H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the basic concepts of analytic functions, entire functions, complex integration, the homotopy version of Cauchy's theorem, the ideas on singularities with their classifications and its role on some important theorems like Rouché's theorem and Mobius transformations, Riemann Mapping theorem and analytic continuation with its geometric interpretations.
- ii) The students would be able to check analyticity of a complex valued functions, to integrate a complex valued function having certain types of singularities and to learn a geometrical study of Mobius transformations.

**References:**

1. Complex Variable and Applications, J. W. Brown and R. V. Churchill, 8th Edition, GcGraw Hill.
2. Foundations of Complex Analysis, S. Ponnusamy, Narosa, 1995.
3. Theory of Functions of a Complex Variable (Vol. I, II & III). A. I. Markushevich (Prentice-Hall (1965& 1967)).
4. The Theory of Functions.E. C. Titchmarsh (Oxford University Press,1939).
5. Introduction to the Theory of Function of a Complex Variable.E. T. Copson (Oxford University press, 1970).

**MTM-103                      Ordinary Differential Equations and Special Functions                      50**

Total Lecture: 40H

Differential equation: Homogeneous linear differential equations, Fundamental system of integrals, Singularity of a linear differential equation, Solution in the neighbourhood of a singularity, Regular integral, Equation of Fuchsian type, Series solution by Frobenius method. [6H]

Hypergeometric equation. Hypergeometric functions, Series solution near zero, one and infinity, Integral formula for the hypergeometric function, Differentiation of hypergeometric function, The confluent hypergeometric function, Integral representation of confluent hypergeometric function. [6H]

Legendre equation: Legendre functions, Generating function, Legendre functions of first kind and second kind, Laplace integral, Orthogonal properties of Legendre polynomials, Rodrigue's formula, Schlaefli's integral. [6H]

Bessel equation: Bessel function, Series solution of Bessel equation, Generating function, Integrals representations of Bessel's functions, Hankel functions, Recurrence relations, Asymptotic expansion of Bessel functions. [6H]

Green's Function: Green's Function and its properties, Green's function for ordinary differential equations, Application to Boundary Value Problems. [4H]

Eigen Value Problem: Ordinary differential equations of the Sturm-Liouville type, Properties of Sturm Liouville type, Application to Boundary Value Problems, Eigen values and Eigen functions, Orthogonality theorem, Expansion theorem. [6H]

System of Linear Differential Equations: Systems of First order equations and the Matrix form, Representation of nth order equations as a system, Existence and uniqueness of solutions of system of equations, Wronskian of vector functions. [6H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the higher order ordinary and systems of first order differential equations with their existence and different essential properties, the SL problem with the eigen value and eigen function, the solution of boundary value problem using Green's function and the solution procedure of special type differential equations which have many applications in engineering design problems
- ii) The students would be able to solve the higher order and the system of first order differential equation, S.L. problem and boundary value problem originated from real life problem.

**References:**

1. G.F. Simmons: Differential Equations, TMH Edition, New Delhi, 1974.

2. S.L. Ross: Differential Equations (3rd edition), John Wiley & Sons, New York, 1984.
3. M. Braun: Differential Equations and Their Applications; an Introduction to Applied Mathematics, 3<sup>rd</sup> Edition, Springer-Verlag. .
4. E.A. Coddington and N. Levinson: Theory of ordinary differential equations, McGraw Hill, 1955.

**MTM-104**

**Advanced Programming in C and MATLAB**

**50**

Total Lecture: 40H

Programming in C: Review of basic concepts of C programming, Arrays, structure and union, Enum, pointers, pointers and functions, pointers and arrays, array of pointers, pointers and structures, strings and string handling functions, [10H]

Dynamic memory allocation: using of malloc(), realloc(), calloc() and free(), file handling functions: use of fopen, fclose, fputc, fgets, fputs, fscanf, fprintf, fseek, putc, getc, putw, getw, append. [8H]

Low level programming and C pre-processor: Directive, #define, Macro Substitution, conditional compilation, #if, #ifdef, #ifndef, #else, #endif. [6H]

Programming in MATLAB: The Matlab workspace, data types, variables, assignment statements, arrays, sets, matrices, string, time, date, cell arrays and structures, introduction to M – file scripts, input and output functions, conditional control statements, loop control statements, break, continue and return statements. [16H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the advanced graphics and visualization, the Arrays and matrices, the Pointers in function, structure, union, dynamic memory management to construct linked list and how to create a data file in which input data and output data can be stored and also able to achieve the concept of low level using MATLAB and C Language.
- ii) The students would be able to solve different numeric computation and to solve the various types of problems such as algebraic, differential, statistical, plotting etc using MATLAB and C Language.

**References:**

1. Balagurusamy E. programming in ANSI C. Tata McGraw-Hill Education; 2012.
2. Byron Gottfried and Jitender Chhabra, Programming with C (Schaum's Outlines Series), 2017
3. Gilat A. MATLAB: an Introduction with Applications. New York: Wiley; 2008.
4. Palm III WJ. Introduction to MATLAB for Engineers. New York: McGraw-Hill; 2011.

**MTM-105**

**Classical Mechanics and Non-linear Dynamics**

**50**

Total Lecture: 40H

Motion of a system of particles. Constraints. Generalized coordinates. Holonomic and non-holonomic system. Principle of virtual work. D'Alembert's Principle. Lagrange's equations. Plane pendulum and spherical pendulum. Cyclic co-ordinates. Coriolis force. Motion relative



to rotating earth.

[6H]

Principle of stationary action. Hamilton's principle. Deduction of Lagrange from Hamilton's principle. Brachitochrone problem. Lagrange's equations from Hamilton's principle. Invariance transformations. Conservation laws. Infinitesimal transformations. Space-time transformations. Hamiltonian. Hamilton's equations. Poisson bracket. Canonical transformations. Liouville's theorem.

[8H]

Small oscillation about equilibrium. Lagrange's method. Normal co-ordinates. Oscillations under constraint. Stationary character of a normal mode. Small oscillation about the state of steady motion. Normal coordinates

[6H]

Orientation and displacement of a rigid body. Eulerian angles. Principal axis transformation. Euler equations of motion. Motion of a free body about a fixed point.

[6H]

Special theory of relativity in Classical Mechanics:-Postulates of special relativity. Lorentz transformation. Consequences of Lorentz transformation. Force and energy equations in relativistic mechanics.

[6H]

Nonlinear Dynamics: Linear systems. Phase portraits: qualitative behavior. Linearization at a fixed point. Fixed points. Stability aspects. Lyapunov functions (stability theorem). Typical examples. Limit cycles. Poincare-Bendixson theory. Bifurcations. Different types of bifurcations.

[8H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the mathematical formalisms of classical Mechanics, conservation laws, symmetries, angular momentum and spin, canonical transformations, generating functions and brackets and functional, Euler-Lagrange equations.
- ii) The students would be able to describe the motion of a mechanical system using Lagrangian and Hamiltonian formalism, solve some physical systems moving under some constraints, solve some physical systems moving under some constraints, find stationary path using use Euler-Lagrange equations, evaluate Lagrange and Poisson brackets and develop Hamilton-Jacobi method to solve physical phenomenon

### References:

1. H. Goldstein, *Classical Mechanics*, Addison-Wesley, Cambridge, 1950.
2. A. S. Gupta, *Calculus of Variations with Applications*, Prentice-Hall of India, New Delhi, 2005.
3. B. D. Gupta and S. Prakash, *Classical Mechanics*, KedarNath Ram Nath, Meerut, 1985.
4. T.W.B. Kibble, *Classical Mechanics*, Orient Longman, London, 1985.
5. N. C. Rana and P. S. Joag, *Classical Mechanics*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004.
6. A. K. Raychaudhuri, *Classical Mechanics-A Course of Lectures*, Oxford University Press, Calcutta, 1983.
7. M. R. Spiegel, *Theoretical Mechanics*, Schaum Series, New York, 1967.
8. K. R. Symon, *Mechanics*, Addison-Wesley Publ. Co., Inc., Massachusetts, 1971.
9. R. G. Takwale and S. Puranik, *Introduction to Classical Mechanics*, Tata McGraw-Hill Publ. Co. Ltd., New Delhi, 1980.

**MTM-106**

Total Lecture 20H

Basic graph theoretical concepts: paths and cycles, connectivity, trees, spanning sub graphs, bipartite graphs, Hamiltonian and Euler cycles. Distance and centre, Cut sets and cut vertices. Colouring and matching. Four colour theorem (statement only). Planar graphs, Dual graph. Directed graphs and weighted graphs. [10H]

Matrix representation of graphs, Algorithms for shortest path and spanning trees, Intersection graph. [6H]

Applications of graphs in operations research.

[4H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about different types of graphs, various, various characterizations of trees with applications and matrix representation of graphs.
- ii) The students would be able to develop the matrix representation of graph, planarity, to solve real world problems that can be modelled by graphs, to get idea about the application of graphs in computer science

**References:**

1. West, D. B. (2001). *Introduction to graph theory*, Upper Saddle River: Prentice hall.
2. Deo, N. (2017). *Graph theory with applications to engineering and computer science*. Courier Dover Publications.
3. Chartrand, G. (2006). *Introduction to graph theory*. Tata McGraw-Hill Education.
4. Gross, J. L., & Yellen, J. (2005). *Graph theory and its applications*. CRC press.

**MTM-197****Lab.1:(Computational Methods: Using MATLAB)****25**

Problem: 20 marks; Lab. Note Book and Viva-Voce: 5.

Total Lecture: 40H

**Working with matrix:** Generating matrix, Concatenation, Deleting rows and columns. Symmetric matrix, matrix multiplication, Test the matrix for singularity, magic matrix. Matrix analysis using function: norm, normest, rank, det, trace, null, orth, rref, subspace, inv, expm, logm, sqrtm, funm.

**Array:** Addition, Subtraction, Element-by-element multiplication, Element-by-element division, Element-by-element left division, Element-by-element power. Multidimensional Arrays, Cell Arrays, Characters and Text in array,

**Graph Plotting:** Plotting Process, Creating a Graph, Graph Components, Figure Tools, Arranging Graphs Within a Figure, Choosing a Type of Graph to Plot, Editing Plots, Plotting Two Variables with Plotting Tools, Changing the Appearance of Lines and Markers, Adding More Data to the Graph, Changing the Type of Graph, Modifying the Graph Data Source, Annotating Graphs for Presentation, Exporting the Graph.

**Using Basic Plotting Functions:** Creating a Plot, Plotting Multiple Data Sets in One Graph, Specifying Line Styles and Colors, Plotting Lines and Markers, Graphing Imaginary and Complex Data, Adding Plots to an Existing Graph, Figure Windows, Displaying Multiple Plots in One Figure, Controlling the Axes, Adding Axis Labels and Titles, Saving Figures.

**Programming:** Conditional Control – if, else, switch, Loop Control – for, while, continue, break, Error Control – try, catch, Program Termination – return.

**Scripts and Functions:** Scripts, Functions, Types of Functions, Global Variables, Passing

String Arguments to Functions, The eval Function, Function Handles, Function Functions, Vectorization, Preallocation.

**Linear Algebra:** Systems of Linear Equations, Inverses and Determinants, Factorizations, Powers and Exponentials, Eigenvalues, Singular Values.

**Polynomials:** Polynomial functions in the MATLAB® environment, Representing Polynomials, Evaluating Polynomials, Roots, Derivatives, Convolution, Partial Fraction Expansions, Polynomial Curve Fitting, Characteristic Polynomials.

**Learning outcomes of the course:**

Upon successful completion of this course, students will learn the following:

- i) An introduction to MATLAB and it is based on interactive examples and hands-on problem solving.
- ii) The utility of basic MATLAB and its demonstration.
- iii) Matrix manipulations, plotting of functions and data implementation of algorithms, the creation of user interfaces, and interfacing with programs written in other languages.
- iv) Applications in various disciplines such as engineering science, and economics.

**References:**

1. Gilat A. MATLAB: an Introduction with Applications. New York: Wiley; 2008.
2. Palm III WJ. Introduction to MATLAB for Engineers. New York: McGraw-Hill; 2011.
3. Chapman SJ. MATLAB programming with applications for engineers. Cengage Learning; 2012.
4. Lopez C. MATLAB programming for numerical analysis. Apress; 2014.

---

## *Semester-II*

**MTM-201**

**Fluid Mechanics**

**50**

Total Lecture 40H

Viscous Flow: Real and Ideal Fluids: Types of fluid Flow ( Real/Ideal Fluid Flow, Compressible/Incompressible flow, Newtonian/Non-Newtonian fluids, Rotational/irrotational flows, Steady/Unsteady Flow, Uniform/Non uniform Flow, One, Two or three Dimensional Flow, Laminar or Turbulent Flow), Preliminaries for the derivation of governing equation (Coordinate systems: Lagrangian description and Eulerian description). Models of the flow( Finite Control Volume and Infinitesimal Fluid Element), Substantial Derivative, Source of Forces) [10H]

Derivation of Governing Equations: Derivation of Continuity Equation, Derivation of Momentum Equation, Special case (Incompressible Newtonian Fluid), Physical interpretation of each term, Derivation of Energy Equation, Boundary Conditions. [6H]

Boundary Layer Theory: Prandtl's Concept of Boundary Layer, Boundary Layer Flow along a Flat Plate, Governing Equations, Boundary Conditions , Exact Solution of the Boundary-Layer

Equations for Plane Flows (Similarity Solution, Vorticity, Stress). [4H]

Exact/Analytical Solution of Navier-Stokes Equation: Reynolds number, Non-dimensionalization, Importance of Reynolds number to Navier-Stokes Equation, Exact Solution of Navier-Stokes Equation (Couette-Poiseuille flow, Flow of a Viscous Fluid with Free Surface on an Inclined Plate) [8H]

Incompressible Viscous Flows via Finite Difference Methods: Variable arrangement (Cell center / Collocated arrangement or Staggered Grid), One-Dimensional Computations by Finite Difference Methods, Space discretization (Simple and general methods based on Taylor's series for first, second, and fourth order accuracy, and hence Accuracy of the Discretisation Process), Time discretization (Explicit Algorithm, Implicit Algorithm, and Semi-implicit Algorithm), Solution of Couette flow using FTCS and Crank-Nicolson methods.[12H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the continuum hypothesis applicable to viscous fluid flows, the solution techniques for boundary layer flows, solution techniques of Navier-Stokes equations for few special cases and incompressible viscous flow.
- ii) The students would be able to describe the motion of fluids and identify the derivation of basic governing equations of fluid mechanics and apply, to find exact solutions of some specific problems of viscous fluid flows and understanding about fundamental equations of flow and energy and experience to construct mathematical models to tackle complex fluid flow problems.

### References:

1. Computational Fluid Dynamics (The Basics with Applications), John D. Anderson Jr., McGraw-Hill Series in Mechanical Engineering
2. An Introduction to Fluid Dynamics, G. K. Batchelor, Cambridge University Press
3. Fluid Mechanics (4<sup>th</sup> Edition), Frank M. White, WCB McGraw-Hill
4. Boundary Layer Theory, Hermann Schlichting, McGraw-Hill Book Company
5. Computational Fluid Dynamics, 2<sup>nd</sup> Ed, T. J. Chung, Cambridge University Press

### MTM-202

### Numerical Analysis

50

Total Lecture 40H

Cubic spline interpolation. Lagrange's bivariate interpolation. Approximation of function.

[4H]

Chebyshev polynomial: Minimax property. Curve fitting by least square method. Use of orthogonal polynomials. Economization of power series.

[6H]

Numerical integration: Newton-Cotes formulae-open type. Gaussian quadrature: Gauss-Legendre, Gauss-Chebyshev. Integration by Monte Carlo method.

[7H]

Roots of polynomial equation: Bairstow method. Solution of a system of non-linear equations by fixed point method and Newton-Raphson methods. Convergence and rate of convergence.

[7H]

Solution of a system of linear equations: Matrix inverse. LU decomposition method. Solution of tri-diagonal system of equations. Ill-conditioned linear systems. Relaxation method.[4H]

Eigenvalue problem. Power method. Jacobi's method.

[2H]

Solution of ordinary differential equation: Runge-Kutta method to solve a system of equations and second order IVP. Predictor-corrector method: Milne's method. Stability. Solution of second order boundary value problem by finite difference and finite element methods. [6H]  
 Partial differential equation: Finite difference scheme. Parabolic equation: Crank-Nicolson method. Iteration method to solve Elliptic and hyperbolic equations. [4H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the numerical methods for interpolation, Function approximation by least square method and using orthogonal polynomials and Gaussian quadrature, solution of system of linear equations, solution of ordinary and partial differential equations by different numerical methods.
- ii) The students would be able to compute of eigenvalues and eigenvectors of a matrix, to apply the numerical techniques for practical problems and implementation of numerical methods to the programming language.

### References:

1. A. Gupta and S.C. Bose, Introduction to Numerical Analysis, Academic Publishers, Calcutta, 1989.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, 1984.
3. E.V. Krishnamurthy and S.K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
4. J.H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, 2<sup>nd</sup> ed., Prentice-Hall, Inc., N.J., U.S.A., 1992.
5. E.A. Volkov, Numerical Methods, Mir Publishers, Moscow, 1986.
6. M.Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa, 2007.

**MTM-203**

**Unit-1: Abstract Algebra**

**25**

**Total Lecture 20H**

Groups: Morphism of groups. Quotient groups. Fundamental theorem on homomorphism of groups. Isomorphism theorems. Automorphism. Solvable groups and theorems on them. Direct product. Conjugacy. Conjugate classes. Class equation. Theorems on finite groups. Cauchy's theorem. Sylow's theorem. Application of Sylow's theorem, Simple groups, Permutation groups, Cayley theorem, Group actions. [6H]

Rings and Field: Integral domain. Fields. Skew fields. Quotient rings. Morphism of rings. Ideals (Prime and maximal). Isomorphism theorem. Euclidean domain. Principal ideal domain.

Unique factorization domain. Polynomial rings. [7H]  
 Field extensions, Finite, algebraic and finitely generated field extensions, Classical ruler and compass constructions, Splitting fields and normal extensions, algebraic closures. Finite fields, Cyclotomic fields, Separable and inseparable extensions. [7H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the quotient groups, solvable groups and properties of them, the concepts of isomorphism and homomorphism for groups and rings and related theorems, the action of a group on a set and its various connection with some important concepts in group theory like Sylow's theorems, application of Euclidean domain (ED), Unique Factorization domain (UFD) to prove Euclidean algorithm and Fundamental Theorem of Arithmetic.
- ii) The students would be able to compute many problems in different field of mathematics using the action of groups, to develop skills to check whether a group is simple or not using Sylow and to completely describe all abelian groups of any order, establish whether a polynomial over a field can be factored non-trivially and to provide examples and counter examples.

### References:

1. D. S. Dummit and R. M. Foote, Abstract Algebra, 2<sup>nd</sup> Edition, John Wiley, 1999.
2. J.A. Gallian, Contemporary Abstract Algebra, 9<sup>th</sup> Edition, Narosa, 2017.
3. M. Artin, Algebra, 2<sup>nd</sup> Edition, Prentice Hall of India, 2011.
4. N. Jacobson, Basic Algebra, 2<sup>nd</sup> Edition, Hindustan Publishing Co., 2009.

## Unit-2: Linear Algebra

25

Total Lecture: 20H

Review of Linear transformations and matrix representation of linear transformation, Linear operators, Isomorphism, Isomorphism theorems, Invertibility and change of coordinate matrix, The dual space, Minimal polynomial, Diagonalization. [9H]

Canonical Forms: Triangular canonical form, Nilpotent transformations, Jordan canonical form, The rational canonical form. [4H]

Inner product spaces, Hermitian, Unitary and Normal transformations, Spectral theorem.

Bilinear forms, Symmetric and Skew-symmetric bilinear forms, Sylvester's law of inertia. [7H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about on advanced concept of Linear Transformation, Inner product space, Bilinear forms, Quadratic forms, Canonical forms, Minimal polynomial and Jordan Canonical forms, the concepts on eigen values and eigen vectors.
- ii) The students would be able to apply linear algebra for solving many problems on Applied Mathematics and several physics-oriented applied problems, to solve many real-life problems using eigen values and eigen vectors

## References:

1. K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. Prentice-Hall of India, 1991.
2. I. N. Herstein, Topics in Algebra, 2nd Ed., John Wiley & Sons, 2006.
3. S. Freidberg, Ainsel, and L Spence, Linear Algebra, Fourth Edition, Pearson, 2015.
4. G. Strang, Linear Algebra and its Applications, Brooks/Cole Ltd., New Delhi, Third Edition, 2003.

### C-MTM-204A

### Statistical and Numerical Methods

50

Total Lecture :40H

Statistical Methods: Mean, median, mode. Bi-variate correlation and regression: Properties and significance. Time series analysis. Hypothesis testing: chi-square test, t-test and F- test. ANOVA. [12H]

Numerical methods: Sources and causes of errors. Types of errors. Lagrange's and Newton's interpolation (deduction is not required). Roots of algebraic and transcendental equations: Bisection, Newton-Rapshon methods. Rate of convergence. [15H]

Solution of system of linear equations: Cramer rule, Gauss-elimination method. Integration by trapezoidal and Simpson 1/3 methods. Solution of ordinary differential equation by Euler's method, Runge-Kutta methods. [13H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the error in the number generated by the solution, compute solution of algebraic and transcendental equation by numerical methods like Bisection method and Newton-Rapshon method to calculate and apply measures of location and measures of dispersion - grouped and ungrouped data cases, learn non-parametric test such as the Chi-Square test for independence as well as goodness of fit.
- ii) The students would be able to apply method of interpolation and extrapolation for prediction, recognize elements and variable in statistics and summarize qualitative and quantitative data, to compute and interpret the results of bivariate and multivariate regression and correlation analysis, for forecasting

### References:

1. A.M. Goon, M.K. Gupta & B. Dasgupta, Fundamentals of Statistics, Vol. 1 & 2, Calcutta : The World Press Private Ltd., 1968.
2. J. Medhi, Stochastic Process, New Age International Publisher, 2ed, 1984.
3. S. Biswas, G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011.
4. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, 1984.
5. E.V. Krishnamurthy and S.K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
6. J.H. Mathews, Numeical Methods for Mathematics, Science, and Engineering, 2nd ed., Prentice-Hall, Inc., N.J., U.S.A., 1992.
7. E.A. Volkov, Numerical Methods, Mir Publishers, Moscow, 1986.

8. M.Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa, 2007.

**C-MTM-204B**

**History of Mathematics**

**50**

Total Lecture: 40H

Ancient Mathematical Sources, Mathematics in Ancient Mesopotamia, The Numeral System and Arithmetic Operations, Geometric and Algebraic Problems, Mathematical Astronomy, Mathematics in Ancient Egypt, Geometry, Assessment of Egyptian Mathematics, Greek Mathematics, [8H]

The Development of Pure Mathematics, The Pre-Euclidean Period, The Elements, The Three Classical Problems, Geometry in the 3rd Century BCE, Archimedes, Apollonius, Applied Geometry, Later Trends in Geometry and Arithmetic, Greek Trigonometry and Menstruation, Number Theory, Survival and Influence of Greek Mathematics. [8H]

Mathematics in the Islamic World (8th–15th Century), Origins, Mathematics in the 9th Century, Mathematics in the 10th Century, Omar Khayyam, Islamic Mathematics to the 15th Century [6H]

The Foundations of Mathematics : Ancient Greece to the Enlightenment, Arithmetic or Geometry, Being Versus Becoming, Universals, The Axiomatic Method, Number Systems, The Reexamination of Infinity, [6H]

Calculus Reopens Foundational The Philosophy of Mathematics: Mathematical Platonism, Traditional Platonism, Nontraditional Versions, Mathematical Anti-Platonism, Realistic Anti-Platonism, Nominalism, Logicism, Intuitionism, and Formalism, Mathematical Platonism: For and Against, The Fregean Argument for Platonism, The Epistemological Argument, Against Platonism [12H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about some of the major concepts of modern mathematics, about the basic, fundamental arguments that were developed centuries ago and are still of central importance today.
- ii) The students would be able to concept from geometry (such as Euclid's constructions) and analysis (such as limit), to solve different problems to differentiate functions using various notions of infinitesimals

**References:**

1. Erik Gregersen, The Britannica Guide to The History of Mathematics, Britannica.
2. Eleanor Robson, Jacqueline Stedall, The Oxford Handbook of THE HISTORY OF MATHEMATICS, Oxford

**MTM-205**

**General Theory of Continuum Mechanics**

**50**

Total Lecture: 40H

Stress: Body force. Surface forces. Cauchy's stress principle. Stress vector. State of stress at a point. Stress tensor. The stress vector –stress tensor relationship. Force and moment equilibrium. Stress tensor symmetry stress quadric of Cauchy. Stress transformation laws. Principal stress. Stress invariant. Stress ellipsoid. [ 10H]

Strain: Deformation Gradients. Displacement Gradient Deformation tensor. Finite strain tensors. Small deformation theory-infinitesimal strain tensor. Relative displacement. Linear rotation tensor. Interpretation of the linear strain tensors. Strength ratio. Finite strain



interpretation. Principal strains. Strain invariant. Cubical dilatation. Compatibility equation for linear strain. Strain energy function. Hook's law. Saint –Venant's principal. Airy's strain function. Isotropic media. Elastic constrains. Moduli of elasticity of isotropic bodies and their relation. Displacement equation of motion. Waves in isotropic elastic media. [14H]  
 Perfect fluid: Kinematics of fluid. Lagrangian method. Eulerian method. Acceleration. Equation of continuity. The boundary surface. Stream lines and path lines. Irrotational motion and its physical interpretation. Velocity potential. Euler's equation of motion of an in viscid fluid. Cauchy's integral. Bernoulli's equation. Integration of Euler's equation. Impulsive motion of fluid. Energy equation. Motion in two dimensions. The stream functions Complex potential. Source, sink and doublet and their images. Milne-Thompson circle theorem and its application. Vorticity. Flow and circulation. Kelvin's circulation theorem. Kelvin's minimum energy theorem. [16H]

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about spatial and material coordinate, general stresses and strain in continuous materials, motion of continuum
- ii) The students would be able to describe motion of a body in continuum, to apply the knowledge in solving the real world problems, to apply Fundamental physical laws such as the conservation of mass, the conservation of momentum, and the conservation of energy to be applied to such models to derive differential equations describing the behaviour of such objects, and some information about the particular material studied to be added through constitutive relations.

### **References:**

1. Continuum Mechanics: T.J.Chung, Prentice – Hall.
2. Continuum Mechanics: Schaum's Outline of Theory and Problem of Continuum Mechanics: Gedrg R. Mase, McGraw Hill.
3. Mathematical Theory of Continuum Mechanics: R.N.Chatterjee, Narosa Publishing House.
4. Continuum Mechanics: A.J.M. Spencer, Longman.

MTM-206

General Topology

25

Total Lecture: 20

Topological Spaces: open sets, closed sets, neighbourhoods, basis, sub-basis, limit points, closures, interiors, continuous functions, homeomorphisms. Examples of topological spaces: subspace topology, product topology, metric topology, order topology, Quotient Topology. [7H]

Connectedness and Compactness: Connected spaces, connected subspaces of the real line, Components and local connectedness, Compact spaces, Local-compactness, Tychonoff's Theorem on compact spaces. [7H]

Separation Axioms: 1st and 2nd countable spaces, Hausdorff spaces, Regularity, Complete Regularity, Normality. [3H]

Urysohn Lemma, Urysohn Metrization Theorem, Tietze Extension theorem (statement only). [3H]

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about how the topology on a space is determined by the collection of open sets, by the collection of closed sets, or by a basis of neighborhoods at each point and different topologies as subspace topology, order topology, product topology, metric topology and quotient topology
- ii) The students would be able to determine how a function to be continuous, can characterize metrizable spaces and present a systematic introduction of the fundamentals course on topology

### **References:**

1. J. R. Munkres, Topology, 2nd Ed., Pearson Education (India), 2000.
2. M. A. Armstrong, Basic Topology, Springer (India), 1983.
3. K. D. Joshi, Introduction to General Topology, New Age International Private Limited, New Delhi, 2014.
4. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York, 1963.

**MTM-297 Lab. 2: (Language: C- Programming with Numerical Methods) 25**  
Total Lecture: 40H

Problem: 20 marks; Lab. note book and viva: 5. (Programs are to be written on the following problems using pointers, data file, structures, etc.)

**On Searching and Sorting Problems:** Linear and binary search, Bubble, Insertion, Selection techniques. [15H]

**String manipulation:** No of occurrence of a letter in a given string, Palindrome nature of string, Rewrite the name with surname first, Print a string in a reverse order, String searching, Sorting of names in alphabetic order, Find and replace a given letter or word in a given string, Combinations of letters of a word, Conversion of name into abbreviation form, Pattern matching. [25H]

### **On Numerical Problems:**

- (i) Evaluation of determinant by Gauss elimination method, using partial pivoting.
- (ii) Matrix inverse by partial pivoting.
- (iii) Roots of Polynomial equation.
- (iv) Solution of system of linear equations by Gauss Seidal iteration method, Matrix inversion method, LU decomposition method, Gauss elimination method.
- (v) Solution of Tri-diagonal equations.
- (vi) Interpolation: Difference table, Lagrange, Newton forward and backward

- interpolation, Cubic spline interpolation.
- (vii) Integration: Gauss quadrature rule, Integration by Monte Carlo method, Double integration.
- (viii) Solution of ODE: Euler and Modified Euler, Runge-Kuta, Predictor and Corrector method: Milne method.
- (ix) Solution of PDE by Finite difference method.
- (x) Eigen value of a matrix: Power method, Jacobi method.

[25H]

**Statistical Problems:**

- (i) On bivariate distribution: Correlation coefficient, Regression lines, Curve fitting.
- (ii) Multiple regressions.
- (iii) Simple hypothesis testing.

[15H]

**Learning outcomes of the course:**

Upon successful completion of this course, students will learn the following:

- i) Interactive examples and hands-on problem solving environment.
- ii) The course is to demonstrate searching, sorting and strings manipulation problems.
- iii) Demonstrate numerical and statistical problems in C.
- iv) Applications in various disciplines such as engineering, science, and economics.

**References:**

1. Jain M K. (2019) Numerical Methods: For Scientific and Engineering Computation, 7th ed., New Age International Private Limited.
2. Rajaraman V. Computer Orientated Numerical Methods, 3<sup>rd</sup> ed., PHI.
3. Kanetkar, V. (2017) Let Us C, 16<sup>th</sup> ed., BPB Publications.
4. Pal, M. (2007) Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa.

## *Semester-III*

**MTM-301                      Partial Differential Equations and Generalized Functions                      50**

Total lecture: 40H

Partial Differential Equations: First order PDE in two independent variables and the Cauchy problem. Semi-linear and quasilinear equations in two-independent variables. Second order linear PDE. Adjoint and self-adjoint equations. Reduction to canonical forms. Classifications. Fundamental equations: Laplace, Wave and Diffusion equations. [8H]

Hyperbolic equations: Equation of vibration of a string. Existence. Uniqueness and continuous dependence of the solution on the initial conditions. Method of separation of variables. D'Alembert's solution for the vibration of an infinite string. Domain of dependence. Higher-dimensional wave equations. [10H]

Elliptic equations: Fundamental solution of Laplace's equations in two variables. Harmonic function. Characterization of harmonic function by their mean value property. Uniqueness. Continuous dependence and existence of solutions. Method of separation of variables for the solutions of Laplace's equations. Dirichlet's and Neumann's problems. Green's functions for the Laplace's equations in two dimensions. Solution of Dirichlet's and Neumann's problem for some typical problems like a disc and a sphere. Poisson's general solution. [12H]

Parabolic equations: Heat equation - Heat conduction problem for an infinite rod - Heat conduction in a finite rod - existence and uniqueness of the solution. [4H]

Generalized Functions: Dirac delta function and delta sequences. Test functions. Linear functional. Regular and singular distributions. Sokhoski-Plemelj formulas. Operations on distributions. Derivatives. Transformation properties of delta function. Fourier transform of generalized functions. [6H]

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the first and second order partial differential equations (PDEs), the general structure of solutions, and analytic methods for solutions, the classification of PDEs by applying analytical methods and how physically interpretation of the solutions
- ii) The students would be able to solve practical PDE problems (Wave, Heat & Laplace equations) with the methods of separation of variables, and analyze the stability and convergence properties of this method and to find solution of Dirichlet's and Neumann's problem for some typical problems like a disc and a sphere

### **References:**

1. Y. Pinchover and J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press, 2005.
2. F. John, Partial Differential Equations, Springer-Verlag, New York, 1978.
3. S. Rao, Introduction to Partial Differential Equations, 3<sup>rd</sup> Edition, PHI Learning Private Limited, New Delhi, 2011.
4. J. J. Duistermaat and J. A. C. Kolk, Distributions Theory and Applications, Birkhäuser Basel, 2010.

**MTM-302**

**Transforms and Integral Equations**

**50**

Total Lecture 40H

Fourier Transform: Fourier Transform, Properties of Fourier transform, Inversion formula, Convolution, Parseval's relation, Multiple Fourier transform, Bessel's inequality, Application of transform to Heat, Wave and Laplace equations (Partial differential equations). [10H]

Laplace Transform: Laplace Transform, Properties of Laplace transform, Inversion formula of Laplace transform (Bromwich formula), Convolution theorem, Application to ordinary and partial differential equations. [10H]

Wavelet Transform: Time-frequency analysis, Multi-resolution analysis, Spline wavelets, Sealing function, Short-time Fourier transforms, Wavelet series, Orthogonal wavelets, Applications to signal and image processing. [4H]

Integral Equation: Formulation of integral equations, Integral equations of Fredholm and Volterra type, Solution by successive substitutions and successive approximations, Resolvent Kernel Method, Integral equations with degenerate kernels, Abel's integral equation, Integral Equations of convolution type and their solutions by Laplace transform, Fredholm's theorems, Integral equations with symmetric kernel, Eigen value and Eigen function of integral equation and their simple properties, Fredholm alternative. [16H]

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the fundamental and theories of Laplace and Fourier transforms and the solution of IVP or BVP of ODE and PDE and fundamental of Wavelet transform which provides more accurate solution and which helps to determine the exact location of the solution.  
Students also gain knowledge about the mathematical foundations of integral equations and integral transforms including techniques of solving unknown function.
- ii) The students would be able to solve IVP or BVP of ODE and PDE originated from physical problem and construct integral equations from physical problems and to convert it to a differential equation and vice-versa

### **References:**

1. LokenathDebnath: Integral Transforms and Their Applications, CRC Press, 1995.
2. P. P. G. Dyke, An Introduction to Laplace Transform and Fourier Series, Springer 2005.
3. R.P. Kanwal: Linear Integral Equations; Theory & Techniques, Academic Press, NewYork, 1971.
4. W. V. Lovitt, Linear Integral Equations, Dover Publications, 1950.

### **MTM-303**

### **Unit-1: Dynamical Oceanology and Meteorology**

**25**

**Total Lecture: 20H**

Dynamical Oceanology: Properties of Sea Water relevant to Physical Oceanography: Measurement of density, temperature and salinity, Relative density,  $\sigma_t$  and specific volume, Density and specific volume as functions of temperature, salinity and pressure;

The Basic Physical Laws used in Oceanography and Classifications of Forces and Motions in the Sea: Basic laws, Classifications of forces and motions; [5H]

The Equation of Continuity of Volume: The concept of continuity of volume, The derivation of the equation of continuity of volume. [2H]

The Equation of Motion in Oceanography: The form of the equation of motion, Obtaining solutions to the equations, including boundary conditions, The derivation of the terms in the equation of motion, The pressure term, Transforming from axes fixed in space to axes fixed in the rotating earth, Gravitation and gravity, The Coriolis terms, Other accelerations. [6H]

Dynamical Meteorology: Dynamical Meteorology: Composition of Atmosphere, Atmospheric Structure, Basic Thermodynamics of the atmosphere, Poisson's Equation, Potential temperature, Equation of state of dry air, hydrostatic equation, variation of Pressure with altitude, hypsometric equation, dry adiabatic lapse rate, Equation of moist air, Virtual temperature, mixing ratio, specific humidity, absolute humidity and relative humidity, fundamental atmospheric forces, derivation of momentum equation of an air parcel in vector and Cartesian form, Geostrophic wind and Gradient wind. [7H]



**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the analytical models of physical processes in the ocean, as e.g. wave driven surface currents and Field observations of currents, internal waves and optical conditions, optical models related to monitoring of water quality based on satellite data
- ii) The students would be able to develop mathematical model about the processes in the atmospheric part of the climate system, atmospheric chemistry in relation to climate change and air pollution, cloud physics and relations between aerosols and clouds and predict the weather forecasting and studies of processes governing weather at mid and high latitudes.

**References:**

1. Introductory Dynamical Oceanology, 2nd Ed, Pond, Stephen; Pickard, George L., Butterworth-Heinemann Ltd Linacre House, Jordan Hill, Oxford OX2 8DP
2. Dynamical and Physical Meteorology: George J. Haltiner and Frank L. Martin, McGraw Hill

**Unit-2: Operations Research****25****Total Lecture 20H**

Inventory control: Deterministic Inventory control including price breaks and Multi-item with constraints. [7H]

Queuing Theory: Basic Structures of queuing models, Poisson queues –M/M/1, M/M/C for finite and infinite queue length, Non-Poisson queue -M/G/1, Machine-Maintenance (steady state). [7H]

Classical optimization techniques: Single variable optimization, multivariate optimization (with no constraint, with equality constraints and with inequality constraints). [6H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the different types of deterministic inventory related problems, queuing system and solution of single variable and multi variable optimization methods.
- ii) The students would be able to. solve different types of deterministic inventory related problems, queuing system originated from real world problem using single variable and multi variable optimization methods.

**References:**

1. Hillier, F.S., 2012. *Introduction to operations research*. Tata McGraw-Hill Education.
2. Rao, S. S. *Engineering optimization: theory and practice*. John Wiley & Sons, 2009.
3. Taha, H. A. *Operations research: An introduction*. Pearson Education India, 2004.
4. Sharma, J.K. *Operations Research: theory and application*, Macmillan Publishers, 2006.

Boolean algebra: Introduction, Basic Definitions, Duality, Basic Theorems, Boolean algebra and lattice, Representation Theorem, Sum-of-product form for sets, Sum-of-products forms for Boolean Algebra. Propositional Logic, Tautology. [5H]

Sets and propositions: Cardinality. Mathematical Induction. Principle of Inclusion and exclusion. [5H]

Computability and Formal Languages: Ordered Sets. Languages. Phrase Structure Grammars. Types of Grammars and Languages. [8H]

Finite State Machines: Equivalent Machines. Finite State Machines as Language Recognizers.

Partial Order Relations and Lattices: Chains and Antichains. [6H]

Graph Theory: Definition, walks, paths, connected graphs, regular and bipartite graphs, cycles and circuits. Tree and rooted tree. Spanning trees. Eccentricity of a vertex radius and diameter of a graph. Centre(s) of a tree. Hamiltonian and Eulerian graphs, Planar graphs. [12H]

Analysis of Algorithms: Time Complexity. Complexity of Problems. Discrete Numeric Functions and Generating Functions. [4H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the simplification and evolution of basic logic statements including compound statements, implications, inverses, converses, and contrapositives using truth tables and the properties of logic, analyze the growth of elementary functions and representation of a graph using an adjacency list and an adjacency matrix and apply graph theory to application problems such as computer networks
- ii) The students would be able to determine if a graph is a binary tree, Euler or a Hamilton path or circuit, N-ary tree, or not a tree and evaluate Boolean functions and simplify expression using the properties of Boolean algebra and use finite-state machines to model computer operations

### References:

1. Rosen, K. H. Discrete Mathematics and its Applications, McGraw-Hill, 2007.
2. Wilson, R. J., & Watkins, J. J. Graphs: an introductory approach: a first course in discrete mathematics. John Wiley & Sons Inc, 1990.
3. N.Deo Graph Theory with Applications to Engineering and Computer Science (Dover Books on Mathematics)
4. B.D west:



The Role of the Non-linear Terms and the Magnitudes of Terms in the Equations of Motion: The non-linear terms in the equation of motion, Scaling and the Reynolds Number, Reynolds stresses, Equations for the mean or average flow, Reynolds stresses and eddy viscosity, Scaling the equations of motion; Rossby number, Ekman number. [8H]

Currents without Friction (Geostrophic Flow): Hydrostatic equilibrium, Inertial motion, Geopotential surfaces and isobaric surfaces, The geostrophic equation, Deriving absolute velocities, Relations between isobaric and level surfaces, Relations between isobaric and isopycnal surfaces and currents, The beta spiral; Currents with Friction (Wind-driven Circulation): The equation of motion with friction included, Ekman's solution to the equation of motion with friction present, Sverdrup's solution for the wind-driven circulation [14H]

Vorticity and Circulation: Vorticity, Circulation, Kelvin's theorem for barotropic fluid, Vortex line and Vortex tube, Helmholtz's theorem, Vorticity equation, Physical Interpretation, Baroclinic vorticity equation. [10H]

Vortex Motion: Circular Vortex, The circulation of circular vortex, Rectilinear Vortex, Vortex Pair, Vortex Doublet, Infinite Row of Parallel Rectilinear Vortices (Single Infinite Row, Two rows of vortices), Karman Vortex. [8H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the Role of the Non-linear Terms and the Magnitudes of Terms in the Equations of Motion
- ii) The students would be able to solve a physical problem of Ocean Currents without Friction (Geostrophic Flow) and Currents with Friction (Wind-driven Circulation),

### References:

1. Introductory Dynamical Oceanology, 2<sup>nd</sup> Ed, Pond, Stephen; Pickard, George L., Butterworth-Heinemann Ltd Linacre House, Jordan Hill, Oxford OX2 8DP
2. Ocean Circulation Theory, Joseph Pedlosky, Springer
3. Fluid Mechanics (4th Edition), Frank M. White, WCB McGraw-Hill

Thermodynamics of the atmosphere: Adiabatic lapse rate for moist unsaturated air, The effect of Ascent and descent on lapse rate and stability, The Clausius – Clapeyron equation, The saturated adiabatic lapse rate and stability, saturation by Isobaric cooling, dew point changes in adiabatic motion, saturation by adiabatic ascent, Pseudoadiabatic change, wet-bulb temperature, wet – bulb potential temperature, equivalent temperature, equivalent potential temperature, vertical stability by Parcel method, Slice method of stability analysis, Horizontal mixing of air masses, vertical mixing of air masses. [20H]

Purpose and use of Aerological diagrams, Area Equivalence, properties of Tephigram, Clapeyron diagram, Emagram [8H]

Dynamics in Atmosphere: Equation of momentum of an air parcel in spherical coordinates, natural coordinates and isobaric coordinates. Vertical shear of Geostrophic wind, Thermal

wind equation, Vertical variation of pressure system, atmospheric energy equation, circulation and vorticity in the atmosphere, equation of vorticity, rate of change of circulation. [12H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about different thermodynamics laws to be applied in the atmosphere to get a state of dry and moist air in the atmosphere and global circulation in the atmosphere
- ii) The students would be able to understand of the basic physical processes occurring in the atmosphere in mathematical perspective and the prediction of weather and climate based on primary scientific basis.

**References:**

- 1. Dynamical and Physical Meteorology: George J. Haltiner and Frank L.Martin, McGraw Hill
- 2. An introduction to Dynamical Meteorology: Holton J.R., Academic Press
- 3. Physical and Dynamical Meteorology: D. Brunt, Cambridge University Press
- 4. Atmospheric Thermodynamics: Iribarne, J.V. and Godson, W.L.

**MTM-305B Special Paper-OR: Advanced Optimization and Operations Research 50  
Total Lecture 40H**

Revised simplex method (with and without artificial variable). Modified dual simplex.

[5H]

Large Scale Linear Programming: Decomposition Principle of Dantzig and Wolf. [6H]

Parametric and post-optimal analysis: Change in the objective function. Change in the requirement vector, Addition of a variable, Addition of a constraint, Parametric analysis of cost and requirement vector.

[6H]

Search Methods: Fibonacci and golden section method.

[2H]

Gradient Method: Method of conjugate directions for quadratic function, Steepest descent and Davodon-Fletcher-Powell method. Methods of feasible direction and cutting hyper-plane method.

[6H]

Integer Programming: Gomory's cutting plane algorithm, Gomory's mixed integer problem algorithm, A branch and bound algorithm.

[6H]

Goal Programming: Introduction, Difference between LP and GP approach, Concept of Goal Programming, Graphical solution-method of Goal Programming, Modified simplex method of Goal Programming.

[6H]

Optimization for Several Variables: Algebraic approach, Algebraic geometrical approach, cost – different approach, Inequality approach. [3H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the identification and development of operational research models from the verbal



- ii) The students would be able to solve linear and non-linear optimization problems and solve problems in inventory management system, queuing theory and others using simulation

**References:**

1. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
2. Sharma, S. D. Operations Research, KedarNath Ram Nath& Co., Meerut.
3. Sharma J.K. Operations Research: theory and application, Macmillan Publishers, 2006.
4. Hillier, F.S., 2012. Introduction to operations research. Tata McGraw-Hill Education.

***Semester-IV***

**MTM-401**

**Functional Analysis**

**50**

**Total Lecture 40H**

Normed spaces, Continuity of linear maps, Bounded linear transformation. Set of all bounded linear transformation  $B(X, Y)$  from NLS  $X$  into NLS  $Y$  is a NLS.  $B(X, Y)$  is a Banach space if  $Y$  is a Banach space. Quotient of normed linear spaces and its consequences. Hahn-Banach Extension theorem and Its applications. Banach spaces. A NLS is Banach iff every absolutely convergent series is convergent. Conjugate spaces, Reflexive spaces. [12H]

Uniform Boundedness Principle and its applications. Closed Graph Theorem, Open Mapping Theorem and their applications. [6H]

Inner product spaces, Hilbert spaces. Orthonormal basis. Complete Orthonormal basis. Cauchy-Schwarz inequality. Parallelogram law. Projection theorem. Inner product is a continuous operator. Relation between IPS and NLS. Bessel's inequality. Parseval's identity. Strong and Weak convergence of sequence of operators. Reflexivity of Hilbert space. Riesz Representation theorem for bounded linear functional on a Hilbert space. [16H]

Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related simple theorems. [6H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the uses of functional analysis and unifies ideas from vector spaces, the theory of metrics, and complex analysis and applications of fundamental theorems from the theory of normed and Banach spaces, including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem, and the Uniform Boundedness principle .
- ii) The students would be able to apply ideas from the theory of Hilbert spaces to other areas, including Fourier series, the theory of self-adjoint operators, normal operators, unitary operators and positive operators and Hilbert space theory, including Riesz representation theorem and weak convergence, and critically reflect over chosen strategies and methods in problem solving.

**References:**

1. B.V. Limaye, Functional Analysis, 2<sup>nd</sup> Edition, New Age International Private Limited New Delhi, 2014.
2. J. B. Conway, A Course in Functional Analysis, 2<sup>nd</sup> Edition, Springer-Verlag New York, 1985.
3. E. Kreyszig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1989.
4. A. Taylor and D. Lay, Introduction to Functional Analysis, Wiley, New York, 1980.



**Total Lecture 20H**

Basic concept and definition of fuzzy sets. Standard fuzzy sets operations and its properties. Basic terminologies such as Support,  $\alpha$ -Cut, Height, Normality, Convexity, etc. [3H]

Fuzzy relations, Properties of  $\alpha$ -Cut, Zadeh's extension principle, Interval arithmetic, Fuzzy numbers and their representation, Arithmetic of fuzzy numbers. [3H]

Basic concept of fuzzy matrices. Basic concepts of fuzzy differential equations.

[3H]

Linear Programming Problems with fuzzy resources:

(i) Vendegay's approach

(ii) Werner's approach

[5H]

L.P.P. with fuzzy resources and objective: Zimmermann's approach. [3H]

L.P.P. with fuzzy parameters in the objective function. Definition of Fuzzy multiobjective linear programming problems. [3H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the fundamentals of fuzzy sets, numbers, matrix, ordinary differential equation and programming, etc. and operations on above fuzzy sets
- ii) The students would be able solve the fuzzy ordinary differential equation, fuzzy linear programming problems, and fuzzy multi-objective linear programming problems and decision making problems using uncertain programming

**References:**

1. Klir, G.J. and Yuan, B., 1996. Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by Lotfi A. Zadeh. World Scientific Publishing Co., Inc.
2. Bector, C.R. and Chandra, S., 2005. Fuzzy mathematical programming and fuzzy matrix games, Berlin: Springer.
3. Dubois, D.J., 1980. Fuzzy sets and systems: theory and applications, Academic press.
4. Gomes, L.T., de Barros, L.C. and Bede, B., 2015. Fuzzy differential equations in various approaches. Berlin: Springer.
5. Meenakshi, A. R., 2019. Fuzzy matrix: Theory and applications. MJP Publish.

**Unit-2: Soft Computing****Total Lecture: 20H**

Introduction of soft computing, fuzzy logic, Genetic Algorithm, Neural networks, Application of fuzzy logic concepts in scientific problems, Solution of optimization problems using Genetic Algorithm. Neural Network approaches in scientific analysis, design, and diagnostic problems. [20H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the the basic concepts Soft

computing like how it resemble biological processes more closely than traditional techniques and the basic neural network models and illustrate with numerical examples.

ii) The students would be able to solve the fuzzy logic and system control with help of fuzzy controller and optimization problems using genetic algorithm

**References:**

1. OglyAliev, R.A. and Aliev, R.R., 2001. Soft computing and its applications. World Scientific.
2. Sivanandam, S.N. and Deepa, S.N., 2007. PRINCIPLES OF SOFT COMPUTING (With CD). John Wiley & Sons
3. Karray, F.O. and De Silva, C.W., 2004. Soft computing and intelligent systems design: theory, tools, and applications. Pearson Education.
4. Jang, J.S.R., Sun, C.T. and Mizutani, E., 1997. Neuro-fuzzy and soft computing; a computational approach to learning and machine intelligence. Prentice Hall, Upper Saddle River NJ (1997).

**MTM-403**

**Unit-1: Magneto Hydro-Dynamics**

**25**

**Total Lecture 20H**

Maxwell's electromagnetic field equations when medium in motion. Lorentz's force. The equations of motion of a conducting fluid. Basic equations. Simplification of the electromagnetic field equation. Magnetic Reynolds number. Alfven theorem. Magnetic body force. Ferraro's law of isorotation. Laminar Flow of a viscous conducting liquid between parallel walls in transverse magnetic fields. M.H.D. Flow Past a porous flat plate without induced magnetic field. MHD Couelte Flow under different boundary conditions, Magneto hydro dynamics waves. Hall currents. MHD flow past a porous flat plate without induced magnetic field. [20H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the basic concepts and the equations of flow of viscous fluids and the electromagnetic induction mechanism. and translate a magnetic hydrodynamic problem in an appropriate mathematical form and to interpret the solutions of the equations established in physical terms
- ii) The students would be able to apply system of equations to different astrophysical and laboratory phenomena

**References:**

1. P. A. Davidson, An Introduction to Magneto hydrodynamics, 2001, Cambridge University Press
2. Hosking, Roger J., Dewar, Robert, 2016, Fundamental Fluid Mechanics and Magneto hydrodynamics, Springer

## Unit-2: Stochastic Process and Regression

25

**Total Lecture 20H**

Stochastic Process: Markov chains with finite and countable state space. Classification of states. Limiting behaviour of  $n$  state transition probabilities. Stationary distribution. Branching process. Random walk. Gambler's ruin problem. Markov processes in continuous time. Poisson's process [15H]

Partial correlation. Multiple correlations. Advanced theory of linear estimation. [5H]

### Learning outcomes of the course:

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the basic of the theory of Markov chains and present proofs for the most important theorems and the differential equations for time continuous Markov processes with a discrete state space
- ii) The students would be able to derive the expression for three or more dimensional curve fitting, including multiple and partial correlations for relevant practical systems

### References:

1. A.M. Goon, M.K. Gupta & B. Dasgupta, Fundamentals of Statistics, Vol. 1 & 2, Calcutta : The World Press Private Ltd., 1968
2. J. Medhi, Stochastic Process, New Age International Publisher, 2ed, 1984.
3. Suddhendu Biswas, G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011

**MTM-404A**

**Special Paper-OM: Computational Oceanology**

50

**Total Lecture 40H**

Shallow water theory, Quasi-Homogeneous Ocean: Derivation of depth-averaged continuity equation, momentum equation and vorticity equation, Potential Vorticity, derivation of potential vorticity equation. [8H]

Analytical Approaches: Linear waves in the absence of rotation, effect of rotation, geostrophic adjustment, Sverdrup waves, inertial waves and Poincare waves, Kelvin waves at a straight coast, Planetary Rossby waves. [8H]

Computational Approaches: One-dimensional gravity waves with centered space differencing, Two-dimensional gravity waves with centered space differencing, The shallow-water equations with explicit-Euler Scheme, Implicit-Euler scheme, leap-frog schemes, Boundary conditions (Closed boundary conditions, Open boundary conditions Cyclic boundary conditions ) [11H]

Finite Volume Method: Equations with First order Derivatives Only, with second order Derivatives, The Finite Volume Method for Shallow Water Equations (one and two-





dimensional situation), First Order Upwind (FOU) and Lax-Friedrichs Schemes for the Shallow Water Equations, The Finite Volume Method for Diffusion Problems (Steady One-dimensional Condition with The Upwind Scheme, Unsteady One-Dimensional Condition, Two-And Three-Dimensional Situations), Convection and Diffusion Problems (one and two-dimensional situation). [13H]

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the solution of simple equations for the motion in the ocean analytically and numerically, and apply these to phenomena such as Shallow water, Kelvin waves at a straight coast
- ii) The students would be able to pursue higher studies, like M.Tech, Ph.D, in the area of computational fluid dynamics, computational oceanology and other allied computational areas.

**Reference:**

- 1. Waves in the Ocean, LeBlond, P. H., and Mysak, L. A., Elsevier 1978
- 2. Numerical Methods for Meteorology and Oceanology, KristoferDöös, Laurent Brodeau and Peter Lundberg Department of Meteorology, Stockholm University ([http://doos.misu.su.se/pub/numerical\\_methods.pdf](http://doos.misu.su.se/pub/numerical_methods.pdf))
- 3. Principle of Computational Fluid Dynamics, Pieter Wesseling, Springer,
- 4. Computational Technique for Fluid Dynamics, Vol.I, C A J Fletcher, Springer

**MTM-405A**

**Special Paper-OM: Dynamical Meteorology –II**

**25**

**Total Lecture 20H**

Surface of discontinuity, slope of frontal surface, pressure distribution near fronts, pressure trough at fronts, pressure tendency below frontal surface, condition for frontogenesis and frontolysis in a deformation field, geostrophic front. Global Circulation: Meridional temperature gradient, Jet stream, Rossby waves. Perturbation method: Gravity waves, Hurricane, Storm Surge, and Numerical Weather Prediction: Grid points, Finite difference equations, forecasting of potential temperature.

**Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the idea of global circulation in the atmosphere and some basic idea of turbulent motion in the atmosphere.
- ii) The students would be able to predict the atmosphere using the concept of front

**References:**

- 1. Dynamical and Physical Meteorology: George J. Haltiner and Frank L.Martin, McGraw Hill.
- 2. An introduction to Dynamical Meteorology: Holton J.R., Academic Press.

3. Physical and Dynamical Meteorology: D. Brunt, Cambridge University Press.
4. Atmospheric Thermodynamics: Iribarne, J.V. and Godson, W.L.

**MTM-495A**

**Special Paper-OM: Lab.( Dynamical Meteorology)**

**25**

**Total Lecture 40H**

Problems on Meteorology:

1. Surface temperature, pressure, humidity, Wind speed and direction measurements.
2. Rainfall and rain measurements.
3. TD charts-analysis.
4. T- diagram :
  - o Geopotential height by isotherm / adiabatic method.
  - o To find dry bulb and wet bulb temperature, potential, virtual, equivalent potential, dew point temperatures and mixing ratio.
5. Numerical method and computer techniques related to Meteorological problems, Handling and analysis of Meteorological data.
6. **Field work (5-marks) (compulsory):** Students should go to one of the University/Institute/Organization laboratory to understand experimental set-ups in advance meteorology (such as Annular experiment for existence of general circulation and Rossby wave, experiment for demonstrating Helmholtz instability, Aerosol measurements, Facsimile recorder for receiving weather charts etc.)

#### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) Determining of relative humidity, mixing ratio, virtual temperature, potential temperature etc., in the atmosphere which are very useful data in the research area of atmosphere.
- ii) Applications of thermodynamic diagram to analysis the stability in the atmosphere.

#### **References:**

1. Dynamical and Physical Meteorology: George J. Haltiner and Frank L.Martin, McGraw Hill.
2. An introduction to Dynamical Meteorology: Holton J.R., Academic Press.
3. Physical and Dynamical Meteorology: D. Brunt, Cambridge University Press.
4. Atmospheric Thermodynamics: Iribarne, J.V. and Godson, W.L.

**MTM-404B**

**Special Paper-OR: Nonlinear Optimization**

**50**

**Total Lecture 40H**

Optimization: The nature of optimization and scope of the theory, The optimality criterion of Linear programming, An application of Farka's theorem, Existence theorem for linear systems, Theorems of the alternatives, Slater's theorem of alternatives, Motzkin theorem of alternatives, Optimality in the absence of differentiability and constraint qualification, Karlin's constraint qualification, Kuhn-Tucker's saddle point necessary optimality theorem, Fritz-John

saddle point optimality theorem, Optimality criterion with differentiability and Convexity, Kuhn-Tucker's sufficient optimality theorem, Fritz-John stationary point optimality theorem, Duality in non-linear programming, Weak duality theorem, Wolfe's duality theorem, Duality for quadratic programming. [15H]

Quadratic Programming: Wolfe's modified simplex method, Beale's method, Convex programming. [6H]

Stochastic Programming: Chance constraint programming technique. [3H]

Geometric Programming: Geometric programming (both unconstrained and constrained) with positive and negative degree of difficulty. [5H]

Games: Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming). [6H]

Multi-objective Non-linear Programming: Introductory concept and solution procedure. [5H]

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the advanced concepts on Non-linear Optimization such as Geometric Programming, Quadratic Programming, Nash Equilibrium (John F. Nash got the Nobel prize in 1994 for this) of Bimatrix Game, Stochastic Programming, Multi-Objective Programming and the rest of these theoretical concepts on nonlinear programming.
- ii) The students would be able to solve complex mathematical modeling of various real-life practical problems, geometric programming for Engineering design problems and random parameters in optimization problems through stochastic programming.

### **References:**

1. Mokhtar S. Bazaraa, Hanif D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, 2006.
2. Olvi L. Mangasarian, Nonlinear Programming, Society for Industrial and Applied Mathematics, 1994.
3. S.S. Rao, Engineering Optimization: Theory and Practice, John Wiley & Sons, 1996.
4. Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2010.

**MTM-405B**

**Special Paper-OR: Operational Research Modelling-II**

**25**

**Total Lecture 20H**

Optimal Control: Performance indices, Methods of calculus of variations, Transversality Conditions, Simple optimal problems of mechanics, Pontryagin's principle (with proof assuming smooth condition), Bang-bang Controls. [5H]

Reliability: Concept, Reliability definition, System Reliability, System Failure rate, Reliability of the Systems connected in Series or / and parallel. MTBF, MTTF, optimization using reliability, reliability and quality control comparison, reduction of life cycle with reliability, maintainability, availability, Effect of age, stress, and mission time on reliability. [6H]

Information Theory: Introduction, Communication Processes— memory less channel, the

channel matrix, Probability relation in a channel, noiseless channel. [3H]

A Measure of information- Properties of Entropy function, Measure of Other information quantities — marginal and joint entropies, conditional entropies, expected mutual information, Axiom for an Entropy function, properties of Entropy function. Channel capacity, efficiency and redundancy. Encoding-Objectives of Encoding. Shannon-Fano Encoding Procedure, Necessary and sufficient Condition for Noiseless Encoding. [6H]

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) The students would gain knowledge about the role of O.R. in solving real life problems, the reliability of a component and a system of components, information theory and sources and causes of uncertainty including memory less and passing of information through different channels and Entropy and its measurement and properties.
- ii) The students would be able to solve the problem using Optimal Control theory. Also, gather the knowledge of Pontryagin's principle and Bang-bang Controls to solve mechanical and other real life problems

### **References:**

1. Swarup, K., Gupta, P.K and Man Mohan, Operation Research, Sultan Chand & Sons.
2. Sharma, J.K Operation Research – Theory and Application, Macmillan.
3. Gupta, P.K. and Hira, D.S., Operation Research, S. Chand & Co.Ltd.
4. Taha H.A., Operation Research –an Introduction, PHI.
5. Bronson, R. and Naadimuthu. G., Theory and problems of Operations Research, Schuam's Outline Series, MGH.

**MTM-495B Special Paper-OR: Lab. (OR methods using MATLAB andLINGO) 25  
Total Lecture 40H**

Problems on Advanced Optimization and Operations Research are to be solved by using MATLAB (one question carrying 9 marks) and LINGO (one question carrying 6 marks) (Total: 15 Marks)

1. Problems on LPP by Simplex Method.
2. Problems on LPP by Revised Simplex Method.
3. Problems on Stochastic Programming.
4. Problems on Geometric Programming.
5. Problems on Bi-matrix Games.
6. Problems on Queuing Theory.
7. Problems on QPP by Wolfe's Modified Method.
8. Problems on IPP by Gomory's Cutting Plane Method.
9. Problems on Inventory.
10. Problems on Monte Carlo Simulation Technique.
11. Problems on Dynamic Programming.
12. Problems on Reliability.

Field Work (Compulsory) (5 Marks)

Application for Optimization problems in real-life problem by visiting any Industry /University/Reputed Institution to understand the practical use of the optimization and making Lab Note Book on the experience gathered during the visit.  
Lab Note Book (must be written in handwriting) and Viva-Voce (Total: 5 Marks)

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) Collecting data from different sources for the real-life optimization problems. For collection of data, learners must visit one of the renowned laboratories and industry where such types of data are available.
- ii) In a nutshell, the learners will handle the real-life application of optimization problems. This course will be useful as Data Science to the learners in future.

**MTM-406**

**Dissertation Project Work**

**50**

Dissertation Project will be performed on Tutorial/ Review Work on Research Papers. For Project Work one class will be held in every week. Marks are divided as the following: Project Work-25, Presentation-15, and Viva-voce-10. Project Work of each student will be evaluated by the concerned internal teacher/supervisor and one External Examiner. The external examiner must be present in the day of evaluation.

### **Learning outcomes of the course:**

The student should have the following learning outcomes after completion of the course:

- i) Identify key research questions within the field of Demography on which you will carry out independent research.
- ii) Demonstrate appropriate referencing and develop skills in other aspects of academic writing.
- iii) Demonstrate knowledge and understanding of report writing.
- iv) Apply the demographic/statistical research training acquired in the taught element of the programme by designing an appropriate research strategy and research methodology to carry out your research.
- v) Use and develop written and oral presentation skills.
  
- vi) Identify, summaries and critically evaluate relevant literature and write a literature review of the relevant field.
- vii) Identify, analyse and interpret suitable data to enable the research question to be answered.
- viii) Understand and apply theoretical frameworks to the chosen area of study.
- ix) Describe the process of carrying out independent research in written format and report your results and conclusions with reference to existing literature.

x) Analyse and synthesise research findings.