Vidyasagar University

Midnapore-721102, West Bengal

The SYLLABUS for
POST-GRADUATE Programme

in

Applied Mathematics with Oceanology and Computer Programming

(up to 2023-24)

From the session 2024-25
The degree will be awarded only on Applied Mathematics

Under Choice Based Credit System (CBCS)
(Semester Programme)

[w.e.f. 2022-23]

Preamble

Post-Graduate (M. Sc.) in Applied Mathematics deals with a deeper knowledge of advanced Mathematics through a vast preference on optimization theory, graph theory, uncertainty theory, theory of computation, computational fluid dynamics, random theory, epidemiology and other topics of Applied Mathematics. This M.Sc of two years duration was initiated under the Faculty of Science of Vidyasagar University from its inception in the year 1985. The Ph.D. programme was also started as well in the year 1998 in Mathematics. So far around 120 scholars have completed their Ph. Research works from this department. The Choice-Based Credit System (CBCS) was initiated in the year 2018. The syllabus also emphasizes pure mathematics as well as almost all the national-level competitive exams, like, CSIR-NET, UGC-NET and GATE exams, as well as the State level competitive exam SET. This course provides training in different aspects of Applied Mathematics, equipping with a range of mathematical skills in problem-solving, project work and presentation. Through project work, which is assigned to the student at the beginning of the fourth semester, students undertake independent research works in their chosen area. The information and communication technology (ICT) enabled smart classrooms, virtual classrooms, computer programming laboratory, departmental library and efficient faculties enrich this department. This department is sponsored by the Department of Science and Technology (DST), Government of India for the improvement of departmental computer laboratory and classroom infrastructure. Various Computer Algebra System (CAS) software's such as Mathematica, MATLAB and LINGO are integrated part of the syllabus of M.Sc to strengthen the conceptual understanding and widen up the horizon of students' by self-experience and skill development. The thrust areas of Research in this department are Optimization & Operations Research, Fuzzy Mathematics, Fluid Dynamics and allied topics.

Program Outcomes (POs)

Post Graduates (M. Sc.) students, after completion of the program, will be able to achieve:

1. Students will be able to read, interpret, critically analyze and discuss scientific papers/articles from course/research projects/peer-reviewed journals and hence disseminate critically reasoned results via oral and written communication in the form of reports, papers and presentations.
2. Different mathematical tools such as mathematical modelling on optimization theory, graph theory, uncertainty theory, theory of computation, epidemiology, random theory and other tools will help students to challenge the aforementioned problems.
3. Students will be able to solve industry-related problems, apply the curriculum of applied mathematics, and develop effective models of real-life phenomena in the context of solving real-world problems.
4. Various types of real-life problems can be solved by using the methodology of Operations Research
5. Students will demonstrate the ability to recognize when scientific or numerical computation is necessary to solve a problem and the ability to perform such computations using modern tools such as MATLAB, MATHEMATICA, LINGO, etc.
6. In the daily operation of weather forecasts, students will be able to predict the weather by solving mathematical equations that model the atmosphere and oceans.
7. The students can succeed in the national- and state-level examinations for higher study.
8. They can confidently teach the students of any higher education institutes (like IITs, NITs, universities, colleges, etc.) as well as schools.
9. Students will also be able to complete a project in a team or group setting.

Programme Specific Outcomes (PSOs)

The M. Sc. in Applied Mathematics course enables the students to enhance computational skills and Mathematical reasoning. The program develops the ability to think critically, logically and analytically thereby preparing the students to enhanced career opportunities in teaching institutes, finance-related works, education and research.

1. Understanding of the fundamental axioms in mathematics and capability of developing ideas based on them.
2. Inculcate mathematical reasoning in interdisciplinary fields.
3. Prepare and motivate students for research studies in mathematics and related fields enhance self-learning and improve their own performance.
4. Provide advanced knowledge on topics in Pure and Applied Mathematics, empowering the students to pursue higher degrees at reputed academic institutions.
5. Nurture problem-solving skills, thinking, and creativity through assignments, project work, etc.
6. Assist students in preparing for competitive exams e.g. NET, GATE, SET, NBHM, etc.

CONTENT:

SEMESTER	COURSE	COURSE TITLES	FULL MARKS	No. of Lectures (hours)	CREDIT (Lecture – Tutorial - Practical)
I	MTM-101	Real Analysis	50	40	4 (3-1-0)
	MTM-102	Complex Analysis	50	40	4 (3-1-0)
	MTM-103	Ordinary Differential Equations And Special Functions	50	40	4 (3-1-0)
	MTM-104	Advanced Programming in C and MATLAB	50	40	4 (3-1-0)
	MTM-105	Classical Mechanics and Non – linear Dynamics	50	40	4 (3-1-0)
	MTM-106	Graph Theory	25	20	2 (2-0-0)
	MTM-197	Lab.1: (Computational Methods: Using MATLAB)	25	20	2 (0-0-4)
	TOTAL		**300**	**240**	**24**
II	MTM-201	Fluid Mechanics	50	40	4 (3-1-0)
	MTM-202	Numerical Analysis	50	40	4 (3-1-0)
	MTM-203	Unit-1: Abstract Algebra	25	20	2 (2-0-0)
		Unit-2: Linear Algebra	25	20	2 (2-0-0)
	C-MTM-204A/ C-MTM-204B	Statistical and Numerical Methods/ History of Mathematics	50	40	4 (3-1-0)
	MTM-205	General Theory of Continuum Mechanics	50	40	4 (3-1-0)
	MTM-206	General Topology	25	20	2 (2-0-0)
	MTM-297	Lab. 2: (Language: C-Programming with Numerical Methods)	25	20	2 (0-0-4)
	TOTAL		**300**	**240**	**24**
	MTM-301	Partial Differential Equations and Generalized Functions	50	40	4 (3-1-0)

III	MTM-302		Transforms and Integral Equations	50	40	4 (3-1-0)
	MTM-303		Unit-1: Stochastic Process and Regression	25	20	2 (2-0-0)
			Unit-2: Cryptography	25	20	2 (2-0-0)
	C-MTM-304		Discrete Mathematics	50	40	4 (3-1-0)
	MTM305	A	Advanced Optimization	50	40	4 (3-1-0)
		B	Dynamical Meteorology: Thermodynamics in Atmosphere	50	40	4 (3-1-0)
		C	Linear and Non-Linear Dynamical Systems	50	40	4 (3-1-0)
	MTM306	A	Operational Research Modelling-I	50	40	4 (3-1-0)
		B	Dynamical Oceanology: Advanced Wave Hydrodynamics	50	40	4 (3-1-0)
		C	Computational Fluid Dynamics	50	40	4 (3-1-0)
	TOTAL			**300**	**240**	**24**
IV	MTM-401		Functional Analysis	50	40	3-1-0
	MTM-402		Unit-1: Fuzzy Mathematics	25	20	2 (2-0-0)
			Unit-2: Magneto Hydro-Dynamics	25	20	2 (2-0-0)
	MTM-403		Soft Computing	25	20	2 (2-0-0)
	MTM404	A	Nonlinear Optimization	25	20	2 (2-0-0)
		B	Dynamical Meteorology: Dynamics in Atmosphere	25	20	2 (2-0-0)
		C	Mathematical Modelling in Population Ecology and Epidemiology	25	20	2 (2-0-0)
	MTM497	A	Lab : Optimization (Methods using MATLAB and LINGO)	25	20	2 (0-0-4)
		B	Lab: Meteorology	25	20	2 (0-0-4)
		C	Lab: Bio-Mathematics	25	20	2 (0-0-4)
	MTM405	A	Operations Research Modelling-II	25	20	2 (2-0-0)
		B	Dynamical Oceanology: Coastal Processes	25	20	2 (2-0-0)

		C	Computational and Semi-Analytical Methods	25	20	2 (2-0-0)
	MTM498	A	Lab: Operational Research (OR methods using MATLAB and LINGO) (Skill development course)	25	20	2 (0-0-4)
		B	Lab: Dynamical Oceanology	25	20	2 (0-0-4)
		C	Lab: Semi-Analytical and Computational Methods (using Mathematica): Skill developments	25	20	2 (0-0-4)
	MTM499		Lab: Soft computing techniques using MATLAB	25	20	2 (0-0-4)
	MTM406		Dissertation Project Work	50	40	4 (0-0-8)
	TOTAL			**300**	**240**	**24**
	GRAND TOTAL			**1200**		**96**

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 examinations.

2. Each student has to choose one Elective paper from each of the series MTM 305, MTM 306, MTM 404, MTM 405, MTM 497, MTM 498, (i.e: if a student would like to opt MTM 305 A, then he has to choose MTM 306A, MTM 404A, MTM 405A, MTM 497A, MTM 498A; it means, A series from each category will be selected for the candidates randomly). Elective Paper will be run with at least 15 students and at most 45 students.
3. Courses C-MTM-204A, C-MTM-204B and C-MTM-304 are open elective (Choice Based-Credit Systems) papers for PG students other than students of Applied Mathematics.
4. The syllabus covers almost all the national-level competitive exams like CSIR-NET, UGC-NET and GATE exams as well as the State level competitive exam SET.

Distinctive features of course content:			
Feature	**Course Code**	**Course Wise Percentage of such courses***	**Programme-wise percentage of courses#**
Value-added course:	MTM104	100	**13.33**
	MTM303	100	
	MTM306A	100	
	MTM306C	100	
	MTM402.1	100	
	MTM403	100	
Employability/entrepreneurship/ skill development:	MTM197	100	**20.00**
	MTM297	100	
	MTM306A	100	
	MTM497A,B	100	
	MTM405A	100	
	MTM405B	100	
	MTM498A,B,C	100	
	MTM499A	100	
	MTM305B	100	
Ethics, gender, human values, environment & sustainability:	MTM306B	100	**8.89**
	MTM404B	100	
	MTM404C	100	
	MTM405B	100	
New course introduced:	MTM303.2	100	**22.22**
	MTM305C	100	
	MTM306C	100	
	MTM404C	100	
	MTM497C	100	
	MTM405B	100	
	MTM405C	100	
	MTM498B	100	
	MTM498C	100	
	MTM499	100	

*Percentage of that feature within this course. #Percentage of that feature with respect to total courses or Programme.

Semester-I

MTM-101: Real Analysis

Course content	No. of Lectures
Functions of bounded variation and their properties, characterization of a function of bounded variation	3
Riemann-Stieltjes integral, necessary and sufficient condition for existence of Riemann Stieltjes integral, integration by parts, change of variables in integral, integral of step functions, first mean value theorem and second mean value theorem for Riemann-Stieltjes integrals	4
Measurable sets, Measure, It's simple properties	4
Set of measure zero, Cantor set	3
Borel set and their measurability , Non measurable sets	3
Measurable functions, continuity and measurability, monotonicity and measurability	2
Borel measurable functions, sequence of measurable functions, Statement of Lusin's theorem, Egoroff's theorem	4
Simple functions and it's properties	2
Lebesgue integral on a measurable set: Definition, Basic simple properties	2
Lebesgue integral of a bounded function over a set of finite measure. Simple properties	2
Comparison of Lebesgue and Riemann integral, Lebesgue criterion of Riemann integrability	2
Integral of nonnegative measurable functions	3
General Lebesgue integral	2
Bounded convergence theorem for a sequence of Lebesgue integrable function, Fatou's lemma	2
Classical Lebesgue dominated convergence theorem. Monotone convergence theorem	2

Course Outcomes (COs)

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

1. Verify whether a function is a function of bounded variation and find the R-S integral of a bounded function
2. Know the measurability of a set, integrability of any function and the Monotone convergence theorem
3. Understand the fundamentals of measure theory and be acquainted with the proofs of the fundamental theorems underlying the theory of integration.

4. 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.
5. Explain the concept of length, area, volume using Lebesgue's theory.
6. Apply the general principles of measure theory and integration in such concrete subjects as the theory of probability or financial mathematics.

Text Books:

1. Rudin, W. (1976). *Principles of mathematical analysis* (Vol. 3). New York: McGraw-hill.
2. Rudin, W. (1970). Real and Complex Analysis, International Student Edition, McGraw-Hill.
3. Rana, I. K. (2002). An Introduction to Measure and Integration (2nd ed.), Narosa Publishing House, New Delhi.

Reference Books:

1. Apostol, T. (2002). Mathematical Analysis, 2nd ed., Narosa Publishers.
2. Kumaresan, S. (2011). Topology of Metric Spaces, 2nd ed., Narosa Publishers.
3. Halmos, P.R. (2013). Measure Theory, Graduate Text in Mathematics, Springer-Verlag.
4. Royden, H.L. (1988). Real Analysis, 3rd ed., Macmillan.

MTM-102: Complex Analysis

Course content	No. of Lectures
Review of basic complex analysis: Cauchy's theorem. Homotopy version of Cauchy's theorem, primitives of analytic functions, Fundamental Theorem of Algebra Cauchy's integral formula.Morer's theorem. Liouville's theorem. Taylor's and Laurent's series. Maximum modulus principle.	3
Multiple valued function: Definition, Branch point and branch cut	2
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, Behavior of Functions Near Isolated Singular, Riemann's theorem, Schwarz's lemma, Casorati-Weierstrass's theorem, winding number, counting zeros	4
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, Rouche's Theorem, Inverse Laplace Transforms	11
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 $z_1^{1/2}$, Square Roots of Polynomials, Riemann Surfaces	7
Conformal Mapping: Preservation of Angles, Scale Factors, Local Inverses, Harmonic Conjugates, Transformations of Harmonic Functions, Transformations of Boundary Conditions, Application of Conformal Mapping (steady temperature, steady temperature in a half plane and related problems, two-dimensional fluid flow)	8
Analytic Continuation: Direct and indirect analytic continuation, indirect analytic continuation using power series and along curve, regular and singular points.	5

Course Outcomes (COs)

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

1. What is multivalued function and difference from the definition of single-real valued function?
2. How the residue theorem can be applied to calculate some of the improper as well as definite integrals.
3. Mapping by different elementary functions
4. What is conformal mapping and how it can be applied to some of the fluid dynamics problem.
5. What is analytic continuation?

Text Books:

1. Brown, J. W. and Churchill, R. V. Complex Variable and Applications, 8th Edition, McGraw Hill.
2. Nayek, P. K. and Seikh, M. R. (2018) A Text Book of Complex Analysis, Universities Press

Reference Books:

1. Ponnusamy, S. (1995) Foundations of Complex Analysis, Narosa.

MTM-103: Ordinary Differential Equations and Special Functions

Course content	No. of Lectures
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.	5
Green's Function: Green's Function and its properties, Green's function for ordinary differential equations, Application to Boundary Value Problems.	5
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.	6
Differential Equation: Homogeneous linear differential equations, Fundamental system of integrals, Singularity of a linear differential equation, Solution in the neighborhood of a singularity, Regular integral, Equation of Fuchsian type, Series solution by Frobenius method.	5
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.	6
Legendre Equation: Legendre functions, Generating function, Legendre functions of first kind and second kind, Laplace integral, Orthogonal	8

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.	5

Course Outcomes (COs)

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

1. In ODEs, there are three topics such as Sturm Liouville Problem, Green’s Function and Systems of Linear Differential Equations.
2. Many real-life problems are designed based on the ordinary differential equations where eigen values and eigen functions play major roles.
3. On solving the SL problem, a broad idea can be carried on eigen value and eigen function which helps a lot to solve real-life problems.
4. Green’s function is an effective technique for solving complex initial and boundary value problems involving differential equations.
5. Nowadays complex real-life problems cannot be designed only single differential equation, so a system of linear differential equations is very much essential for modelling this type of problem.
6. Learners achieve the overall concept for solving system of differential equations which have a great impact to extract the solutions for real-life problems.
7. In SFs, there are three types such as Hypergeometric differential equation, Legendre differential equation and Bessel’s function.
8. 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.

Text Books:

1. Simmons, G.F. (1974) Differential Equations, TMH Edition, New Delhi.
2. Ross, S.L. (1984) Differential Equations (3rd edition), John Wiley & Sons, New York.

Reference Books:

1. Eastham, M.S.P. (1970) Theory of Ordinary Differential Equations, Van Nostrand, London.
2. Braun, M. Differential Equations and Their Applications; An Introduction to Applied Mathematics, 3rd Edition, Springer-Verlag.
3. Rainville, E.D. and Bedient, P.E. (1969) Elementary Differential Equations, McGraw Hill, NewYork.
4. Coddington, E.A. and Levinson, N. (1955) Theory of ordinary differential equations, McGraw Hill.
5. King,A.C., Billingham, J. & Otto, S.R. (2006) Differential equations, Cambridge University Press.

MTM-104: Advanced Programming in C and MATLAB

Course content	No. of Lectures
Basic concepts of C programming	10
Arrays, structure and union, Enum	3
Pointers, Pointers and functions, pointers and arrays	3
Array of pointers, pointers and structures, strings and string handling functions	3
Dynamic memory allocation: using of malloc(), reallc(), calloc() and free()	3
File handling functions: use of fopen, fclose, fputc, fgets, fputs, fscanf, fprintf,	3
Low level programming and C pre-processor	1
Programming in MATLAB: The Matlab workspace, data types	3
Variables, Assignment statements, arrays, sets, matrices	3
Introduction to M – file scripts	2
Input and output functions, conditional control statements	3
Loop control statements, break, continue and return statements	3

Course Outcomes (COs)

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

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

Text Books:

1. Balagurusamy, E. (2012) Programming in ANSI C. Tata McGraw-Hill Education.
2. Gottfried, B. and Chhabra, J. (2017) Programming with C (Schaum's Outlines Series).

References Books:

1. Gilat, A. (2008) MATLAB: an Introduction with Applications. New York: Wiley.
2. Palm III, W.J. (2011) Introduction to MATLAB for Engineers. New York: McGraw-Hill.

MTM-105: Classical Mechanics and Non- Linear Dynamics

Course content	No. of Lectures
Motion of a system of particles. Constraints. Generalized coordinates. Holonomic and non-holonomic system. Principle of virtual work. D'Alembart's Principle.	4
Rotating frame, Coriolis force. Motion relative to rotating earth.Motion of a free body about a fixed point.	3
Lagrange's equations. Plane pendulum and spherical pendulum. Hamiltonian. Hamilton's equations. Cyclic coordinates. Routhian equation.	5
Orientation and displacement of a rigid body. Eulerian angles. Principal axis transformation. Euler equations of motion.	3
Variational principle, Principle of stationary action. Hamilton's principle. Brachistochrone problem. Lagrange's equations from Hamilton's principle.	4
Invariance transformations. Conservation laws. Infinitesimal transformations. Space-time transformations. Canonical transformations. Liouville's theorem.	3
Poisson bracket.	2
Small oscillation about equilibrium. Lagrange's method. Normal coordinates. Oscillations under constraint. The stationary character of a normal mode. Small oscillation about the state of steady motion. Normal coordinates	3
The special theory of relativity in Classical Mechanics:-Postulates of special relativity. Lorentz transformation. Consequences of Lorentz transformation. Force and energy equations	5
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.	8

Course Outcomes (COs)

Upon successful completion of this course, the students can do the following:

1. The student will be able to apply the Lagrangian formalism to analyze problems in Mechanics; and dissect and describe the dynamics of systems of particles, rigid bodies, and systems in noninertial reference frames.
2. The student will 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.
3. Students will 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.
4. Able to solve some mathematical problems using variational principle.
5. Using Lorentz transformation, the student will describe the physical situations in inertial frames of reference.
6. The student will able to solve some fundamental problems of non-linear dynamics.

Text Books:

1. Goldstein, H. (1950) Classical Mechanics, Addison-Wesley, Cambridge.
2. Pal, M. (2009) A Course on Classical Mechanics, Narosa, New Delhi, & Alpha Science, Oxford, London.

Reference Books:

1. Gupta, A.S. (2005) Calculus of Variations with Applications, Prentice-Hall of India, New Delhi.
2. Gupta, B.D. and Prakash, S. (1985) Classical Mechanics, KedarNath Ram Nath, Meerut.
3. Kibble, T.W.B. (1985) Classical Mechanics, Orient Longman, London.
4. Rana, N.C. andJoag, P.S. (2004) Classical Mechanics, Tata McGraw-Hill Publishing Company Limited, New Delhi.
5. Symon, K.R. (1971) Mechanics, Addison-Wesley Publ. Co., Inc., Massachusetts.
6. Takwale, R.G. andPuranik, S. (1980) Introduction to Classical Mechanics, Tata McGraw-Hill Publ. Co. Ltd., New Delhi.

MTM-106: Graph Theory

Course content	No. of Lectures
Basic graph theoretical concepts.	2
Paths and cycles.	1
Connectivity, trees, spanning sub graphs, bipartite graphs, Hamiltonian and Euler cycles.	2
Distance and centre.	2
Cut sets and cut vertices.	2
Colouring and matching. Four colour theorem (statement only). Chromatic Polynomial.	3
Planar graphs, Dual graph. Directed graphs and weighted graphs.	2
Matrix representation of graphs	2
Algorithms for shortest path and spanning trees, Applications of graphs in traveling salesman problem	2
Intersection graph	2

Course Outcomes (COs)

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

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

Text Books:

1. Deo, N. (2017). Graph theory with applications to engineering and computer science. Courier Dover Publications.
2. West, D. B. (2001). Introduction to graph theory, Upper Saddle River: Prentice hall.

Reference Books:

1. Chartrand, G. (2006). Introduction to graph theory. Tata McGraw-Hill Education.
2. Gross, J. L., & Yellen, J. (2005). Graph theory and its applications. CRC press.

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

Problem: 20 marks, Lab. Note Book and Viva-Voce: 05 marks

Course content	No. of Lab Hours
Vector: Creating, indexing, operations, standard library functions.	**2**
Matrix: Creating, indexing, operations, standard library functions, solution of a system of linear equation, characteristic values and vectors of the matrix.	**4**
Function: Library functions, user-defined function, primary function, anonymous function, sub-function, private function, function of functions, user-defined functions of some basic logical problems.	**4**
Graph Plotting: 2D plotting for data and function, adding titles, axis labels, and annotations, specifying line styles and colors, multiple plots, matrix plots, polar plots, 3D plotting (line, surface, mesh, and contour) for data and function.	**4**
Ordinary Differential Equations: Euler, Modified Euler, Runge-Kutta method, ode45 algorithm in single variable.	**4**
Debugging M-files	**2**

Course Outcomes (COs)

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

1. The interactive examples and hands-on problem-solving.
2. The utility of basic MATLAB and its demonstration.
3. Vector & Matrix manipulations, plotting of functions and data, solution ODE and its graph, and the creation of user interfaces, etc. Applications in various disciplines such as engineering science, and economics

Text Books:

1. Gilat, A. (2008) MATLAB: an Introduction with Applications. New York: Wiley.
2. Palm III, W. J. (2011) Introduction to MATLAB for Engineers. New York: McGraw-Hill.

References:

1. Chapman, S. J. (2012) MATLAB programming with applications for engineers. Cengage Learning.
2. Lopez, C. (2014) MATLAB programming for numerical analysis. Apress.

Semester-II

MTM-201: Fluid Mechanics

Course content	No. of Lectures
Basics: The concept of a fluid, the fluid as continuum, primary dimensions with examples, Real and Ideal Fluids, Viscosity, 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).	5
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, Examples	3
Derivation of Governing Equations along with Initial and Boundary Conditions: Derivation of Continuity Equation, Four Forms (non-conservation/conservation, partial differential /integral) of Continuity Equations, Derivation of Momentum (Navier-Stokes) Equation for a compressible viscous flow in non-conservation and conservation forms, Special case (Incompressible Newtonian Fluid), Physical interpretation of each term, Equivalent forms of Navier-Stokes in Spherical and Cylindrical Coordinate system, Derivation of Energy Equation, Similarity/dissimilarity between Navier-Stokes and Energy equations, Associated typical Initial and Boundary Conditions for velocity and thermal fields. Examples for each of the governing equations	8
Non-dimensionalization: Non-dimensionalization process, Reynolds number, Importance of Reynolds number to Navier-Stokes Equation, Examples for Reynold numbers	2
Exact/Analytical Solution of Navier-Stokes Equation: Exact Solution of Navier-Stokes Equation (Couette-Poisseuille flow, Flow of a Viscous Fluid with Free Surface on an Inclined Plate)	6
Boundary Layer Theory: Prandtl's Concept of Boundary Layer, Expressions of displacement thickness and momentum thickness of the boundary layer, Vorticity and stress components within the boundary layer in two-dimensional motion. Separation of the boundary layer from an obstacle, Boundary Layer Flow along a Flat Plate, Governing Equations, Boundary Conditions, and Exact Solution of the Boundary-Layer Equations for Plane Flows (Similarity Solution, Vorticity, Stress).Examples	8
Role of the Non-linear Terms of Navier-Stokes Equation and Reynolds average Navier-Stokes (RANS) : Scaling the equations of motion, limiting case of very small/ large viscosity, the Magnitudes of Terms in the Equations of Motion, Reynolds stresses, Equations for the mean or average flow, Reynolds stresses and eddy viscosity, Reynolds average Navier-Stokes (RANS) equation, scaling RANS. Examples	8

Course Outcomes (COs)

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

1. General concept of what is fluid and its properties, and different kind of flows
2. Preliminaries (substantial derivative, different types of forces, etc) for the derivation of governing equation for fluid flow
3. Derivation of Governing Equations (Continuity, Navier-Stokes and Energy) in a mathematical flavour.
4. Implementation of Initial and Boundary Conditions for the governing equations
5. The exact solution of the Navier-Stokes Equation in some of the special cases, like, the Couette-Poisseuille flow
6. Calculate momentum and thermal boundary layer thickness, friction of force on the plate, flow rate, point of separation and reattachment, governing equations for boundary layer flows
7. Scaling the equations of motion and seeing the role of nonlinear terms in the Navier-Stokes equation, the derivation of Reynolds averaged Navier-Stokes (RANS) equation

Text Books:

1. Computational Fluid Dynamics (The Basics with Applications), John D. Anderson Jr., McGraw-Hill Series in Mechanical Engineering
2. Boundary Layer Theory, Hermann Schlichting, McGraw-Hill Book Company

Reference Books:

1. Batchelor, G. K. An Introduction to Fluid Dynamics, Cambridge University Press
2. White, F. M. Fluid Mechanics (4^{th} Edition), WCB McGraw-Hill

MTM-202: Numerical Analysis

Course content	No. of Lectures
Cubic spline interpolation. Lagrange's bivariate interpolation.	3
Approximation of function. Chebyshev polynomial: Minimax property. Curve fitting by least square method. Use of orthogonal polynomials. Economization of power series.	5
Numerical integration: Newton-Cotes formulae-open type. Gaussian quadrature: Gauss-Legendre, Gauss-Chebyshev. Integration by Monte Carlo method.	5
Roots of polynomial equation: Bairstow method.	2
System of linear equations: Pivoting, Matrix inverse. LU decomposition method. Tri-diagonal system of equations. Ill-conditioned linear systems. Relaxation method.	6
System of non-linear equations, fixed point method, Newton methods. Convergence, rate of convergence.	3
Eigenvalue problem. Power method. Jacobi's method.	3
Ordinary differential equation: Runge-Kutta method for linear ODEs and second order IVP. Predictor-corrector method: Milne's method. Stability. Second order BVP:	6

Shooting method, finite difference method, finite element method.	
Partial differential equation: Finite difference scheme. Explicit and implicit methods of Hyperbolic and Parabolic equations, Crank-Nicolson method. Elliptic equation. Stability. Consistency and convergence.	7

Course Outcomes (COs)

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

1. Interpolation using spline interpolation.
2. Approximate a function by least square method, orthogonal polynomials and Gaussian quadrature.
3. Solve the ordinary differential equations (RK methods, predictor-corrector method, finite difference method, finite element method)
4. Solve a system of linear and non-linear equations and matrix inversion with pivoting.
5. Determine the eigenvalues and eigenvectors of a matrix.
6. Solve the partial differential equations (finite difference method) and analyse of stability of the methods to solve ODEs and PDEs.
7. Students will understand the theory behind these methods. Their programming skills will increase after this course and hence they can write computer programs for any mathematical and logical problems.

Text Book:

1. Pal, M. (2007) Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa.
2. Jain, M.K., Iyengar, S.R.K. and Jain, R.K. (1984) Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi.

References:

3. Krishnamurthy, E.V. and Sen, S.K. (1986) Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi.
4. Mathews, J.H. (1992) Numerical Methods for Mathematics, Science, and Engineering, 2nd ed., Prentice-Hall, Inc., N.J., U.S.A..

MTM-203.1: Abstract Algebra

Course content	No. of Lectures
Normal series, subnormal series, solvable series, solvable groups	**2**
Field extensions, Finite, algebraic and finitely generated field extensions	**4**
Classical ruler and compass constructions	**4**
Splitting fields and normal extensions, Algebraic closures	**2**
Finite fields, Cyclotomic fields	**2**
Separable and inseparable extensions.	**2**
Galois groups, Fundamental Theorem of Galois Theory	**4**

Course Outcomes (COs)

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

1. Analyze and demonstrate examples of solvable groups and properties of them.
2. Understand the importance of field extension.
3. Analyze and demonstrate examples of classical ruler and compass constructions, normal extensions and separable extensions.
4. Understand the Galois group of a field extension.

Text Books:

1. Dummit, D. S. and Foote, R. M. (1999) Abstract Algebra, 2nd Edition, John Wiley.
2. Gallian, J.A. (2017) Contemporary Abstract Algebra, 9thEdition, Narosa.

Reference Books:

1. Artin, M. (2011) Algebra, 2nd Edition, Prentice Hall of India, 2011.
2. Jacobson, N. (2009) Basic Algebra, 2nd Edition, Hindustan Publishing Co.

MTM-203.2: Linear Algebra

Course content	No. of Lectures
Review of Linear transformations: Review of linear transformations and matrix representation of linear transformation, linear operators, linear functional, isomorphism, invertibility and change of coordinate matrix	3
The Quotient Space, Isomorphism theorems: The quotient space, first isomorphism theorem, second isomorphism theorem	2
Dual Space: The dual Space, Dual Basis, Double Dual, Transpose of a Linear Transformation and its matrix w. r. t. dual basis	4
Diagonalization and Canonical Forms: Eigen spaces of a linear operator, diagonalizability, invariant subspaces, Projection operator and its relation with the eigen values of a linear operator, the minimal polynomial for a linear operator, primary decomposition theorem, Nilpotent operator, Invariant factors and elementary divisors, Rational and Jordan canonical forms of a linear operator.	3
Inner Product Spaces: Inner product spaces, orthogonal and orthonormal inner product spaces, Gram-Schmidt orthogonalization process, the adjoint of linear operator, normal and self-adjoint operators, Hermitian, unitary and normal transformations, spectral theorem.	4
Bilinear Forms: Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic form, rank, signature and index of a quadratic form, reduction of a quadratic form to its normal form, Sylvester's law of inertia.	4

Course Outcomes (COs)

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

1. In this course, there are several concepts about on Linear Algebra namely concept of Linear Transformation, Inner product space, Bilinear forms, Quadratic forms, Canonical forms, Minimal polynomial and Jordan Canonical forms.
2. Learners gain more knowledge from the topics and they can apply to solve many problems on Applied Mathematics and several physics-oriented applied problems.
3. In addition to the above, the more concepts on eigen values and eigen vectors are discussed in this course which helps a lot for solving many real-life problems.
4. The contents of the syllabus are fully covered with the National level examinations such as CSIR (NET), Graduate Aptitude Test in engineering (GATE) and State level Examination as State Level Test (SET) etc.

Text Books:

1. Hoffman, K. and Kunze, R. (1991) Linear Algebra, Pearson Education (India), 2003. Prentice-Hall of India.
2. Freidberg, S., Insel, A. and Spence, L. (2015) Linear Algebra, Fourth Edition, Pearson.

Reference Books:

1. Herstein, N. (2006) Topics in Algebra, 2nd Ed., John Wiley & Sons.
2. Rao, R. and Bhimasankaram, P. (2000) Linear Algebra, Hindustan.
3. Lang, S. (1989) Linear Algebra, Springer-Verlag, New York.
4. Artin, M. (1994) Algebra, Prentice Hall of India.
5. Strang, G. (2003) Linear Algebra and its Applications, Brooks/Cole Ltd., New Delhi, Third Edition.
6. Datta, K. B. Matrix and Linear Algebra, Prentice Hall India Pvt.

C-MTM-204A: Statistical and Numerical Methods (CBCS)

Course content	No. of Lectures
Statistical Methods: Mean, median, mode.	2
Bivariate correlation and regression: Properties and significance.	4
Time series analysis.	4
Hypothesis testing: chi-square test, t-test and F-test.	4
ANOVA.	4
Numerical methods: Sources and causes of errors. Types of errors.	4
Lagrange's and Newton's interpolation (deduction is not required).	4
Roots of algebraic and transcendental equations: Bisection, Newton-Rapshon methods. Rate of convergence.	4

Solution of system of linear equations: Cramer rule, Gauss-elimination method.	4
Integration by trapezoidal and Simpson 1/3 methods.	2
Solution of ordinary differential equation by Euler's method, Runge-Kutta methods.	4

Course Outcomes (COs)

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

1. Apply method of interpolation and extrapolation for prediction, recognize elements and variable in statistics and summarize qualitative and quantitative data.
2. 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.
3. 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.
4. Compute and interpret the results of bivariate and multivariate regression and correlation analysis, for forecasting.

Text Books:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B. (1968) Fundamentals of Statistics, Vol. 1 & 2, Calcutta : The World Press Private Ltd.
2. Biswas, S., Sriwastav, G. L. (2011) Mathematical Statistics: A Textbook, Narosa.
3. Pal, M. (2007) Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa.

Reference Books:

1. Medhi, J. (1984) Stochastic Process, New Age International Publisher, 2ed.
2. Jain, M.K., Iyengar, S.R.K. and Jain, R.K. (1984) Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi..
3. Krishnamurthy, E.V. andSen, S.K. (1986) Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi.
4. Mathews, J.H. (1992) Numeical Methods for Mathematics, Science, and Engineering, 2nd ed., Prentice-Hall, Inc., N.J., U.S.A.
5. Volkov, E.A. (1986) Numerical Methods, Mir Publishers, Moscow.

C-MTM-204B: History of Mathematics (CBCS)

Course content	No. of Lectures
Ancient Mathematical Sources, Mathematics in Ancient Mesopotamia, The Numeral System and Arithmetic Operations	2
Geometric and Algebraic Problems, Mathematical Astronomy, Mathematics in Ancient Egypt, Geometry, Assessment of Egyptian Mathematics	4
Greek Mathematics, The Development of Pure Mathematics, The Pre-Euclidean Period, The Elements	4
The Three Classical Problems, Geometry in the 3rd Century BCE, Archimedes, Apollonius, Applied Geometry	4
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),	4
Origins, Mathematics in the 9th Century, Mathematics in the 10th Century, Omar Khayyam, Islamic Mathematics to the 15th Century	4
The Foundations of Mathematics : Ancient Greece to the Enlightenment, Arithmetic or Geometry, Being Versus Becoming, Universals	4
The Axiomatic Method, Number Systems, The Reexamination of Infinity	4
Calculus Reopens Foundational The Philosophy of Mathematics: Mathematical Platonism, Traditional Platonism	4
Nontraditional Versions, Mathematical Anti-Platonism, Realistic Anti-Platonism, Nominalism, Logicism, Intuitionism, and Formalism	2
Mathematical Platonism: For and Against, The Fregean Argument for Platonism, The Epistemological Argument, Against Platonism	4

Course Outcomes (COs)

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

1. A general idea of the evolution of some of the major concepts of modern mathematics.
2. Understand basic, fundamental arguments that were developed centuries ago and are still of central importance today.
3. Concepts from geometry (such as Euclid’s constructions) and analysis (such as limit) should be understood.
4. Solve different problems to differentiate functions using various notions of infinitesimals.

Text Book:

1. Gregersen, E., The Britannica Guide to The History of Mathematics, Britannica.

Reference Book:

1. Robson, E. and Stedall, J. The Oxford Handbook of THE HISTORY OF MATHEMATICS, Oxford

MTM-205: General Theory of Continuum Mechanics

Course content	No. of Lectures
Stress: Body force, Surface forces, Cauchy's stress principle	2
Stress vector, State of stress at a point, Stress tensor, The stress vector –stress tensor relationship	2
Force and moment equilibrium. Stress tensor symmetry stress quadric of Cauchy	4
Stress transformation laws, Principal stress, Stress invariant, Stress ellipsoid, maximum and minimum shear stress, Mohr's Circles for stresses	2
Strain: Deformation Gradients, Displacement Gradient Deformation tensor, Finite strain tensors	2
Small deformation theory-infinitesimal strain tensor, Relative displacement, Linear rotation tensor, Interpretation of the linear strain tensors	3
Strength ratio, Finite strain interpretation, Principal strains, Strain invariant	2
Cubical dilatation, Compatibility equation for linear strain, Strain energy function.	2
Hook's law, Saint-Venant's principal, Airy'sstress function, Isotropic media	2
Elastic constrains, Moduli of elasticity of isotropic bodies and their relation, Displacement equation of motion, Waves in isotropic elastic media	3
Perfect fluid: Kinematics of fluid, Lagrangian method, Eulerian method, Acceleration	3
Equation of continuity, The boundary surface, Stream lines and path lines, Irrotational motion and its physical interpretation	3
Velocity potential, Euler's equation of motion of an in viscid fluid, Cauchy's integral, Bernoulli's equation	2
Integration of Euler's equation, Impulsive motion of fluid	2
Energy equation, Motion in two dimensions, The stream functions Complex Potential, Source, sink and doublet and their images	3
Milne-Thompson circle theorem, Vorticity, Flow and circulation, Kelvin's circulation theorem, Kelvin's minimum energy theorem.	3

Course Outcomes (COs)

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

1. 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.
2. The knowledge about stress vector which is applied on material points in an object.
3. The relationship between strain tensor and stress tensors in an elastic substance.
4. 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 behavior of such objects, and some information about the particular material studied to be added through constitutive relations.

Text Books:

1. Chatterjee, R.N. Mathematical Theory of Continuum Mechanics.Narosa Publishing House.
2. Spencer, A.J.M. Continuum Mechanics. Longman.

Reference Books:

1. Chung, T.J. Continuum Mechanics. Prentice – Hall.
2. Mase, G. R. Continuum Mechanics: Schaum's Outline of Theory and Problem of Continuum Mechanics. McGraw Hill.

MTM-206: General Topology

Course content	No. of Lectures
Topological spaces, Examples, open sets, closed sets, neighborhoods, basis, sub-basis	**4**
Subspace topology, Limit points, Closure, interiors	**3**
Continuous functions, homeomorphisms	**2**
Product topology, metric topology, order topology, Quotient Topology	**2**
Connected spaces, connected subspaces of the real line, Components and local connectedness	**2**
Compact spaces, Local–compactness, Tychnoff'stheorem on compact spaces	**3**
1st and 2nd countable spaces, Hausdorff spaces, Regularity, Complete Regularity, Normality	**3**
Urysohn Lemma, UrysohnMetrization Theorem, Tietze Extension theorem (statement only)	**1**

Course Outcomes (COs)

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

1. 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 neighbourhoods at each point.
2. Subspace topology, order topology, product topology, metric topology and quotient topology.
3. What it means for a function to be continuous.
4. Urysohn Lemma and the Tietze extension theorem, and can characterize metrizable spaces.

Text Books:

1. Munkres, J. R. (2000) Topology, 2nd Ed., Pearson Education (India).
2. Armstrong, M. A. (1983). Basic Topology, Springer (India).

Reference Books:

1. Joshi, K. D. (2014) Introduction to General Topology, New Age International Private Limited, New Delhi.
2. Simmons, G. F. (1963) Introduction to Topology and Modern Analysis, McGraw-Hill, New York.

MTM-297: Lab 2: Language: C-Programming with Numerical Methods

Problem: 20 marks; Lab. Note Book and Viva-Voce: 05 marks.

(Programs will be written on the following problems using pointers, data files, structures, etc.)

Course content	No. of Lab hours
Linear and binary search; Bubble, Insertion, Selection sort techniques	**2**
Matrix inverse by partial pivoting, Roots of polynomial equation.	**2**
Gauss elimination, Gauss Seidal, Matrix inversion, LU decomposition methods, Solution of Tri-diagonal equations.	**4**
Lagrange, Newton forward and backward interpolation, Cubic spline interpolation.	**4**
Gauss quadrature rule, Integration by Monte Carlo method, Double integration.	**2**
Euler and Modified Euler, Runge-Kutta, Milne-Simpson method.	**4**
Power method and Jacobi method for eigenvalues.	**2**

Course Outcomes (COs)

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

1. Interactive examples and hands-on problem solving environment.
2. The course is to demonstrate searching, sorting and strings manipulation problems.
3. Demonstrate numerical problems in C.
4. Applications in various disciplines such as engineering, science, and economics.

Text Books:

1. Rajaraman, V. Computer Orientated Numerical Methods, 3rd ed., PHI.
2. Pal, M. (2007) Numerical Analysis for Scientists and Engineers: Theory and C Programs Narosa.

References

1. Jain, M K. (2019) Numerical Methods: For Scientific and Engineering Computation,7th ed., New Age International Private Limited.
2. Kanetkar, V. (2017) Let Us C, 16th ed., BPB Publications

Semester-III

MTM-301: Partial Differential Equations and Generalized Functions

Course content	No. of Lectures
First-order PDE in two independent variables and the Cauchy problem. Semi-linear and quasilinear equations in two independent variables	**5**
Second-order linear PDE	**3**
Adjoint and self-adjoint equations	**1**
Reduction to canonical forms. Classifications	**5**
Laplace, Wave and Heat equations	**1**
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	**5**
Heat equation - Heat conduction problem for an infinite rod – Heat conduction in a finite rod - existence and uniqueness of the solution	**5**
The fundamental solution of Laplace's equations is in two variables. Harmonic function. Characterization of harmonic functions 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	**5**
Solution of Dirichlet's and Neumann's problem for some typical problems like a disc and a sphere. Poisson's integral formula	**3**
Green's functions for the Laplace's equations in two dimensions	**2**
Test functions. Regular and singular generalized functions. Dirac delta function. Operations on generalized functions. Derivatives. Transformation properties of generalized functions. Fourier transform of generalized functions	**5**

Course Outcomes (COs)

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

1. Use the knowledge of first and second order partial differential equations (PDEs),the general structure of solutions, and analytic methods for solutions.
2. Classify PDEs, apply analytical methods, and physically interpret the solutions.
3. Solve practical PDE problems (Wave, Heat & Laplace equations) with the methodsof separation of variables, and analyse the stability and convergence properties ofthis method.
4. Find solution of Dirichlet's and Neumann's problem for some typical problems like adisc and a sphere.

Text Books:

1. Pinchover, Y. and Rubinstein, J. (2005) An Introduction to Partial Differential Equations, Cambridge University Press.

2. Rao, S. (2011) Introduction to Partial Differential Equations, 3rd Edition, PHI Learning PrivateLimited, New Delhi.
3. Duistermaat, J. J. and Kolk, J. A. C. (2010) Distributions Theory and Applications, BirkhäuserBasel.

Reference Books:

1. John, F. (1978) Partial Differential Equations, Springer-Verlag, New York.
2. Gelfand, I. M. and Shilov, G.E. (2016) Generalized Functions, AMS, Recent Edition.

MTM-302: Transforms and Integral Equations

Course content	No. of Lectures
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).	10
Laplace Transform: Laplace Transform, Properties of Laplace transform, Inversion formula of Laplace transform (Bromwich formula), Convolution theorem, Application to ordinary and partial differential equations.	10
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.	6
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.	14

Course Outcomes (COs)

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

1. In this course there are four topics namely Laplace Transform, Fourier Transform, Wavelet Transform and Integral Equation.
2. A large number of realistic problems in sciences and engineering involve the solution of linear ordinary and partial differential equations.
3. Laplace and Fourier transforms are the powerful tools for solving realistic problems of ODE and PDE, particularly IVP or BVP.
4. 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.

5. Wavelet transform is another transform technique with the special advantage that it provides a more accurate solution which helps to determine the exact location of the solution.
6. 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.
7. Integral equation is an important concept in Applied Mathematics to find the unknown function within the integral sign.
8. Many dynamical problems and applied-based practical problems can be solved with the help of Integral equations.

Text Books:

1. Dyke, P.P.G. (2001)An Introduction to Laplace Transforms and Fourier Series, Springer, Springer-Verlag London Limited.
2. Debnath, L.(1995) Integral Transforms and Their Applications, CRC Press.
3. Walnut, D. F. (2002) An introduction to Wavelet Analysis, Birkhauser.
4. Kanwal, R.P. (1971) Linear Integral Equations; Theory & Techniques, Academic Press, NewYork.

Reference Books:

1. Sneddon, I.N. (1974). The use of Integral Transforms, Tata McGraw Hill, Publishing Company Ltd, New Delhi.
2. Davis, H.T. (1962). Introduction to Nonlinear Differential and Integral Equations, Dover Publications.
3. Krasnov, M.L. (1971) Problems and Exercises Integral Equations, Mir Publication Moscow.
4. Hildebrand, F. B. (1992). Methods of Applied Mathematics, Dover Publication.

MTM-303.1: Stochastic Process and Regression

Course content	No. of lectures
Stochastic Process: Markov chains with finite and countable state space. Classification of states. Limiting behaviour of n state transition probabilities, Stationary distribution, Random walk, Gambler's ruin problem, Markov processes in continuous time.	9
Birth and death processes. Markov Processes with Continuous State Space. Wiener Process. Branching process.	6
Multiple regression: Partial correlation. Multiple correlations.	5

Course Outcomes (COs)

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

1. Basic concepts of Markov chains and present proofs for the most important theorems.

2. Identification of states in Markov chains and characterize the classes.
3. Derivation of differential equations for time continuous Markov processes with a discrete state space.
4. Solution of differential equations for distributions and expectations in time continuous processes and determine corresponding limit distributions.
5. Formulation simple stochastic process models in the time domain and provide qualitative and quantitative analyses of such models.
6. Birth and death processes. The student also knows about Wiener Process and branching process.
7. Derivation of the expression for three or more dimensional curve fitting, including multiple and partial correlations for relevant practical systems.

Text Books:

1. J.Medhi, Stochastic Process, New Age International Publisher, 2ed, 1984.
2. Suddhendu Biswas and G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011.

Reference Books:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (1968) Fundamentals of Statistics, Vol. 1 & 2, Calcutta: The World Press Private Ltd.
2. Montgomery, D.C., Peck, E.A. and Geoffrey, G. (2012) Vining, Introduction to Linear Regression Analysis, 5ed, Wiley.

MTM-303.2: Cryptography

Course content	No. of Lectures
Cryptographic algorithms and protocols, Computer security concepts, Fundamental security design principles	2
Classical Encryption Techniques: Basic terminology: Ciphertext, encryption, decryption, cryptanalysis and cryptology	2
Substitution techniques: Caesar Cipher, Mono-alphabetic Cipher, Play-fair Cipher, Hill Cipher, Poly-alphabetic Cipher, Transposition techniques	4
Traditional Block Cipher Structure: Stream Ciphers and Block Ciphers, Motivation for the Feistel Cipher Structure, Feistel Cipher	4
Public-Key Encryption: Public-Key cryptosystems, decryption algorithm.	2
Digital Signatures: One-time signatures, Rabin and ElGamal signatures schemes, Digital Signature Standard (DSS).	4
Hashing: Motivation and applications, Cryptographically Secure Hashing.	2

Course Outcomes (COs)

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

1. To understand basics of Cryptography and Network Security.

2. To be able to secure a message over insecure channel by various means.
3. To learn about how to maintain the Confidentiality, Integrity and Availability of a data.
4. To understand various protocols for network security to protect against the threats in the networks.

Text Books:

1. Stallings, W. (2006) Cryptography and Network Security, 4th Ed, Prentice Hall PTR, Upper Saddle River, NJ.
2. Trappe, W. and Washington, L. C. (2006) Introduction to cryptography with coding Theory, Prentice-Hall, 2nd ED.

Reference Books:

1. Stinson, D. R. (2005) Cryptography: Theory and Practice, Third Edition, Chapman & Hall/ CRC.
2. Mao, W. Modern Cryptography – Theory and Practice, Pearson Education.
3. Pfleeger, C. P. and Pfleeger, S. L. Security in computing, Prentice Hall of India.

C-MTM-304: Discrete Mathematics (CBCS)

Topics to be covered	No. of Lectures
Boolean algebra: introduction, basic definitions, duality, basic theorems	2
Boolean algebra and lattice, representation theorem, sum-of-product form for sets, sum-of-products forms for Boolean algebra	4
Proposional logic, tautology	4
Sets and propositions: cardinality. Mathematical induction. Principle of inclusion and exclusion.	4
Computability and formal languages: ordered sets. Languages. Phrase structure grammars. Types of grammars and languages.	4
Finite state machines: equivalent machines. Finite state machines as language recognizers.	4
Partial Order Relations and Lattices: Chains and antichains.	4
Graph Theory: Definition, walks, paths, connected graphs, regular and bipartite graphs, cycles and circuits. Tree and rooted tree.	4
Spanning trees. Eccentricity of a vertex radius and diameter of a graph. Centre(s) of a tree. Hamiltonian and Eulerian graphs, planar graphs.	4
Analysis of algorithms: time complexity. Complexity of problems.	2
Discrete numeric functions and generating functions.	4

Course Outcomes (COs)

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

1. Simplify and evaluate basic logic statements including compound statements, implications, inverses, converses, and contra positives using truth tables and the properties of logic, analyze the growth of elementary functions.
2. Represent a graph using an adjacency list and an adjacency matrix and apply graph theory to application problems such as computer networks.
3. Determine if a graph is a binary tree, Euler or a Hamilton path or circuit, N-ary tree, or not a tree.
4. Evaluate Boolean functions and simplify expression using the properties of Boolean algebra and use finite-state machines to model computer operations.

Text Books:

1. Rosen, K. H. (2007) Discrete Mathematics and its Applications, McGraw-Hill.
2. Deo, N. (2017) Graph theory with applications to engineering and computer science. Courier Dover Publications.

Reference Book:

1. Wilson, R. J. & Watkins, J. J. (1990) Graphs: an introductory approach: a first course in discrete mathematics. John Wiley & Sons Inc.

MTM-305A: Advanced Optimization

Course content	No. of Lectures
Post-optimal analysis: Changes in cost vector, and resource vector, Addition of a variable, Deletion of an existing variable, Addition of a new constraint.	**4**
Integer Programming: Gomory's cutting plane algorithm, Gomory's mixed-integer problem algorithm, branch-and-bound algorithm.	**4**
Quadratic Programming Wolfe's modified simplex method, Beale's method, and convex programming.	**4**
Goal Programming Introduction, Concept of Goal Programming (GP), Difference between LP and GP, formulation, graphical solution, modified simplex method.	**4**
Dynamic Programming Introduction, Nature of dynamic programming, Deterministic processes, Non-Sequential discrete optimization, Allocation problems, Assortment problems, Sequential discrete optimization, Long-term planning problems, Multi-stage decision process.	**4**

Unconstrained Optimization Techniques General structure of a numerical method for unconstrained optimization problems, exact and inexact line search, trust region method, Dogleg technique, Fibonacci section method and its convergence, Golden section method and its convergence, Newton's method (for line search) and its convergence, Steepest descent and its convergence, Newton's method (for several variable optimizations) and its convergence, Conjugate direction method, Conjugate gradient methods: Beale's and preconditioned methods, Global convergence and convergence rate of conjugate gradient methods	**12**
Constrained optimization techniques Penalty and barrier function method, Augmented Lagrangian Method, Feasible direction methods: Reduced gradient and projected gradient methods, Sequential quadratic programming techniques: Lagrange-Newton and Watch-dog technique	**5**

Course Outcomes (COs)

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

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

Text Books:

1. Rao, S. S. (2009) Engineering optimization: theory and practice. John Wiley & Sons.
2. Belegundu, A. D. and Chandrupatla, T.R.(2011) Optimization concepts and applications in engineering. Cambridge University Press.

References Books:

1. Taha, H.A. (2004) Operations research: An introduction. Pearson Education India.
2. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.

MTM-305B: Dynamical Meteorology: Thermodynamics in Atmosphere

Course content	No. of Lectures
Structure and composition of the atmosphere, Equation of state for dry, Laws of thermodynamics	3
Different thermodynamic processes and its applications in atmosphere, Hydrostatic Equation and its application	3
Pressure and its variation with height, variation of temperature with height, stability	3

of dry air, potential temperature	
Equation of state of moist air, Virtual temperature, Humidity Parameters	3
Standard Atmosphere, Barometric Altimetry, Hypsometric Equation	3
Adiabatic lapse rate for moist unsaturated air, effect of ascent and descent on lapse rare and stability	4
Clausius – Clapeyron equation, saturated adiabatic lapse rate and stability, saturation by Isobaric cooling	4
Dew point changes in adiabatic motion, saturation by adiabatic ascent, Pseudo-adiabatic process	3
Equivalent Temperature, Equivalent Potential Temperature, Wet-bulb temperature, Wet-bulb potential temperature	3
Thermodynamic Diagrams. Uses of thermodynamic diagrams: LCL, LFC, Precipitable Water Vapor	4
Role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in thunderstorm development, Reduction of pressure to sea level	3
Stability and Instability of Atmosphere: Parcel Method, Slice method of stability analysis, Horizontal mixing of air masses, vertical mixing of air masses.	4

Course Outcomes (COs)

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

1. Different thermodynamics laws to be applied in the atmosphere to get a state of dry and moist air in the atmosphere.
2. The understanding of the basic physical processes occurring in the atmosphere from a mathematical perspective.
3. Measuring formula of the height in the atmosphere.
4. Measurement of humidity variables
5. Stability analysis of the atmosphere

Text Books:

1. Haltiner, G. J. and Martin, F. L. Dynamical and Physical Meteorology, McGraw Hill
2. Holton, J.R., An introduction to Dynamical Meteorology, Academic Press

Reference Books:

1. Brunt, D. Physical and Dynamical Meteorology, Cambridge University Press
2. Iribarne, J.V. and Godson, W.L. Atmospheric Thermodynamics.

MTM-305 C: Linear and Non- Linear Dynamical Systems

Course content	No. of Lectures
Dynamical System, autonomous and non-autonomous	3
Fundamental existence uniqueness theorem, discrete and continuous	4
Equilibrium point: saddles, nodes, foci, centres	4
Jordon canonical form, stability, asymptotic stability, configuration space and phase space	4
Floquet's theorem, Hartman – Grobman Theorem	4
Liapunov function, periodic solution	4
Global stability: limit sets, attractors, periodic orbit, limit cycles	4
Poincare Map, Poincare – Bendixson Theorem	5
Bifurcation analysis, local: Hof bifurcation saddle – node bifurcation, transcritical bifurcation,	4
global: homoclinic bifurcation, heteroclinic bifurcation, infinite period bifurcation	4

Course Outcomes (COs)

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

1. Find equilibria in 1D, 2D and 3D systems and determine their local stability using linear analysis or graphical means.
2. Identify various types of bifurcations (saddle-node, transcritical, super- and sub-critical pitchfork, Hopf)
3. Construct bifurcation diagrams, and interpret in the context of applications.
4. Students will be able to find equilibria and periodic solutions and determine their stability and interpret results in applications.

Text Books:

1. Perko, L. Differential Equations and Dynamical Systems, Springer

Reference Books:

1. Arrowsmith, D. K., An Introduction to Dynamical System, Cambridge University Press.
2. Strogatz, S. H., Nonlinear Dynamics and Chaos: with Applications to Physics, Biology, Chemistry and Engineering, CRC Press.

MTM-306A: Operational Research Modelling-I

Course content	No. of Lectures
Inventory control: Deterministic including price breaks and Multi-item with constraints, Probabilistic inventory control (with and without lead time), and Dynamic inventory models. Basic concept of supply–chain management.	10
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.	8
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.	6
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.	6
Basic Structures of queuing models, Poisson queues –M/M/1, M/M/C for finite and infinite queue length, Machine-Maintenance (steady state).	10

Course Outcomes (COs)

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

1. Understand of network optimization techniques.
2. Analyze of network using CPM and PERT.
3. Understand the project time-cost, trade-off, updating of the project and resource allocation techniques.
4. Know the simulation process and its advantages and disadvantages for solving a problem.
5. Generate random numbers and understanding of Monte-Carlo simulation.
6. Know the use of simulation to solve problems in inventory management system, queuing theory and others.

Text Books:

1. Sharma, S. D. Operations Research, Kedar Nath Ram Nath & Co., Meerut.
2. Sharma J.K. (2006) Operations Research: theory and application, Macmillan Publishers.

Reference Books:

1. Taha, H. A. (2004) Operations research: An introduction. Pearson Education India.
2. Hillier, F.S., (2012) Introduction to operations research. Tata McGraw-Hill Education.

MTM-306B: Dynamical Oceanology: Advanced Wave Hydrodynamics

Course content	No. of Lectures
Liquid Surface Waves: Introduction, General equation of wave motion, Mathematical representation of (a) Progressive waves (b) Stationary waves.	4
Kinematical condition at the free surface, Pressure condition at the free surface	2
Surface waves: (a) Progressive waves on the surface of a canal of finite depth (b) Progressive waves on deep water (c) Stationary waves on the surface of a canal of finite depth (d) Stationary waves on deep water	6
Kinetic and Potential energy of stationary waves	4
Steady motion: (a) Progressive waves on the surface of a canal of finite depth (b) Progressive waves in deep water (i) First-order approximation to the wave speed (ii) Second-order approximation to the wave speed (c) Progressive waves at an interface of two liquids (d) Progressive waves at an interface of two liquids when the upper surface is free (e) Waves over a sinuous bottom	8
Group velocity, Dynamical significance of group velocity,	4
Capillary waves, Effect of capillarity on surface waves, Effect of capillarity on surface waves at an interface	6
Effect of wind on deep water, Long waves, Steady motion for long waves, Solitary waves	6

Course Outcomes (COs)

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

1. To have knowledge of the theoretical basis for and good physical understanding of ocean surface waves, this is covered by the topics described in the academic content.
2. To have skills and general competence to be able to apply this knowledge and understanding within own research work.
3. To master the concepts and terminology which are used in the description of ocean surface waves.

Text Books:

3. Gupta, A. (2013) Groundwork of mathematical fluid dynamics, Academic Publishers.
4. Batchelor, G. K. (1967) An Introduction to fluid dynamics, Cambridge University Press.
5. White, F. M. (2008) Fluid mechanics. Tata McGraw - Hill publishing company, New Delhi.

Reference Books:

1. Milne-Thomson, L.M. (1950) Theoretical hydrodynamics, The Macmillan Company, New York.
2. Streeter, V.L. (1948) Fluid dynamics, McGraw Hill Book Company Inc. New York.

3. Streeter, V.L. (1948) Handbook of Fluid dynamics, McGraw Hill Book Company Inc. New York.
4. Yuan, S.W. (1969) Foundations of fluid mechanics, Prentice-Hall of India pvt. Ltd., New Delhi.

MTM 306 C: Computational Fluid Dynamics

Course content	No. of Lectures
Preliminaries for Computational Fluid Dynamics(CFD): Advantage of CFD, overview of CFD, Size of Computational Domain, Consideration of Grid (uniform/non-uniform), Variable arrangement (Cell center / Collocated arrangement and Staggered Gird), Space discretization and Time discretization (Explicit Algorithm, Implicit Algorithm, and Semi-implicit Algorithm), Implementation of boundary conditions (inlet/outlet/wall boundary) for collocated and staggered grid, Solution of discretised equation: Tri-diagonal matrix algorithm, Line-Gauss Seidel method, relaxation method	7
Finite Difference Methods (FDM): Space discretisation (Simple and general methods based on Taylor's series), Accuracy of the Discretisation Process, *Conceptual Implementation to(i) parabolic type:* 1D transient heat conduction (diffusion) problem and Couette Flow using FTCS , DuFort-Frankel, Richardson , Leap-frog schemes and Crank-Nicolson methods, and *(ii) Hyperbolic*: 1D first order Linear Convection-dominated problems and second order linear Wave Problems using FTCS, Upwind and the CFL conditions, Lax-Friedrich, LeapFrog, Lax-Wendroff, Crank-Nikolson, linear convection of a truncated sine wave	12
Theoretical Background: Convergence (Lax Equivalence Theorem, Analytical Treatment of Convergence), Consistency (FTCS, Fully Implicit Scheme), Stability (Matrix Method and Von Neumann Method) and Solution Accuracy (Richardson Extrapolation **)**	8
Finite Volume Method (FVM): Equations with First order Derivatives Only, with second order Derivatives, The Finite Volume Method for Steady/unsteady one/two/three-dimensional heat conduction equation, Steady/unsteady one/two/three-dimensional convection and diffusion equation, continuity, Navier-Stokes Equation, Central Difference Scheme (CDS), Different Upwind Schemes for uniform and non-uniform grids: First Order Upwind (FOU) , Second Order Upwind Scheme (SOU), Third Order Upwind differencing (QUICK), Assessment (Conservativeness, Boundedness, Transportiveness and Accuracy) of CDS, FOU and Stability problems of QUICK and remedies, Generalisation of upwind-biased discretization schemes	13

Course Outcomes (COs)

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

1. Learn the preliminaries of CFD tools, how to set the size of computational domain, consider the grid, arrange variables in the control volume.

2. Derive discretized equations for diffusion and convection-diffusion equations, central differencing, upwind scheme, QUICK scheme, Navier-Stokes equations in conservative form
3. Formulate Marker and Cell Method (MAC), Semi Implicit Method for Pressure Linked Equations (SIMPLE Algorithm), stream function vorticity formulation of Navier-Stokes equations in two-dimension.
4. Write a C-program to solve fluid dynamics problems using the methods described above along with the setting of boundary conditions
5. Validate computational results with existing solutions, study of grid-independent tests, plotting of results, finally they will get to know that CFD is nothing but numerical experiments in a virtual flow laboratory.

Text Books:

1. Fletcher, C. A. J. (1988) Computational Techniques for Fluid Dynamics, Vol-I, Springer.
2. Versteeg, H. K. and Malalasekera, W (2008) An Introduction to Computational Fluid Dynamics, Pearson.

Reference Books:

1. Smith, G. D. Numerical Solution of Partial Differential Equations: Finite Difference Methods (Oxford Applied Mathematics & Computing Science Series) by G. D. Smith, Oxford University Press

Semester-IV

MTM-401: Functional Analysis

Course content	No. of Lectures
Normed spaces, Examples and related theorems, Bounded linear transformation, equivalent norms and its properties, finite dimensional normed linear spaces, Set of all bounded linear transformation B(X, Y) from NLS X into NLS Y is a NLS, Continuity of linear maps	**5**
Banach spaces with examples, B(X, Y) is a Banach space if Y is a Banach space, quotient spaces and its completeness property , consequences of quotient spaces, Riesz lemma and its applications in Banach spaces, space of all square integrable functions over [a.b] and its properties	**4**
Hahn-Banach Extension theorem and Its applications	**3**
Banach spaces, series in Banach spaces, convergence of a series in Banach spaces, A NLS is Banach if and only if every absolutely convergent series is convergent. Conjugate spaces, Reflexive spaces	**2**
Open Mapping Theorem and their applications, Inverse Mapping Theorem, Closed Graph Theorem	**4**
Uniform Boundedness Principle and its applications	**2**
Inner product spaces, Inner product is a continuous operator. Relation between IPS and NLS	**3**
Orthogonal and orthonormal vectors, Bessel'sinequality. Parseval's identity, Cauchy-Schwarz inequality, Parallelogram law	**3**
Hilbert spaces, Orthonormal basis. Complete orthonormal basis	**3**
Projection theorem	**2**
Minimization of norm problems in inner product spaces, Riesz Fischer theorem, Riesz representation theorem for bounded linear functional on a Hilbert space, Fourier expansion	**3**
Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related simple theorems	**4**
Strong and weak convergence of a sequence in a normed linear space, convergence of sequence of bounded linear operators	**2**

Course Outcomes (COs)

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

1. How functional analysis uses and unifies ideas from vector spaces, the theory of Metrics, and complex analysis.
2. 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.
3. Apply ideas from the theory of Hilbert spaces to other areas, including Fourier series,the theory of self-adjoin operators, normal operators, unitary operators and positive operators.

4. Apply Hilbert space theory, including Riesz representation theorem and weak convergence, and critically reflect over chosen strategies and methods in problem solving.

Text Books:

1. Limaye, B.V. (2014) Functional Analysis, 2nd Edition, New Age International Private Limited New Delhi.
2. Conway, J. B. (1985) A Course in Functional Analysis, 2nd Edition, Springer-Verlag New York

Reference Books:

1. Kreyzig, E. (1989) Introduction to Functional Analysis with Applications, John Wiley & Sons, New York.
2. Taylor, A. and Lay, D. (1980) Introduction to Functional Analysis, Wiley, New York.

MTM 402.1: Fuzzy Mathematics

Course content	No. of Lectures
Basic concept and definition of fuzzy sets. Standard fuzzy sets operations and its properties.	**3**
Basic terminologies such as Support, α-Cut, Height, Normality, Convexity, etc..	**1**
Fuzzy relations, Properties of α-Cut, Zadeh's extension principle, Interval number and its arithmetic.	**3**
Fuzzy numbers and their representation, Arithmetic of fuzzy numbers..	**3**
Fuzzy measures. Evidence theory. Necessity measure. Possibility measure. Possibility distribution.	**4**
Defuzzification: centre of area, centre of maxima, and mean of maxima methods	**1**
Decision Making in Fuzzy Environment- Individual decision making. Multiperson decision making. Multicriteria decision making. Multistage decision making.	**3**
Fuzzy ranking methods. Fuzzy linear programming.	**2**

Course Outcomes (COs)

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

1. Some fundamental knowledge of fuzzy sets, numbers, matrix, ordinary differential equation and programming, etc.
2. Acquire knowledge of various operations on above fuzzy sets.
3. Solving some Multi-person, Multi-criteria, Multi-stage decision making problems.
4. Some fundamental uncertain programming solving skill which occur almost all decision making problems.

Text Books:

1. Klir, G.J. and Yuan, B.(1995) Fuzzy sets and fuzzy logic, Prentice-Hall of India, New Delhi.
2. Dubois, D.J.(1980) Fuzzy sets and systems: theory and applications, Academic press.

Reference Books:

1. Bector, C.R. and Chandra, S. (2005) Fuzzy mathematical programming and fuzzy matrix games, Berlin: Springer.
2. Zimmermann, H. J. (1991) Fuzzy set theory and its Applications, Allied Publishers Ltd, New Delhi.

MTM-402.2: Magneto Hydro-Dynamics

Course content	No. of Lectures
Maxwell's electromagnetic field equations when medium in motion.	2
Lorentz's force. The equations of motion of a conducting fluid. Basic equations.	2
Simplification of the electromagnetic field equation.	2
Magnetic Reynolds number. Alfven theorem.	2
Magnetic body force. Ferraro's law of isorotation.	2
Laminar Flow of a viscous conducting liquid between parallel walls in transverse magnetic fields.	2
M.H.D. Flow Past a porous flat plate without induced magnetic field.	2
MHD Couelte Flow under different boundary conditions	2
Magneto hydro dynamics waves. Hall currents.	2
MHD flow past a porous flat plate without induced magnetic field.	2

Course Outcomes (COs)

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

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

Text Book:

1. Davidson, P. A. (2001) An Introduction to Magneto-hydrodynamics, Cambridge University Press

Reference Book:

1. Hosking, R. J., Dewar, R. (2016) Fundamental Fluid Mechanics and Magneto-hydrodynamics, Springer

MTM 403: Soft Computing

Course content	No. of Lectures
Introduction Evolution of Computing: Soft Computing Constituents, "Soft" versus "Hard" computing, Characteristics of Soft computing, Some applications of Soft computing techniques	**3**
Artificial Neural Network Biological neurons and their working, Simulation of biological neurons to problem-solving, Different ANNs architectures, Learning rules and various activation functions, Basic models of ANN, Single layer Perceptrons, and Applications of ANNs to solve some real-life problems.	**7**
Genetic Algorithm Goals of optimization, Concept of "Genetics" and "Evolution" and its application to probabilistic search techniques, Basic GA framework and different GA architectures, Working Principle, Various Encoding methods, Fitness function, GA Operators- Reproduction, Crossover, Mutation, Solving single-objective optimization problems using GAs.	**5**
Fuzzy Logic Fuzzy relations, rules, propositions, implications and inferences, De-fuzzification techniques, Fuzzy logic controller design, and some applications of Fuzzy logic.	**5**

Course Outcomes (COs)

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

1. Understanding the basic concepts of soft computing like how it resembles biological processes more closely than traditional techniques.
2. Understanding the basic neural network models and illustrating with numerical examples.
3. Understand the fuzzy logic and system control with the help of a fuzzy controller.
4. Understand genetic algorithms and solve optimization problems.

Text Books:

1. Sivanandam, S.N. and Deepa, S.N. (2007) PRINCIPLES OF SOFT COMPUTING, John Wiley & Sons.
2. 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.

Reference Books:

1. OglyAliev, R.A. and Aliev, R.R. (2001) Soft computing and its applications, World Scientific.
2. Karray, F.O. and De Silva, C.W. (2004) Soft computing and intelligent systems design: theory, tools, and applications. Pearson Education.

MTM-404A: Nonlinear Optimization

Course content	No. of Lectures
Stochastic Programming: Chance constraint programming technique.	2
Geometric Programming: Geometric programming (unconstraint) with positive and negative degree of difficulty.	2
Games: Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming).	3
Multi-objective Non-linear Programming: Introductory concept and solution procedure. Fuzzy Multi-objective Nonlinear Programming	3
Non-Linear Optimization: The general nonlinear programming problem, The nature of optimization and scope of the theory,	1
Optimality without differentiability: Convex sets and separation theorem, 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	3
Optimality with differentiability: Differentiable convex and concave functions, Optimality criterion with differentiability and Convexity, Kuhn-Tucker's sufficient optimality theorem, Fritz-John stationary point optimality theorem,	4
Duality in non-linear programming: Duality in non-linear programming, Weak duality theorem, Wolfe's duality theorem, Duality for quadratic programming.	2

Course Outcomes (COs)

Upon successful completion of this course, students will be able to

1. In this course, there are several advanced concepts about on Non-linear Optimization such as Geometric Programming, Nash Equilibrium (John F. Nash got the Nobel prize in 1994 for this) of Bimatrix Game, Stochastic Programming, Multi-Objective Non-linear Programming and the rest of these theoretical concepts of exclusive nonlinear programming. This course will help the learners to solve complex mathematical modelling of various real-life practical problems.
2. Especially the geometric programming is more useful for solving Engineering design problems.
3. The contents of the syllabus are fully covered with National level examinations such as CSIR (NET), Graduate Aptitude Test in Engineering (GATE) and State level Examination State Level Test (SET) etc.

Text Books:

1. Olvi, L. (1994) Mangasarian, Nonlinear Programming, Society for Industrial and Applied Mathematics.
2. Rao, S. S. (1996) Engineering Optimization: Theory and Practice, John Wiley & Sons.

Reference Books:

1. Bazaraa, M. S., Sherali, H. D. and Shetty, C.M. (2006) Nonlinear Programming: Theory and Algorithms, John Wiley & Sons.
2. Miettinen, K. (1999) Nonlinear Multi-objective Optimization, Kluwer Academic Publishers, Boston.
3. Hillier, F. S. and Lieberman, G. J. (2010) Introduction to Operations Research, McGraw-Hill.

MTM-404B: Dynamical Meteorology: Dynamics in Atmosphere

Course content	No. of Lectures
Fundamental atmospheric forces, inertial and non-inertial frame of references	3
Equation of momentum of an air parcel: in vector form, Cartesian coordinates spherical coordinates, natural coordinates and isobaric coordinates	4
Balance of forces: Geostrophic wind, Gradient wind, inertial wind	3
Cyclostrophic wind and Thermal wind	2
Thermodynamic energy equation, Atmospheric energy equation	3
Circulation, vorticity, divergence. Surface of discontinuity	5

Course Outcomes (COs)

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

1. The understanding of the basic physical processes occurring in the atmosphere in mathematical perspective.
2. Dynamics of air flow in the atmosphere
3. Some knowledge about circulation, vortices in the atmosphere.
4. The concept of front which is very useful in prediction

Text Books:

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

Reference Books:

1. Brunt, D. Physical and Dynamical Meteorology, Cambridge University Press
2. Iribarne, J.V. and Godson, W.L. Atmospheric Thermodynamics.

MTM 404 C: Mathematical Modelling in Population Ecology and Epidemiology

Course content	No. of Lectures
Models for single species: Malthus model, Logistic model, Gompertz model and its analysis	6
Models for interacting Species: Lotka-Voltera model, Kolmogorov model, Prey-predator Syste and its analysis	6
Models in Epidemiology: Kermack- McKendrick epidemic model, SIR, SIRS, SCI, SIS	6
The Basic Reproductive Number	2

Course Outcomes (COs)

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

1. Students will be able to understand the spread of parasites, viruses, and disease.
2. Students will be able to perceive how population models work when species become endangered.
3. Students will be able to determine how population models can track the fragile species and work and curb the decline.
4. Students will be able to give real-life examples illustrating the main ideas of the course (such as equilbria, stability, bifurcations).
5. Will be able to describe qualitatively the behavior of the solution of a dynamical system without necessarily finding the exact solution.
6. Will be able to draw phase portraits and interpret them in several applications from biology, physics, chemistry and engineering.

Text Books:

1. Dynamical Systems for Biological Modeling: An Introduction, Fred Brauer, Christopher Kribs, CRC Press
2. Mathematical Models in Population Biology and Epidemiology, Fred Brauer, Carlos Castillo-Chavez, Springer.

Reference Books:

1. Lynch, S. Dynamical Systems with Applications using MATLAB, Springer International Publishing.
2. Bernstein, R.Population Ecology: An Introduction to Computer Simulations, John Wiley & Sons.
3. Lee, S. and Buzby, M. Mathematical Modeling and Simulation with MATLAB.

MTM 497 A: Special Paper-OR: Lab. OR methods (using MATLAB and LINGO)

Problems on Advanced Optimization and Operations Research are to be solved by using MATLAB (one question carrying 09 marks) and LINGO (one question carrying 06 marks) (Total: 16 Marks) Lab Note: 5 Marks, Viva-Voce: 5 Marks

Problems on LPP, QPP, Fuzzy LPP, Goal Programming Problems, Stochastic Programming, Bi-matrix Game, Nonlinear Optimization with Equality and Inequality Constraints.

Course Outcomes (COs)

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

1. This course is totally computer-based laboratory-oriented.
2. In this course, data are collected from different sources for the real-life optimization problems. For the collection of data, learners must visit one of the renowned laboratories and industries where such types of data are available.
3. In a nutshell, the loaners will handle the real-life application of optimization problems. This course will be useful as Data Science to the learners in future.

Text Books:

1. Gilat, A. (2008) MATLAB: an Introduction with Applications. New York: Wiley.
2. Palm III, W. J. (2011) Introduction to MATLAB for Engineers. New York: McGraw-Hill.

Reference Books:

1. Chapman, S. J. (2012) MATLAB programming with applications for engineers. Cengage Learning.
2. Lopez, C. (2014) MATLAB programming for numerical analysis. Apress.

MTM-497 B: Lab: Dynamical Meteorology

Course content	No. of Lectures
Surface temperature, potential temperature, virtual temperature, wet bulb temperature, pressure	4
Relative humidity, specific humidity, mixing ratio, saturation pressure, vapor pressure, Wind speed and direction measurements	4
Rainfall and rain measurements	2
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.	6
Station model analysis	2
Students should go to one of the University/Institute/Organization laboratory to understand experimental set-ups in advance meteorology.	2

Course Outcomes (COs)

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

6. 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.
7. Applications of thermodynamic diagram to analysis the stability in the atmosphere.

Text Books:

1. Haltiner, G. J. and Martin, F. L. Dynamical and Physical Meteorology, McGraw Hill.
2. Holton, J.R. An introduction to Dynamical Meteorology, Academic Press.

Reference Books:

1. Brunt, D. Physical and Dynamical Meteorology, Cambridge University Press.
2. Iribarne, J.V. and Godson, W.L. Atmospheric Thermodynamics.

MTM 497 C: Lab: Bio-Mathematics

Course content	No. of Lectures
MATLAB Programs to draw and analysis phase portraits map of the above mentioned models	9
MATLAB Programs to draw and analysis limit cycles, bifurcation diagram map of the above mentioned models	8
MATLAB Programs to draw and analysis periodic orbit, Poincare map of the above mentioned models	8

Course Outcomes (COs)

Upon successful completion of this course, the students will learn the following: Students will be able to give real-life examples illustrating the main ideas of the course (such as equilbria, stability, bifurcations).

1. Will be able to describe qualitatively the behavior of the solution of a dynamical system without necessarily finding the exact solution.
2. Will be able to draw phase portraits and interpret them in several applications from biology, physics, chemistry and engineering.

Text Books:

1. Brauer, F. and Kribs, C. Dynamical Systems for Biological Modeling: An Introduction, CRC Press.
2. Brauer, F. and Castillo-Chavez, C. Mathematical Models in Population Biology and Epidemiology, Springer.

Reference Books:

1. Lynch, S. Dynamical Systems with Applications using MATLAB,Springer International Publishing.
2. Bernstein, R. Population Ecology: An Introduction to Computer Simulations, John Wiley & Sons.
3. Lee, S. and Buzby, M. Mathematical Modeling and Simulation with MATLAB.

MTM 405 A: Operational Research Modelling-II

Course content	No. of Lectures
Optimal Control: Performance indices, Methods of calculus of variations, transversal conditions, Simple optimal problems of mechanics, Pontryagin's principle (with proof assuming smooth condition), Bang–bang Controls.	6
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 the life cycle with reliability, maintainability, availability, Effect of age, stress, and mission time on reliability.	5
Information Theory: Introduction, Communication Processes- memoryless channel, the channel matrix, Probability relation in a channel, noiseless channel. A Measure of information- Properties of Entropy function, Marginal and joint entropies, conditional entropies, expected mutual information,	5
Encoding-Objectives of Encoding. Shannon-Fano Encoding Procedure, Necessary and Sufficient Condition for Noiseless Encoding.	4

Course Outcomes (COs)

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

1. Prepare and motivate future specialists to continue in their study by having an insightful overview of operations research.
2. 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.
3. Thorough understanding of reliability of a component and a system of components. The mathematical investigation is also performed.
4. Understanding of information theory and sources and causes of uncertainty. Knowledge of memory less and passing of information through different channels.
5. Entropy and its measurement and properties.
6. Knowledge of Shannon-Fano Encoding procedure and necessary and sufficient condition for noiseless encoding.

Text Books:

1. Sharma, S.D. Operations Research, Ram Nath, Kedar Bath & Co. Meerut
2. Swarup, K., Gupta,P.K and Man, M. Operation Research, Sultan Chand & Sons.

References Books:

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

MTM-405 B: Dynamical Oceanology: Coastal Processes

Course content	No. of Lectures
Wave Propagation: Wave Shoaling, Refraction, Diffraction, Reflection	2
Effect of Currents, Wave Breaking, Wave Set up and Set down, Wave Run-up.	2
Tsunamis, Properties of tsunamis, Inundation levels, Conservation of mass equation, Prediction of storm surge	4
Waves over Real Sea beds: Waves over smooth, rigid, impermeable bottoms	4
Water waves over a viscous mud bottom, Waves over rigid porous bottoms	4
Wave deformation	2
Sediment characteristics and long-shore sediment transport	2

Course Outcomes (COs)

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

1. To determine the theory of wave hydrodynamics can search for a credible solution for coastal engineers in predicting the danger or in alleviating the impact
2. To modeling of tsunami wave and propagation across oceans and their impact on coastlines considering the aspects of modeling of large ocean waves.

Text Books:

1. Dean, R. G. and Robert A. Dalrymple, R. A. (2002) Water Wave Mechanics for Engineers and Scientists, World Scientific Publishing Co. Pte. Ltd., Volume 2.
2. Deo, M. C. (2013) Waves and Structures.
3. Silvester, R. and Hsu, J.R.C. (1997) Coastal Stabilisation, Advances on Ocean Engineering-Volume 14, World Scientific.

Reference Books:

1. Kamphius, J.W. (2002) Introduction to Coastal Engineering and Management, Advances on Ocean Engineering-Volume 16, World Scientific.
2. Goldstein, S. (1938) Modern Developments in Fluid Dynamics, Oxford University Press, New York.
3. Lamb, H. (1932) Hydrodynamics, Dover Publications, New York.
4. McCormack, P. D. and Crane, L. (1973) Physical Fluid Dynamics, Academic Press, New York.

MTM 405 C: Computational and Semi-Analytical Methods

Course content	No. of Lectures
Primitive Variable Formulation for Incompressible Viscous Flow: The Momentum equation, Pressure and Velocity Corrections, Pressure-Correction equation, Semi-Implicit Method for Pressure-Linked Equation (SIMPLE), Boundary Condition for Pressure-Correction equation, Revised-SIMPLE, Numerical Examples	7
Adomian Decomposition Method (ADM): ADM for ODEs, Solving System of ODEs by ADM, ADM for Solving Partial Differential Equations, ADM for System of PDEs, Numerical Examples	4
Homotopy Perturbation Method (HPM) : Basic Idea of HPM, Numerical Examples	2
Variational Iteration Method (VIM): VIM Procedure, Numerical Examples	2
Homotopy Analysis Method (HAM): Concept of Homotopy, Zeroth order Homotopy equation, Higher order deformation equation, convergence of homotopy-series solution, essence of convergence control parameter, Choice of linear operator and initial guess, Optimal HAM (Different types of residual calculating and optimal methods) and their flexibility Generalised Newtonian Iteration formula	5

Text Books:

1. H.K.Versteeg and W Malalasekera-An Introduction to Computational Fluid Dynamics, Pearson 2008
2. C. A. J. Fletcher, Computational Techniques for Fluid Dynamics, Vol-I, Springer, 1988.
3. S. Chakraverty, N R Mahato, P. Karunakar, and T. D. Rao, Advanced Numerical and Semi-Analytical Methods for Differential Equations, Wiley, 2019.

Reference Books:

1. Patanker, S. V. Numerical Heat Transfer and Fluid Flow, McGrow-Hill Book Company

MTM 498 A Special Paper-OR: Lab: OR methods (using MATLAB and LINGO)

Problems on Advanced Optimization and Operations Research are to be solved by using MATLAB /LINGO (Total: 15 Marks)

Problems with Queuing Theory, Inventory, Monte Carlo Simulation Technique, Dynamic Programming, and Reliability.

Field Work (Mandatory) (10 Marks)

Application for Optimization problems in real-life problems by visiting any Industry /University/Reputed Institution to understand the practical use of the theory of optimization and OR Methods. A report based on the field visit must be prepared. The evaluation must be done based on the participation in the field work and report writing.

Course Outcomes (COs)

Upon successful completion of this course, the students can do the following:

1. This course is totally computer-based laboratory-oriented and hence increases the computational capacity of the students.
2. The data is collected from different sources for real-life optimization problems. For a collection of data, learners must visit one of the renowned laboratories and industries where such types of data are available.
3. In a nutshell, the learners will handle the real-life application of optimization problems.

Text Books:

1. Gilat, A. (2008) MATLAB: an Introduction with Applications. New York: Wiley.
2. Palm III, W. J. (2011) Introduction to MATLAB for Engineers. New York: McGraw-Hill.

Reference Books:

3. Chapman, S. J. (2012) MATLAB programming with applications for engineers. Cengage Learning.
4. Lopez, C. (2014) MATLAB programming for numerical analysis. Apress.

MTM-498B: Lab: Dynamical Oceanology

Course content	No. of Lectures
Determine the distribution of stream-wise, transverse, wall-normal mean velocity from 15 vertical measurements for current only flow.	4
Determine the turbulence intensity and Reynolds shear stress profile from 15 vertical measurements for current-only flow.	3
Evaluate the coefficient of skewness and kurtosis from 15 vertical measurements for current-only flow.	3
Determine the distribution of stream-wise, transverse, wall-normal mean velocity from 15 vertical measurements for wave-current flow.	4
Determine the turbulence intensity and Reynolds shear stress profile from 15 vertical measurements for wave-current flow.	3
Evaluate the coefficient of skewness and kurtosis from 15 vertical measurements for wave-current flow.	3

Course Outcomes (COs)

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

1. Evaluation of turbulent flow situations.
2. Use of self-preservation solutions for free shear flows (jets, wakes, etc).
3. Choose a turbulence model for computational flow analysis (CFD).
4. Evaluate and interpret experimental measurements.

Text Books:

1. Nezu, I, Nakagawa, H. (1993) Turbulence in Open-Channel Flows. A.A. Balkema, CRC Press, Rotterdam.

Reference Books:

1. Pope, S.B. (2000) Turbulent Flows, Cambridge University Press, Cambridge, 1-771.
2. Dey, S. (2014) Fluvial Hydrodynamics – Hydrodynamic and Sediment Transport Phenomena, Springer.

MTM 498: C Lab: Computational and Semi-Analytical Methods

Numerical experiments for the solution of steady/unsteady one-dimensional diffusion and / or convection equation using Finite difference method (FTCS and Crank-Nicolson methods) and Finite volume method (Central Difference Scheme (CDS) and different upwind scheme)

Numerical experiments for the solution of some problems on fluid dynamics using SIMPLE algorithm

Solution of Some Non-linear differential equations using ADM, HPM and HAM with the help of Mathematica software

Course Outcomes (COs)

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

1. Derive discretized equations for diffusion and convection-diffusion equations, central differencing, upwind scheme, QUICK scheme, one-dimensional diffusion and / or convection equation, Navier-Stokes equations in conservative form
2. Formulate Semi Implicit Method for Pressure Linked Equations (SIMPLE Algorithm) of Navier-Stokes equations in two-dimension.
3. Writing programs in different programming languages to find the approximate solution of one-dimensional diffusion and / or convection equations, Navier-Stokes equations in conservative form
4. Validate computational results with existing solutions, study of grid-independent tests, and plot results, finally they will get to know that CFD is nothing but a 'Numerical Experiment in Virtual Flow Laboratory'
5. With the help of MATHEMATICA software students will be able to get semi-analytical solution by applying ADM, VI, HPM and HAM. Thereby their skill will be developed on MATHEMATICA software

Text Book:

1. Versteeg, H.K. and Malalasekera, W (2008) An Introduction to Computational Fluid Dynamics, Pearson.
2. Fletcher, C. A. J. (1988) Computational Techniques for Fluid Dynamics, Vol-I, Springer.
3. Chakraverty, S.,Mahato, N. R., Karunakar, P. and Rao, T. D. (2019) Advanced Numerical and Semi-Analytical Methods for Differential Equations, Wiley.

Reference book:

1. Patanker, S. V. Numerical Heat Transfer and Fluid Flow, McGrow-Hill Book Company

MTM 499: Lab.: Soft computing techniques using MATLAB

Course content	No. of Lab Hours
Artificial Neural Network i. Generate AND NOT function using McCulloch-Pitts neural net. ii. Generate XOR function using McCulloch-Pitts neural net. iii. Hebb Net to classify two-dimensional input patterns in bipolar with given targets. iv. Perceptron net for an AND function with bipolar inputs and targets. v. Perceptron net for an OR function with bipolar inputs and targets. vi. Create a perceptron with an appropriate number of inputs and outputs. Train it using vii. Fixed increment learning algorithm until no change in weights is required.	**6**
Genetic Algorithm Optimization of real-valued singe-and multi-parameter, single- and multi-objective problems with constraints, solving of integer programming problems, solving travelling salesperson problem (TSP)	**7**
Fuzzy Logic Implement Union, Intersection, Complement and Difference operations on fuzzy sets. Also, create fuzzy relation by the Cartesian product of any two fuzzy sets and perform max-min composition on any two fuzzy relations, Use Fuzzy toolbox to implement FIS Editor.	**7**

Course Outcomes (COs)

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

1. Learn artificial neural networks
2. Learn the operators of genetic algorithms and solved single and multi-objective optimization problems with constraints.
3. Understand Fuzzy concepts.
4. Hands on practice of the problems in science and engineering using neural network, genetic algorithm, and fuzzy logic tools.

Text Books:

1. OglyAliev, R.A. and Aliev, R.R. (2001) Soft computing and its applications.WorldScientific.
2. Karray, F.O. and De Silva, C.W. (2004)Soft computing and intelligent systems design:theory, tools, and applications. Pearson Education.

Reference Books:

1. Sivanandam, S. N., and Deepa, S. N. (2006). Introduction to neural networks using Matlab 6.0.Tata McGraw-Hill Education.
2. Sivanandam, S. N., Sumathi, S., and Deepa, S. N. (2007). Introduction to fuzzy logic using MATLAB (Vol. 1). Berlin: Springer.

MTM-406: Dissertation Project Work

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.