Vidyasagar University

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 A**PPLIED 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
			TOTAL	300	24
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	*STATISTICAL AND NUMERICAL METHODS*	50	4
		C-MTM 204B	*HISTORY OF MATHEMTICS*		
	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
			TOTAL	300	24
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		
			TOTAL	300	24
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
			TOTAL	300	26
			GRAND TOTAL	1200	98

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

Semester-I

Course No.	*Topics*	*Marks*	No. of Lectures (Hours)	Credit
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

Course No.	*Topics*	*Marks*	No. of Lectures (Hours)	Credit
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

Course No.	*Topics*	*Marks*	No. of Lectures (Hours)	Credit
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

Course No.	*Topics*	*Marks*	No. of Lectures (Hours)	Credit
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)

- Ø On an average each year 12 students qualified NET and 10 students qualified GATE. For example, in the academic year 2017-18: NET=18 and GATE= 10, SET (WB)=4.
- Ø Students go for higher studies (M.Tech&Ph.D) in different Institutions in India and Abroad. For example, in the academic year 2017-18: Six students went for M.Tech at IIT Kharagpur, and Fifteen students are doing Ph.D(One @ ISI Calcutta, One @ NISER Bhubaneswar, One @ IIT Kharagpur, One@ IIT Patna, Three @ Jadavpur University, One @ Calcutta University, Seven @ Vidyasagar University).
- Ø Students get jobs (Govt./ Non-Govt.) through off-campus selection in teaching, Software Company, rail etc. Mostly they are absorbed in teaching position in Schools, College, University (in India and Abroad), IITs, and NITs.

Semester-I

MTM-101 **Real Analysis** **50**

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

Functions of bounded variation, R-S Integral.

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.

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.

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 Lebesgueintegrable function, Fatou's lemma. Classical Lebesgue dominated convergence theorem. Monotone convergence theorem, Relation between Lebesgue integral and Riemann integral

Learning outcomes of the course:

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

- Ø Understand compactness, completeness and connectedness of metric spaces.
- Ø Verify whether a function is a function of bounded variation and find the R-S integral ofa bounded function.
- Ø Understand the fundamentals of measure theory and be acquainted with the proofs of thefundamental theorems underlying the theory of integration like Lebesgue integration.
- Ø They will develop a perspective on the broader impact of measure theory and have the ability to pursue further studies in this and related area.

References:

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

MTM-102 Complex Analysis 50

The definition of an analytic function. Cauchy- Riemann differential equation. Construction of analytic function. Jardan 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.

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

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

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

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

The Schwarz–Christoffel Transformation: Mapping the Real Axis Onto a Polygon, Schwarz–Christoffel Transformation, Triangles and Rectangles, Degenerate Polygons.

Learning outcomes of the course:

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

- Ø The fundamental concepts of complex analysis and their role in modern mathematics and applied contexts
- Ø Accurate and efficient use of complex analysis techniques
- Ø Mathematical reasoning through analyzing, proving andexplaining concepts from complex analysis
- Ø Problem-solving using complex analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts.

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.

MTM-103 Ordinary Differential Equations and Special Functions 50

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.
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.
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.
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.
Green's Function:Green's Function and its properties, Green's function for ordinary differential equations, Application to Boundary Value Problems.
Eigen Value Problem: Ordinary differential equations of the Strum-Liouville type, Properties of
Strum Liouville type, Application to Boundary Value Problems, Eigen values and Eigen functions, Orthogonality theorem, Expansion theorem.
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.

Learning outcomes of the course:

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

- Many real-life problems are designed based on the ordinary differential equations where eigenvalues and eigen functions play major role. On solving the SL problem, a broad idea can be carried on eigen value and eigen function which help lot to solve real-life problems.
- Green's function is an effective technique for solving complex initial and boundary value problemsinvolving differential equations.
- Nowadays complex real-life problems cannot be designed only single differential equation, so a system of linear differential equations is very much essential for modeling this type of problem.
- In this content, learners mainly achieve the solution procedure of special type differential equations which have many applications in engineering design problems and these are more related with real-life complex problems also.

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, 3rd 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

Programming in C:Review of basic concepts of C programming**,** Arrays, structureandunion, Enum, pointers, pointers and functions, pointers and arrays, array of pointers, pointers and structures, strings and string handling functions, Dynamic memory allocation: using of malloc(), reallc(), calloc() and free(), file handling functions: use of fopen, fclose, fputc, fgets, fputs, fscanf, fprintf, fseek, putc, getc, putw, getw, append, low level programming and C pre-processor: Directive, #define, Macro Substitution, conditional compilation, #if, #ifdef, #ifndef, #else, #endif.
Programming in MATLAB:TheMatlab workspace, data types, variables, assignmentstatements, 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.

Learning outcomes of the course:

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

- Ø The features of numeric computation, advanced graphics and visualization using MATLAB.
- Ø Arrays and matrices to solve the various types of problems such as algebraic, differential, statistical, plotting etc using MATLAB.
- Ø Pointers in function, structure, union, dynamic memory management to construct linked list using C Language.
- Ø Apply 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; programming using C language.

References:

1. Balagurusamy E. programming in ANSI C. Tata McGraw-Hill Education; 2012.
2. Byron Gottfried and JitenderChhabra, 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

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

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

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.

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

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.

Learning outcomes of the course:

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

- Ø The Lagrangian formulation to analyze problems in Mechanics and describe the dynamics of systems of particles, rigid bodies, and systems in noninertial reference frames.
- Ø Deconstruct complex problems into their building blocks. Translate physical problems into appropriate mathematical language and apply appropriate mathematical tools to analyze and solve the resulting equations.
- Ø Demonstrate the ability to apply basic methods of classical mechanics towards solutions of various problems, including the problems of complicated oscillatory systems, the motion of rigid bodies, etc.
- Ø Can solve some mathematical problems using vibrational principle.
- Ø Using Lorentz transformation the student will describe the physical situations in inertial frames of reference.
- Ø Knowledge above special theory of relativity frames of reference using Lorentz transformation.
- Ø Understanding of some fundamental problems of non-linear dynamics.

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.

Graph Theory **25**

MTM-106

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. Matrix representation of graphs, Algorithms for shortest path and spanning trees, Intersection graph, Applications of graphs in operations research.

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

- Ø Understand and apply the fundamental concepts in graph theory.
- Ø Describe and solve some real time problems using concepts of graph theory.
- Ø Discuss the concept of graph, tree, Euler graph, cut set and Combinatorics.
- Ø Apply graph theory based tools in solving practical problems in science, business and industry.

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.

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:

- An introduction to MATLAB and it is based on interactive examples and hands-on problemsolving.
- The utility of basic MATLAB anditsdemonstration.
- Matrix manipulations, plotting of functions and data implementation of algorithms, the creation of user interfaces, andinterfacing with programs written in other languages.
- 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**

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)
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.
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).

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-Poisseuille flow, Flow of a Viscous Fluid with Free Surface on an Inclined Plate)

Incompressible Viscous Flows via Finite Difference Methods: Variable arrangement (Cell center / Collocated arrangement or Staggered Gird), One-Dimensional Computations by Finite Difference Methods, Space discresiation (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.

Learning outcomes of the course:

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

- Solve hydrostatic problems.
- Describe the motion of fluids and identify the derivation of basic governing equations of fluid mechanics and apply.
- Make dimensional analysis and similitude.
- Know boundary layer theory.
- Finding the exact/analytical Solution of Navier-Stokes equation for some physical problems.
- Know the preliminary computational techniques for the Navier-Stokes equation.

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^{th} Edition), Frank M. White, WCB McGraw-Hill
4. Boundary Layer Theory, Hermann Schlichting, McGraw-Hill Book Company
5. Computational Fluid Dynamics, 2^{nd} Ed, T. J. Chung, Cambridge University Press

MTM-202 Numerical Analysis 50

Cubic spline interpolation. Lagrange's bivariate interpolation. Approximation of function. Chebyshev polynomial: Minimax property. Curve fitting by least square method. Use of orthogonal polynomials. Economization of power series.

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

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.

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.

Eigenvalue problem. Power method. Jacobi's method.

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.
Partial differential equation: Finite difference scheme. Parabolic equation: Crank-Nicolson method. Iteration method to solve Elliptic and hyperbolic equations.

Learning outcomes of the course:

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

- Ø The numerical methods for interpolation (spline interpolation).
- Ø Function approximation by least square method and using orthogonal polynomials and Gaussian quadrature.
- Ø The solution of ordinary differential equations (RK-methods, predictor-corrector method, finite difference method, finite element method)
- Ø The solution of system of linear and non-linear equations and matrix inversion with pivoting.
- Ø Computation of eigenvalues and eigenvectors of a matrix.
- Ø The solution of partial differential equations (finite difference method) and analysis of stability of the methods to solve ODEs and PDEs.
- Ø Some computer programs will learn in this course. The programming skill will increase after this course. Hence, they can write computer program of any mathematical and logical problems.

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, Numeical Methods for Mathematics, Science, and Engineering, 2nd 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

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.
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.
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.

Learning outcomes of the course:

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

- Analyze and demonstrate examples of quotient groups, solvable groups and properties of them.
- Use the concepts of isomorphism and homomorphism for groups and rings and relatedtheorems.
- Understand the importance of class equation, Cauchy's theorem, Sylow's theorem, Cayley's theorem and group action.
- Analyze and demonstrate examples of ideals, quotient rings and field extensions.

References:

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

Unit-2: Linear Algebra 25

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, Diagonlization.
Canonical Forms: Triangular canonical form, Nilpotent transformations, Jordan canonical form, The rational canonical form.
Inner product spaces, Hermitian, Unitary and Normal transformations, Spectral theorem.
Bilinear forms, Symmetric and Skew-symmetric bilinear forms, Sylvester's law of inertia.

Learning outcomes of the course:

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

- Gain knowledge on advanced concept of Linear Transformation, Inner product space, Bilinear forms, Quadratic forms, Canonical forms, Minimal polynomial and Jordan Canonical forms.
- How to apply linear algebra for solving many problems on Applied Mathematics and several physics-oriented applied problems.
- More concepts on eigen values and eigen vectors which helps a lot for solving many real-life problems.

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

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.
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. 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.

Learning outcomes of the course:

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

- Apply method of interpolation and extrapolation for prediction, recognize elements and variable in statistics and summarize qualitative and quantitative data.
- Recognize 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.
- Process 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.
- 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**

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, 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 Mensuration, Number Theory, Survival and Influence of Greek Mathematics. 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 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, 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

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

- A general idea of the evolution of some of the major concepts of modern mathematics.
- Understand basic, fundamental arguments that were developed centuries ago and are still of central importance today.
- Concepts from geometry (such as Euclid’s constructions) and analysis (such as limit) should be understood.
- Solve different problemsto 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**

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.

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.

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.

Learning outcomes of the course:

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

- Ø The concept of strain deformation of an object as a continuum which assumes that the substance of the object completely fills the space it occupies.
- Ø The knowledge about stress vector which is applied on material points in an object.
- Ø The relationship between strain tensor and stress tensors in an elastic substance
- Ø 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: Gedrge R. Mase, McGraw Hill.
3. Mathematical Theory of Continuum Mechanics: R.N.Chatterjee, Narosa Publishing House.
4. Continuum Mechanics: A.J.M. Spencer, Longman.

25

MTM-206 **General Topology**

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.

Connectedness and Compactness: Connected spaces, connected subspaces of the real line, Components and local connectedness, Compact spaces, Local–compactness, Tychnoff's Theorem on compact spaces.

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

Urysohn Lemma, UrysohnMetrization Theorem, Tietze Extension theorem (statement only).

Learning outcomes of the course:

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

- How the topology on a space is determined by the collection of open sets, by thecollection of closed sets, or by a basis of neighborhoods at each point.
- Subspace topology, order topology, product topology, metric topology andquotient topology.
- What it means for a function to be continuous.
- Urysohn lemma and the Tietze extension theorem, and can characterizemetrizable spaces.

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 InternationalPrivate 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 NumericalMethods) 25

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.

String manipulation:No of occurrence of a letter in a given string, Palindrome natureof 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.

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.

Statistical Problems:

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

Learning outcomes of the course:

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

- Interactive examples and hands-on problem solving environment.
- The course is to demonstrate searching, sorting and strings manipulation problems.
- Demonstrate numerical and statistical problems in C.
- 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, 3rd ed., PHI.
3. Kanetkar, V. (2017) Let Us C, 16th ed., BPB Publications.
4. Pal, M. (2007) Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa.

Semester-III

MTM-301 Partial Differential Equationsand Generalized Functions 50

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.
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.
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'sandNaumann's problems. Green's functions for the Laplace's equations in two dimensions. Solution of Dirichlet's and Naumann's problem for some typical problems like a disc and a sphere. Poisson's general solution.
Parabolic equations:Heat equation - Heat conduction problem for an infinite rod - Heat conduction in a finite rod - existence and uniqueness of the solution.
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.

Learning outcomes of the course:

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

- Use the knowledge of first and second order partial differential equations (PDEs), thegeneral structure of solutions, and analytic methods for solutions.
- Classify PDEs, apply analytical methods, and physically interpret the solutions.
- Solve practical PDE problems (Wave, Heat & Laplace equations) with the methods ofseparation of variables, and analyze the stability and convergence properties of thismethod.
- Find solution of Dirichlet's and Neumann's problem for some typical problems like a discand 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, 3rd 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 IntegralEquations 50

Fourier Transform:Fourier Transform, Properties of Fourier transform, Inversion formula, Convolution, arseval's relation, Multiple Fourier transform, Bessel's inequality, Application of transform to Heat, Wave and Laplace equations (Partial differential equations).
Laplace Transform:Laplace Transform, Properties of Laplace transform, Inversion formula of Laplace transform (Bromwich formula), Convolution theorem, Application to ordinary and partial differential equations.
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.
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.

Learning outcomes of the course:

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

- Laplace and Fourier transforms are the powerful tools for solving realistic problems of ODE and PDE, particularly IVP or BVP.
- PDE is very difficult to solve directly but using these transforms, PDE is reduced to an

ODE and then ODE is reduced to an algebraic equation, which is very easy to find the solution.

- Wavelet transform is another transform technique with the special advantage that it provides more accurate solution which helps to determine the exact location of the solution. Specifically, scientist and engineers use the wavelet transform for determining the exact location of an area where the natural gases such as oil and various minerals exist.
- Integral equation is an important concept in Applied Mathematics to find the unknown function within the integral sign. Many dynamical problems and applied based practical problems can be solved with the help of Integral equation.

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

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;

The Equation of Continuity of Volume: The concept of continuity of volume, The derivation of the equation of continuity of volume.

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.

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,Virtualtemperature, 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.

Learning outcomes of the course:

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

- Numerical modelingof ocean currents and transport, analytical models of physical processes in the ocean, as e.g. wave driven surface currents.
- Field observations of currents, internal waves and optical conditions, optical models related to monitoring of water quality based on satellite data.
- Modelling and use of observations to understand 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.
- Numerical 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 0X2 8DP
2. Dynamical and Physical Meteorology: George J. Haltiner and Frank L.Martin, McGraw Hill

Unit-2: Operations Research 25

Inventory control: Deterministic Inventory control including price breaks and Multi-item with constraints.

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).

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

Learning outcomes of the course:

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

- Demonstrate and solve the different types of deterministic inventory related problems.
- Can solve the problems involving queuing system.
- Demonstrate 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.

C-MTM-304 Discrete Mathematics 50

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. Proposional Logic, Tautology
Sets and propositions: Cardinality. Mathematical Induction. Principle of Inclusion and exclusion.
Computability and Formal Languages: Ordered Sets. Languages. Phrase Structure Grammars. Types of Grammars and Languages.
Finite State Machines: Equivalent Machines. Finite State Machines as Language Recognizers.
Partial Order Relations and Lattices: Chains and Antichains.
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.
Analysis of Algorithms: Time Complexity. Complexity of Problems. Discrete Numeric Functions and Generating Functions.

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

- Simplify and evaluate 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.
- Represent a graph using an adjacency list and an adjacency matrix and apply graph theory to application problems such as computer networks.
- Determine if a graph is a binary tree,Euler or a Hamilton path or circuit, N-ary tree, or not a tree.
- 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.DeoGraph Theory with Applications to Engineering and Computer Science (Dover Books on Mathematics
4. B.D west:

MTM-305A Special Paper-OM: Dynamical Oceanology 50

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,
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

Vorticity and Circulation:Vorticity, Circulation, Kelvin's theorem for barotropic fluid, Vortex line and Vortex tube, Helmholtz's theorem, Vorticity equation, Physical Interpretation, Baroclinicvorticity equation.

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.

Learning outcomes of the course:

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

- The Role of the Non-linear Terms and the Magnitudes of Terms in the Equations of Motion,
- How to solve a physical problem of Ocean Currents without Friction (Geostrophic Flow) and Currents with Friction (Wind-driven Circulation),
- Different subareas of Oceanology where s/he can pursue higher studies, like M.Tech, Ph.D.

References:

1. Introductory Dynamical Oceanology, 2nd Ed, Pond, Stephen; Pickard, George L., Butterworth-Heinemann Ltd Linacre House, Jordan Hill, Oxford 0X2 8DP
2. Ocean Circulation Theory, Joseph Pedlosky, Springer
3. Fluid Mechanics (4th Edition), Frank M. White, WCB McGraw-Hill

MTM-306A Special Paper-OM: Dynamical Meteorology -I 50

Thermodynamics of the atmosphere: Adiabatic lapse rate for moist unsaturated air, The effect of Ascent and descent on lapse rare and stability,TheClausius – 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.

Purpose and use of Aerological diagrams, Area Equivalence, properties of Tephigram, Clapeyron diagram, Emagram

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.

Learning outcomes of the course:

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

- Different thermodynamics laws to be applied in the atmosphere to get a state of dry and moist air in the atmosphere.

- Ø The understanding of the basic physical processes occurring in the atmosphere in mathematical perspective.
- Ø Some knowledge about global circulation in the atmosphere.
- Ø The primary scientific basis for weather and climate prediction, and thus plays a primary role in the atmospheric sciences.

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

Revised simplex method (with and without artificial variable). Modified dual simplex.
Large Scale Linear Programming: Decomposition Principle of Dantzig and Wolf.
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.
Search Methods: Fibonacci and golden section method.
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.
Integer Programming:Gomory's cutting plane algorithm, Gomory's mixed integer problem algorithm, A branch and bound algorithm.
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.
Optimization for Several Variables: Algebraic approach, Algebraic geometrical approach, cost – different approach, Inequality approach.

Learning outcomes of the course:

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

- Ø Identify and develop operational research models from the verbal description of the real system.
- Ø Understand the mathematical tools that are needed to solve optimization problems.
- Ø Use of mathematical software to solve the proposed models.
- Ø Develop a report that describes the model and the solving technique, analyze the results and propose recommendations in language understandable to the decision-making processes in Management Engineering.

References:

1. S. S. Rao. Engineering optimization: theory and practice. John Wiley & Sons, 2009.
2. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.

3. Belegundu, Ashok D., and Tirupathi R. Chandrupatla. Optimization concepts and applications in engineering. Cambridge University Press, 2011.
4. Sharma, S. D. Operations Research, KedarNath Ram Nath& Co., Meerut.

MTM-306B Special Paper-OR: Operational Research Modelling-I 50

Dynamic Programming:Introduction,Nature of dynamic programming, Deterministic processes, Non-Sequential discrete optimization, Allocation problems, Assortment problems, Sequential discrete optimization, Long-term planning problem, Multi-stage decision process, Application of Dynamic Programming in production scheduling and routing problems.

Inventory control:Probabilistic inventory control (with and without lead time), Dynamic inventory models. Basic concept of supply – chain management and two echelon supply chain model.

Network: PERT and CPM:Introduction, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis, Probability in PERT analysis, Project Time-Cost, Trade-off, Updating of the project, Resource allocation — resource smoothing and resource leveling.

Replacement and Maintenance Models:Introduction, Failure Mechanism of items, Replacement of items deteriorates with time, Replacement policy for equipments when value of money changes with constant rate during the period, Replacement of items that fail completely— individual replacement policy and group replacement policy, Other replacement problems — staffing problem, equipment renewal problem.

Simulation:Introduction, Steps of simulation process, Advantages and disadvantages of simulation, Stochastic simulation and random numbers— Monte Carlo simulation, Random number, Generation, Simulation of Inventory Problems, Simulation of Queuing problems, Role of computers in Simulation, Applications of Simulations.

Learning outcomes of the course:

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

- Formulate mathematical models for uncertain inventory control supply chain and replacement management problems, Network analysis, etc.
- Understand the techniques likedynamic programming, simulation processto solve a large number of optimization problems.
- Can solve linear and non-linear optimization problems.
- Application of simulation to solve problems in inventory management system, queuing theory and others

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**

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. Quotioent of normed linear spaces and its consequences. Hahn-Banach Extension theorem and Its applications. Banach spaces. A NLS is Banachiff every absolutely convergent series is convergent. Conjugate spaces, Reflexive spaces.
Uniform Boundedness Principle and its applications. Closed Graph Theorem, Open Mapping Theorem and their applications.
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.
Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related simple theorems.

Learning outcomes of the course:

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

- How functional analysis uses and unifies ideas from vector spaces, the theoryof metrics, and complex analysis.
- Applications of fundamental theorems from the theory of normed and Banachspaces, including the Hahn-Banach theorem, the open mapping theorem, the closed graphtheorem, and the Uniform Boundedness principle.
- Apply ideas from the theory of Hilbert spaces to other areas, includingFourier series, the theory of self-adjoin operators, normal operators, unitary operators and positive operators.
- Apply Hilbert space theory, including Riesz representation theorem and weakconvergence, and critically reflect over chosen strategies and methods in problem solving.

References:

1. B.V. Limaye, Functional Analysis, 2nd Edition, New Age InternationalPrivate Limited New Delhi, 2014.
2. J. B. Conway, A Course in Functional Analysis, 2nd Edition, Springer-Verlag New York, 1985.
3. E. Kreyzig, 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.

Basic concept and definition of fuzzy sets. Standard fuzzy sets operations and its properties. Basic terminologies such as Support, α-Cut, Height, Normality, Convexity, etc.

Fuzzy relations, Properties of α-Cut, Zadeh's extension principle, Interval arithmetic, Fuzzy numbers and their representation, Arithmetic of fuzzy numbers.

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

Linear Programming Problems with fuzzy resources:

(i) Vendegay's approach

(ii) Werner's approach

L.P.P. with fuzzy resources and objective: Zimmermann's approach.

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

Learning outcomes of the course:

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

- Some fundamental knowledge of fuzzy sets, numbers, matrix, ordinary differential equation and programming, etc.
- Acquire knowledge of various operations on above fuzzy sets.
- Solving the fuzzy ordinary differential equation, fuzzy linear programming problems, and fuzzy multi-objective linear programming problems.
- Some fundamental uncertain programming solving skill which occur almost all decision making problems.

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 **25**

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.

Learning outcomes of the course:

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

- Understanding the basic conceptsSoft computing like how it resemble biological processes more closely than traditional techniques.

- Ø Understandingthe basic neural network models and illustrate with numerical examples.
- Ø Understand the fuzzy logic and system control with help of fuzzy controller.
- Ø Understand genetic algorithm and hands on solving optimization problems.

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

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.

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

- Ø The basic concepts and the equations of flow of viscous fluids and the electromagnetic induction mechanism.
- Ø Ability to translate a magnetic hydrodynamic problem in an appropriate mathematical form and to interpret the solutions of the equations established in physical terms.
- Ø Skills in analysis and synthesis; the application of knowledge and problem solving, critical thinking and independent learning.
- Ø System of equations can be applied to different astrophysical and laboratory phenomena.

References:

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

Unit-2: Stochastic Process and Regression 25

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 Partial correlation. Multiple correlations. Advanced theory of linear estimation.

Learning outcomes of the course:

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

- Ø Define basic concepts from the theory of Markov chains and present proofs for the most important theorems.
- Ø Compute probabilities of transition between states and return to the initial state after long time intervals in Markov chains.
- Ø Derive differential equations for time continuous Markov processes with a discrete state space.
- Ø Formulate simple stochastic process models in the time domain and provide qualitative and quantitative analyses of such models.
- Ø Acquired more detailed knowledge about Poisson processes and birth and death processes. The student also knows about Wiener Process and branching process.
- Ø 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. SuddhenduBiswas, G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011

MTM-404A Special Paper-OM: Computational Oceanology 50

Shallow water theory, Quasi-Homogeneous Ocean:Derivationofdepth-averaged continuity equation, momentum equation and vorticity equation, Potential Vorticity, derivation of potential vorticity equation.

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.

Computational Approaches: One-dimensional gravity waves with centred space differencing, Two-dimensional gravity waves with centred 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)

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).

Learning outcomes of the course:

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

- Ø Solving 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.
- Ø Different computational methodology where s/he can 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)
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

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: Meridionaltemperature 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:

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

- Ø The concept of front which is very useful in prediction
- Ø The idea of global circulation in the atmosphere
- Ø The phenomena of numerical prediction in the atmosphere
- Ø The some basic idea of turbulent motion 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-495A Special Paper-OM: Lab.(Dynamical Meteorology) 25

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 :
   - Geopotential height by isotherm / adiabatic method.
   - 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 Meterological 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:

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

- 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.
- 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

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.
Quadratic Programming:Wolfe's modified simplex method, Beale's method, Convex programming.
Stochastic Programming:Chance constraint programming technique.
Geometric Programming:Geometric programming (both unconstrained and constrained) with positive and negative degree of difficulty.
Games:Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming).
Multi-objective Non-linear Programming:Introductory concept and solution procedure.

Learning outcomes of the course:

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

- Ø There are several 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.
- Ø To help the learners for solving complex mathematical modeling of various real-life practical problems.
- Ø To use the geometric programming for solving Engineering design problems.
- Ø Tackling of random parameters in optimization problems through stochasticprogramming.

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

Optimal Control:Performance indices, Methods of calculus of variations, Transversally Conditions, Simple optimal problems of mechanics, Pontryagin's principle (with proof assuming smooth condition), Bang–bang Controls.
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.
Information Theory:Introduction, Communication Processes— memory less channel, the

channel matrix, Probability relation in a channel, noiseless channel.
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.

Learning outcomes of the course:

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

- Have the knowledge of role of O.R. in solving real life problems.
- Prepare and motivate future specialists to continue in their study by having an insightful overview of operations research.
- Understand the technique 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.
- Thorough understanding of reliability of a component and a system of components. The mathematical investigation is also performed.
- Understanding of information theory and sources and causes of uncertainty. Knowledge of memory less and passing of information through different channels.
- Entropy and its measurement and properties.
- Knowledge of Shannon-Fano Encoding procedure and necessary and sufficient condition for noiseless encoding.

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

Problems on Advanced Optimization and Operations Researchare 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:

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

- Collectingdata 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.
- 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 ResearchPapers. 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:

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

- Identify key research questions within the field of Demography on which you will carry out independent research.
- Demonstrate appropriate referencing and develop skills in other aspects of academic writing.
- Demonstrate knowledge and understanding of report writing.
- 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.
- Use and develop written and oral presentation skills.

- Identify, summarise and critically evaluate relevant literature and write a literature review of the relevant field.
- Identify, analyse and interpret suitable data to enable the research question to be answered.
- Understand and apply theoretical frameworks to the chosen area of study.
- Describe the process of carrying out independent research in written format and report your results and conclusions with reference to existing literature.
- Analyse and synthesise research findings.