Master of Science

In

Mathematics and Computing

Course Structure & Syllabus

Department of Mathematics & Scientific Computing

National Institute of Technology Hamirpur

Hamirpur (HP) – 177005, India

Course structure of M.Sc. Mathematics and Computing

SEMESTER-I

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours /week	Credit
			L	T	P		
1	MA-611	Real Analysis	4	0	0	4	4
2	MA-612	Abstract Algebra	4	0	0	4	4
3	MA-613	Differential Equations	4	0	0	4	4
4	MA-614	Operations Research	4	0	0	4	4
5	MA-615	Object Oriented Programming	4	0	0	4	4
6	MA-616	Programming in Python Lab	0	0	4	4	2
7	MA-617	Mathematical Software Lab	0	0	4	4	2
8	MA-618	Operations Research Lab	0	0	2	2	1
Total			**20**	**0**	**10**	**30**	**25**

SEMESTER-II

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours /week	Credit
			L	T	P		
1	MA-621	Complex Analysis	4	0	0	4	4
2	MA-622	Probability and Statistics	4	0	0	4	4
3	MA-623	Mathematical Methods	4	0	0	4	4
4	MA-624	Data Structure and Algorithms	4	0	0	4	4
5	MA-7MN	Program Elective-I	4	0	0	4	4
6	MA-625	Advanced Python Lab	0	0	4	4	2
7	MA-626	Data Structure Lab	0	0	4	4	2
8	MA-627	SPSS Software Lab	0	0	2	2	1
Total			**20**	**0**	**10**	**30**	**25**

Programme Elective - I: List of Programme Electives is given in the Annexure-I.

SEMESTER-III

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours /week	Credit
			L	T	P		
1	MA-631	Functional Analysis	4	0	0	4	4
2	MA-632	Numerical Analysis	4	0	0	4	4
3	MA-7MN	Program Elective-II	4	0	0	4	4
4	XY-8MN	Open Elective-I	4	0	0	4	4
5	MA-633	R Software Lab	0	0	4	4	2
6	MA-634	Numerical Methods Lab	0	0	4	4	2
7	MA-635	Program Elective Lab	0	0	2	2	1
Total			**16**	**0**	**10**	**26**	**21**

Programme Elective – II: List of Programme Electives is given in the Annexure-I.

Open Elective – I: Course can be opted from list of Open Elective courses of Chemistry /Physics department

SEMESTER-IV

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours /week	Credit
			L	T	P		
1	MA-7MN	Program Elective-III	4	0	0	4	4
2	MA-7MN	Program Elective-IV	4	0	0	4	4
3	XY-8MN	Open Elective-II	4	0	0	4	4
4	MA-851	Seminar	**-**	**-**	**-**	**-**	**1**
5	MA-699	Project Work	-	-	-	-	6
Total			**12**	**0**	**0**	**12**	**19**

Programme Electives – III and IV: List of Programme Electives is given in the Annexure-I

Open Elective – II: Course can be opted from list of Open Elective courses of Chemistry /Physics department.

Total Credit of the Programme= 25 + 25 + 21+ 19 = 90

Annexure – I

List of Program Electives – I

Code No.	Subject Name	L-T-P	Credits
MA-721	Viscous Fluid Dynamics	4-0-0	4
MA-722	Topology	4-0-0	4
MA-723	Advanced Operations Research	4-0-0	4
MA-724	Applied Linear Algebra	4-0-0	4
MA-725	Mathematics Behind Machine Learning	4-0-0	4
MA-726	Theory of Stability	4-0-0	4

List of Program Electives – II

Code No.	Subject Name	L-T-P	Credits
MA-731	Database Management System	4-0-0	4
MA-732	Text Mining & Analytics	4-0-0	4
MA-733	Digital Image Processing	4-0-0	4
MA-734	Computer Graphics	4-0-0	4
MA-735	Parallel Algorithms	4-0-0	4

List of Program Electives – III

Code No.	Subject Name	L-T-P	Credits
MA-741	Numerical Methods for Differential Equations	4-0-0	4
MA-742	Advanced Statistical Modelling	4-0-0	4
MA-743	Soft Computing	4-0-0	4
MA-744	Orthogonal Polynomials and Special Functions	4-0-0	4
MA-745	Artificial Intelligence	4-0-0	4
MA-746	Dynamical Systems	4-0-0	4

List of Program Electives – IV

Code No.	Subject Name	L-T-P	Credits
MA-751	Computer Networks	4-0-0	4
MA-752	Software Engineering	4-0-0	4
MA-753	Web Development	4-0-0	4
MA-754	Cloud Computing	4-0-0	4
MA-755	Data Mining	4-0-0	4

List of Open Elective Courses

Code No.	Subject Name	L-T-P	Credits
MA-811	Statistical Data Analysis	4-0-0	4
MA-812	Numerical and Statistical Methods	4-0-0	4

Course Name: **Real Analysis**
Course Code: **MA-611**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To impart knowledge about Set theory, convergence of sequence and series.
- To enable the students to evaluate integration using Riemann integration theory
- To impart knowledge about metric space and its properties.
- To understand the concept of improper integrals, power series.

Course Content

Riemann Integral : Partitions and Riemann sum, upper and lower R-integrals, R-integrability, Riemann's necessary and sufficient condition for R-integrability, Fundamental theorem of integral calculus, Mean value theorems.

Improper Integrals: Definition, the μ-test, Abel's test, Dirichlet's test, Absolute convergence.

Uniform Convergence of Sequence and Series of Functions: Uniform convergence, Cauchy's general principle of uniform convergence, Dini's criterion for uniform convergence of sequence of continuous functions. Uniform convergence and continuity, Uniform convergence and differentiation, Uniform convergence and integration.

Power Series: Definition, Cauchy's theorem on limits, Radius of convergence, Uniform convergence, Abbel'ssummability.

Metric Spaces : Definition, Neighbourhoods, limit points, open and closed sets, connectedness, compactness, completeness, Cantor's intersection theorem, Baire category theorem, contraction mapping.

Course Outcomes

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

CO1. Learn the methods of convergence of sequence and series.
CO2. Obtain the basic concept of the power series expansion of function.
CO3. Understand the method of Riemann integration.
CO4. Learn the basic concepts of Improper integrals.
CO5. Understand the basic concepts of Metric space and its properties.

Books and References

1. Principles of Mathematical Analysis by W. Rudin, McGraw Hill Inc.
2. Mathematical Analysis by S.C. Malik, Savita Arora, New Age International (P) Ltd.
3. Real Mathematical Analysis by C.C. Pugh, Springer.
4. Mathematical Analysis by T. M. Apostol, Addison-Wesley Publishing Company.
5. Introduction to Topology and Modern Analysis by G. F. Simmons, Tata McGraw-Hill.

Course Name: **Abstract Algebra**
Course Code: **MA-612**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To introduce students to the language and precision of modern abstract algebra
- Applications of abstract algebra are increasingly important in certain areas, for example in communication theory, electrical engineering, computer science, and cryptography.
- To understand, construct, and write proofs.
- To give the students a good mathematical maturity and enables to build mathematical thinking and skill.

Course Content

Groups: Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems.

Rings: Rings, ideals, prime and maximal ideals, quotient rings, Chinese Remainder Theorem for pairwise coaximal ideals. Euclidean Domains, Principal Ideal Domains and Unique Factorizations Domains. Polynomial rings over UFD's.

Fields: Fields, Characteristic and prime subfields, Field extensions, Finite, algebraic and finitely generated field extensions, normal extensions, algebraic closures.

Galois Theory: Galois theory, Fundamental Theorem of Galois Theory, Composite extensions. Solvability by radicals, Galois' Theorem on solvability. Cyclic and abelian extensions, transcendental extensions.

Course Outcomes

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

CO1. Understand the connection and transition between previously studied mathematics and more advanced mathematics.
CO2. Gain experience and confidence in proving theorems.
CO3. Have knowledge of many mathematical concepts studied in abstract mathematics.

Books and References

1. Algebra by Artin, Prentice Hall of India.
2. Abstract Algebra by D.S. Dummit and R.M. Foote, John Wiley.
3. Contemporary Abstract Algebra by J.A. Gallian, NarosaPublishing House.
4. Basic Algebra I by N. Jacobson, Hindustan Publishing.
5. Algebra I by S. Lang, Addison Wesley.
6. A course in Abstract Algebra by V K Khanna and S K Bhambari,Vikas Publishing House.

Course Name: **Differential Equations** Course Code: **MA-613** Course Type: **Core**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives • To impart knowledge about existence and uniqueness of solution of initial value problem. • To enable the students to obtain the power series solution of several important ordinary differential equations. • To impart knowledge to solve Sturm-Liouville problems and to analyse stability of linear and nonlinear system. • To understand various analytic methods to find exact solution of partial differential equations.
Course Content
Introduction: Review of fundamentals of ODEs, Lipschitz condition, Gronwall's lemma, Existence and uniqueness theorems, Method of successive approximation, Dependence of solutions on initial conditions. **Series Solution:** Review of Linear second order differential equations and Power series solutions, Legendre, Chebyshev, Bessel, Hermite and Laguerre's differential equations, generating functions and recurrence relations. **Sturm-Liouville Boundary Value Problems:** Sturm-Liouville Problems, Eigen value problems ,Orthogonality of Characteristic Functions, The Expansion of a Function in a Series of Orthonormal Functions **Non-Linear Differential Equations:** Phase Plane, Paths, Autonomous systems and Critical Points, Type of critical points, Stability of critical points, Critical points and Paths of Linear Systems **Partial Differential Equations:** First-order linear and quasi-linear PDE's, Lagrange's method, Charpit's method, Cauchy problem, Second order PDEs, Classification of PDE, Canonical form, Solution of hyperbolic, Parabolic and elliptic equations, Dirichlet and Neumann problems.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Learn how the differential equations are used to study various physical problems CO2. Obtain power series solutions of several important classes of ordinary differential equations CO3. Understand the Sturm-Liouville problem and analyze stability of linear and non-linear systems. CO4. Solve the first-order linear and non-linear PDE's by using Lagrange's and Charpit's methods respectively CO5. Classify second order PDE and solve standard PDE using separation of variable method.
Books and References 1. Differential Equations by S.L. Ross, John Wiley and Sons. 2. Ordinary Differential Equations by E.L. Ince, Dover Publications, INC, New York. 3. Differential Equations with Applications and Historical Notes by G.F. Simmons, Tata McGraw Hill. 4. Elements of Partial Differential Equations by I.N. Sneddon, Tata McGraw Hill. 5. Theory of Ordinary Differential Equations by E.A. Coddington and N.Levinson, Tata McGraw Hill. 6. Differential Equations by H.T.H. Piaggio, CBS Publisher. 7. Partial differential equations for engineers and scientists by J.N. Sharma, K. Singh, Alpha Science. 8. Introduction to Partial Differential Equations by K.S. Rao, Prentice Hall of India Pvt. Ltd., New Delhi.

Course Name: **Operations Research** Course Code: **MA-614** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To provide quantitative insight and understanding of fundamental methods of linear programming problems.
- To demonstrate the powerful capabilities of optimization theory to enable reducing costs, improving efficiency, optimal usage of resources and providing benefits in many other key dimensions in engineering / industry / managerial / decision making problems.
- To have flavor of both sound theoretical foundation of various methods and their actual implementations in problems solving.

Course Content

Introduction to LPP: Hyper plane and hyper spheres, Convex sets and their properties, Convex functions, Linear Programming Problems; Formulation and examples, Basic feasible and optimal solutions, Extreme points, Graphical Method, Simplex Method, Big-M Method, Degeneracy, Duality and Dual LPP and its properties, Dual simplex Algorithm and sensitivity analysis.

Assignment and Transportation Problems: Transportation problem, mathematical formulation, basic feasible solution, North-West Corner Method, Least Cost Method, Vogel's approximation Method, Optimal solution by U-V Method, Stepping Stone Method, Degeneracy in Transportation problem. Assignment problem, mathematical formulation, solution by Hungarian Method, unbalanced problem, Traveling Sail's man problem and its solution.

Goal Programming: Mathematical formulation, Graphical goal attainment and Simplex method for solution of GPP.

Game Theory: Two-Person Zero sum games, The Maximin-minimax principle, pure and mixed strategies, graphical solution, Dominance property, General solution of mxn rectangular games, Linear programming of GP.

Network Analysis: PERT – Background, development, networking, estimating activity time, Determination of earliest expected and allowable times, determination of critical path, PERT cost, scheduling of a project, CPM method, Applications of these methods

Course Outcomes

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

CO1. Understand the characteristics of different types of decision-making environments and the appropriate decision making approaches and tools to be used in each type.

CO2. Build and solve Transportation and Assignment Models.

CO3. Design new simple models, like: CPM, PERT to improve decision –making and develop critical thinking and objective analysis of decision problems.

Books and References

1. Operation Research: An Introduction by H.A. Taha, Prentice Hall of India.
2. Linear programming by G. Hadley, Narosa Publishing House.
3. Operation Research: Theory by Methods and Applications, S.D. Sharma and H. Sharma, KedarNath& Co.
4. Operations Research for Management by G.V. Shenoy, U.K. Srivastava, S C Sharma, New Age International (P) Ltd.

Course Name: **Object Oriented Programming** Course Code: **MA-615** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To understand basic notions of object oriented programming.
- To acquire object-oriented problem solving skills.
- To be able to write programs in C++.

Course Content

Concepts of Object-Oriented Programming: Object Oriented Programming Paradigm, Basic concepts of OOP"s, Benefits of OOPS, and Introduction to object oriented design and development, Design steps, Design example, Object oriented languages, Comparison of structured and object-oriented programming languages.

Arrays, Pointers and Functions: Arrays, Storage of arrays in memory, Initializing Arrays, Multi-Dimensional Arrays, Pointers, accessing array elements through pointers, passing pointers as function arguments, Arrays of pointers, Pointers to pointers, Functions, Arguments, Inline functions, Function Overloading Polymorphism.

Classes and Objects: Data types, operators, expressions, control structures, arrays, strings, Classes and objects, access specifiers, constructors, destructors, operator overloading, type conversion.

Storage Classes: Fixed vs Automatic declaration, Scope, Global variables, register specifier, Dynamic memory allocation.

Inheritance: Inheritance, single Inheritance, Multiple Inheritance, Multi-level inheritance, hierarchical inheritance, hybrid inheritance, Virtual functions.

Streams and Files Opening and closing a file, File pointers and their manipulations, Sequential Input and output operations, multi-file programs, Random Access, command line argument, string class, Date class, Array class, List class, Queue class, User defined class, Generic Class.

Exception Handling and Graphics: List of exceptions, catching exception, handling exception. Text Mode, Graphics mode functions, Rectangles, and Lines, Polygons and Inheritance, Sound and Motion, Text in Graphics Mode.

Standard Template Library: Standard Template Library, Overview of Standard Template Library, Containers, Algorithms, Iterators, Other STL Elements, Container Classes, General Theory of Operation, Vectors.

Course Outcomes

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

CO1. Understand the concept of object oriented paradigm and programming.

CO2. Apply the concept of polymorphism and inheritance.

CO3. Implement exception handling and templates.

CO4. Handling of files and streams during programming.

Books and References

1. Object Oriented programming with C++ by E. Balagurusamy, Tata McGraw Hill.
2. The C++ programming Language by Bjarne Strustrup, Addison Wesley.
3. Object Oriented Analysis and Design with Applications by Grady Booch, Addison Wesley.
4. The Complete Reference Visual C++ by Chris H. Pappas and William H. Murray, Tata McGraw Hill.
5. C++ Primer by S. B. Lippman, JoseeLajoie, Barbara E. Moo, Pearson Education.

Course Name: **Programming in Python Lab** Course Code: **MA-616**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- To understand and apply the basic principles of programming.
- To identify/characterize/ define a problem.
- To design a program to solve the problem.
- To read more Python code.

List of Experiments

1. Write a NumPy program to create a 2d array with 1 on the border and 0 inside.
2. Write a NumPy program to get the number of nonzero elements in an array.
3. Write a NumPy program to compute the multiplication of two given matrixes.
4. Write a NumPy program compute the inverse of a given matrix
5. Remember that $n! = n \times (n - 1) \times \cdot \cdot \cdot \times 2 \times 1$. Compute 15! Assigning the result to a sensible variable name.
6. Write a function that tests if a number is prime. Test it by writing out all prime numbers less than 50.
7. Write a NumPy program to compute the eigenvalues and right Eigen vectors of a given square array.
8. Generate two array of same length and plot on x axis and y-axis
9. Write a NumPy program to get the element-wise remainder of an array of division
10. Plot a sign wave using matplotlib
11. Calculate Fourier transformation and plot sum of two sines wav
12. Write a program, which will find all such numbers between 1000 and 3000 (both included) such that each digit of the number is an even number. The number obtained should be printed in a comma-separated sequence on a single line
13. Given f(x) = x and g(x) = $xe^{(1-\frac{x}{2})}$:
    a. Plot the functions on the x-interval [0, 5] on the same set of axes.
    b. Find the points of intersection and find the volume when the region between these curves is rotated about the x-axis.
    c. Find the volume when the region between these curves is rotated about the line y = 3.
14. Write a Python class named Rectangle constructed by a length and width and a method which will compute the area of a rectangle
15. Find the partial fraction decomposition of $\frac{x+4}{x^2-2x}$

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

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

CO1. Express different Decision Making statements and Functions.
CO2. Understand and summarize different File handling operations.
CO3. Design and develop network applications using Python.

Course Name: **Mathematical Software Lab**
Course Code: **MA-617**

Contact Hours/Week: **4P** Course Credits: **02**

Course Objectives

- To understand and apply the basic principles of programming.
- To provide skills for designing flowcharts and writing MATALB programs.
- To create simple programming scripts and functions.
- To solve basic and advanced numerical and symbolic mathematics problems.
- To visualize and present data.
- To enable the students to debug programs.

List of Experiments

1. Brief Introduction, Installation of MATLAB, History, Use of MATLAB, Key features
2. Introduction to MATLAB Software and MATLAB window
3. Data files and Data types: Character and string, Arrays and vectors, Column vectors, Row vectors.
4. Program for Arithmetic operations and equations, Matrix operations, and Trigonometric functions.
5. Working with script tools
6. Writing program for Plotting and Graphics
7. Writing programs with logic and flow control and Writing functions.
8. Use of Control Flow and Conditional Control.
9. Writing user defined functions.
10. Programs for Symbolic Math
11. Simulink Environment & Interface

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problmes at the start of semester based on above generic list.*

Course Outcomes

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

CO1. Represent mathematical objects as data structures.
CO2. Translate mathematical methods to MATLAB code.
CO3. Break a complex task up into smaller, simpler tasks.
CO4. Tabulate results and represent data visually.

Course Name: **Operations Research Lab**
Course Code: **MA-618**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To understand and apply the basic principles of programming.
- To identify/characterize/ define a problem.
- To design a program to solve the problem.
- To learn the modeling skills necessary to describe and develop algorithm for optimization problem.

List of Experiments

1. To solve linear programming problem using Graphical Method with multiple constraints, unbounded and infeasible solution.
2. Solution of LPP with Simplex method.
3. Graphical Solution of Weighted Goal Programming.
4. Graphical Solution of Pre-emptive Goal Programming.
5. Solution of Transportation Problem as a LPP.
6. Solution of Assignment problem as a LPP.
7. Solution of Travelling Salesman Problem.
8. Solution of Shortest Path Problem as a LPP.
9. Project Planning (Deterministic Case- CPM, Probabilistic Case- PERT).
10. Solution of Two-Person-zero-sum pure and mixed strategy game.
11. Linear Programming solution of game problem.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

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

CO1. Identify different types of optimization problems.
CO2. Understanding of different optimization techniques.
CO3. Ability to solve optimization problem using MATLAB, Excel solver, LINGO.

Course Name: **Complex Analysis**
Course Code: **MA-621**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits:**04**

Course Objectives

- To impart knowledge about complex numbers, its topology and its geometric representation.
- To understand the concept of limit, continuity, differentiability and mapping properties of complex function.
- To impart knowledge about analytic function, their singularities series expansion and integration.

Course Content

Analytic Functions: limit, continuity and differentiability of complex valued function, necessary and sufficient conditions for a function to be analytic, method of construction of an analytic function, Cartesian and polar form of Cauchy-Riemann equation.

Conformal Mappings: Definition, necessary condition for mapping to be conformal, sufficient condition for mapping to be conformal, linear transformations, bilinear transformations, resultant of two bilinear transformations, cross-ratio, fixed points of a bilinear transformation.

Complex Integration: Cauchy's fundamental theorem, Cauchy's integral formula, Poisson's integral formula for a circle, Morera's theorem, Liouville's theorem, Taylor's theorem, Laurent's theorem, Rouche's theorem.

Calculus of Residues: zeros, poles, singularities, evolution of residue at pole of order one and more than one, Cauchy's residue theorem and its applications.

Uniform Convergence: uniform convergence of sequence and series, general principle of uniform convergence, Wierstrass's M-test, Hardy's test, continuity of sum function, term by term differentiation, term by term integration.

Course Outcomes

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

CO1. Obtain the basic concept of complex numbers and their topology.

CO2. Understand the nature of analytic function, its differentiation, integration, series expansion, and singularities.

CO3. Learn the basic concepts of mapping properties of complex function and Mobius transformation.

Books and References

1. Introduction to Complex Analysis by H.A. Priestley, Oxford.
2. Complex Analysis by L.V. Ahlfors, Tata McGraw Hill.
3. Basic Complex Analysis by J.E. Marsden and M.J. Hoffman, W.H. Freeman.
4. Complex Variables and Applications by J.W. Brown and R.V. Churchill, McGraw Hill.
5. Complex Analysis for Mathematics and Engineering by J.H. Mathews and R.W. Howell, Narosa Publishing House.
6. Visual Complex Analysis by T. Needham, Oxford.

Course Name: **Probability and Statistics**

Course Code: **MA-622**

Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide students with the foundations of probabilistic and statistical analysis mostly used in varied applications in engineering.
- To define and identify some basic probability distributions and random variables.
- To introduce the fundamental concepts relevant to the modeling of experimental data.
- To enable the students to understand the factors that cause the physical process in real life situations.

Course Content

Probability and Random Variable: Axioms of probability. Conditional probability. Total probability, Bayes' theorem. Random variable. Probability mass function. Probability density function. Moments. Moment generating function and their properties.

Bivariate Random Variable: Joint distributions. Marginal and conditional distribution. Transformation of random variables. Central limit theorem. Covariance. Correlation.

Theoretical Distributions: Binomial, Poisson, Geometric, Negative Binomial, Uniform, Exponential, Gamma, Weibull and Normal distributions and their properties.

The General Liner Model: Ordinary Least Square (OLS) estimation and prediction. Use of Dummy variables and seasonal adjustment. Generalizes Least Square (GLS) estimation and prediction. Heteroscedastic disturbances, Pure and Mixed estimator, grouping of observations and of equations.

Time Series Analysis: Time series as discrete parameter stochastic process. Auto covariance and autocorrelation function and their properties. Test for trends and seasonality. Exponential and moving average smoothing. Holt and Winters Smoothing. Forecasting based on smoothing.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Understand and analyze the theoretical & practical aspects of random variables, theoretical distributions, linear model and time series analysis.

CO2. Identify an appropriate theoretical distribution to fit the empirical data and find out the properties of data.

CO3. Use the linear regression modeling to find out the cause and effect relationship.

CO4. Understand and apply the concept of stationarity to the analysis of time series data in various contexts.

CO5. Run and interpret time-series analysis and regression models for time series.

Books and References

1. A First Course in Probability by Ross, S., Pearson Education India.
2. An Introduction to Probability and Statistics, Rohtagi by V.K. & Saleh, A.K.M.E., Wiley.
3. Time Series Analysis, Forecasting and Control, Box by G.E.P; Jenkins, G.M.; Reinsel G.C. &Ljung, G.M., Wiley-Blackwell.
4. Forecasting: Methods and Applications by Spyros M., Wheelwright, S.C.,& Hyndman, R.J.; Wiley-Blackwell.

Course Name: **Mathematical Methods** Course Code: **MA-623** Course Type: **Core**
Contact Hours/Week: **4L** — Course Credits: **04**
Course Objectives • To formulate and solve abstract mathematical problems. • To recognize and appreciate the connections between theory and applications. • To develop skills to think quantitatively and analyse problems critically..
Course Content
Integral Transform (Laplace & Fourier): Fourier series expansion and Fourier integrals, Properties, inversion formulae of Laplace and Fourier transforms, convolution, application to ordinary, partial differential equations and integral equations. **Calculus of Variations:** Basic concepts of the calculus of variations such as maxima and minima, functionals, extremum, variations, function spaces, Euler's equations with the cases of one variable and several variables. Natural boundary conditions and transition conditions. Variational notation, constraints and Lagrange multipliers, variable end points. Sturm-Liouville problems, Hamilton's principle, Lagrange's equations. Generalized dynamical entities, constraints in dynamical systems. The Variational problems for deformable bodies, The variational problem for the elastic plate. The Rayleigh-Ritz method. **Integral Equations:** Definition and classification of linear integral equations. Conversion of initial and boundary value problems into integral equations. Green's function approach. Linear equations in cause and effect. The influence function. Fredholm equations with separable kernels. Hilbert-Schmidt theory. Iterative methods for solving equations of the second kind. The Neumann series. Fredholm theory. Singular integral equations. Iterative approximations to characteristic functions. Approximate method of undetermined coefficients. The method of collocation. The method of weighting functions.
Course Outcomes Upon successful completion of the course, the student will be able to: CO1. Explain fundamental mathematical concepts or analyse real-world problems to non-mathematicians. CO2. Understand the differences between proofs and other less formal arguments. CO3. Recognize real-world problems that are amenable to mathematical analysis and formulate mathematical models of such problems.
Books and References 1. Methods of applied mathematics by F. B. Hildebrand, Dover Publications, Inc., New York. 2. Fourier transforms, Cambridge Tracts in Mathematics and Mathematical Physics, No. 52 by R. R. Goldberg, Cambridge University Press, New York. 3. Integral equations by H. Hochstadt, Wiley Classics Library, John Wiley & Sons, Inc., New York. 4. A first course in the calculus of variations by M. Kot, Student Mathematical Library, 72, American Mathematical Society, Providence. 5. Integral equations: A practical treatment, from spectral theory to applications by D. Porter and D. S. G. Stirling, Cambridge University Press.

Course Name: **Data Structure and Algorithms**
Course Code: **MA-624**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart the basic concepts of data structures and algorithms.
- To understand concepts about searching and sorting techniques.
- To understand basic concepts about stacks, queues, lists, trees and graphs.
- To understand about writing algorithms and step by step approach in solving problems with the help of fundamental data structures.

Course Content

Introduction: Data types, data structures, abstract data types, the running time of a program, the running time and storage cost of algorithms, complexity, asymptotic complexity, obtaining the complexity of an algorithm.
Array, Stacks and Queues: Notations and Analysis, Storage structures for arrays - sparse matrices - structures and arrays of structures, Stacks and Queues: Representations, implementations and applications.
Linked Lists: Singly linked lists, stacks and queues using linked lists, operations on Polynomials, Doubly Linked Lists, Circularly Linked Lists, dynamic storage management – Garbage collection and compaction.
Trees Basic terminology, General Trees, Binary Trees, Tree Traversing: in-order, pre-order and post-order traversal, building a binary search tree, Operations on Binary Trees, Height Balanced Trees(AVL), B-trees, B+ -trees.
Graphs: Basic definitions, representations of directed and undirected graphs, the single-source shortest path problem, the all-pair shortest path problem, traversals of directed and undirected graphs, directed acyclic graphs, strong components, minimum cost spanning tress, articulation points and bi-connected components, graph matching.
Sorting and Searching Techniques: Bubble sorting, Insertion sort, Selection sort, Shell sort, Merge sort, Heap and Heap sort, Quick sort, Radix sort and Bucket sort, Sequential searching, Binary Searching, Hash table methods.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Interpret and compute asymptotic notations of an algorithm to analyze the time complexity.
CO2. Use of linear and non-linear data structures as the foundational base for computer solutions to problems.
CO3. Demonstrate the ability to implement various types of static and dynamic lists.
CO4. Implement binary trees, binary tree traversals, binary search trees and perform related analysis to solve problems.
CO5. Implement various types of sorting algorithms.

Books and References

1. An Introduction to Data Structures with applications by J.P. Tremblay and P.G. Sorenson, Tata McGraw Hill.
2. Algorithms ad Applications in C++ by S. Sahni, Data structures, WCB/McGraw Hill.
3. Data Structures and Algorithms by Aho Ullman and Hopcroft, Pearson Education India.
4. Data Structures using C by Y. Langsam, M. J. Augenstein and A. M. Tenenbaum, Pearson Education
5. Data Structures – A Pseudocode Approach with C by Richard F. Gilberg, Behrouz A. Forouzan, Thomson Brooks.

Course Name: **Advanced Python Lab** Course Code: **MA-625**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- To understand that how to analyze Data using Python.
- To provide the basics of Python and explore many different types of data.
- To create simple programming scripts and functions.
- To prepare data for analysis, perform simple statistical analysis.
- To visualize and present data.

List of Experiments

1. Write a Pandas program to create the mean and standard deviation of the data of a given Series
2. Write a Pandas program to select the specified columns and rows from a given data frame.
3. Write a Pandas program to Data Formatting and Normalization in Python.
4. Write a Pandas program to Turning categorical variables into quantitative variables.
5. Write a Pandas program to Exploratory Data Analysis.
6. Write a Pandas program to Descriptive Statistics.
7. Write a Pandas program to Correlation, Analysis of Variance (ANOVA).
8. Write a Pandas program to linear regression and Multiple Linear Regression.
9. Create a Python project to guess a number that has randomly selected.
10. Given $f(x) = e^{x/2}$ and g(x) = 3 − 3x:
    a) Graph both functions on the x-interval [−1, 2] on the same set of axes.
    b) Find the area between these curves on the interval −1 ≤ x ≤ 2.
11. Given the function f(x) = $x^3 - 3x^2 - \frac{10}{3}x + \frac{200}{27}$
    a) Plot f on the interval x ∈ [0, 4].
    b) Evaluate the definite integral $\int_0^4 f(x)$ dx
12. Construct a simple dense layer neural network architecture.
13. Construct a simple convolution layer neural network architecture.
14. Construct a AUTOENCODER using dense and convolution neural network.
15. Construct MSE loss function.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

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

CO1. To load, manipulate, analyze, and visualize cool datasets.
CO2. Using machine learning algorithms to build smart models.
CO3. To predict future trends from data.

Course Name: **Data Structure Lab** Course Code: **MA-626**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- To teach students various data structures and to explain them algorithms for performing various operations on these data structures.
- This lab complements the data structures course.
- Students will gain practical knowledge by writing and executing programs using various data structures such as arrays, linked lists, stacks, queues, trees, graphs, hash tables and search trees.

List of Experiments

1. Write a program that uses functions to perform the following: a) Create a singly linked list of integers. b) Delete a given integer from the above linked list. c) Display the contents of the above list after deletion.
2. Write a program that uses functions to perform the following: a) Create a doubly linked list of integers. b) Delete a given integer from the above doubly linked list. c) Display the contents of the above list after deletion.
3. Write a program that uses stack operations to convert a given infix expression into its postfix equivalent, Implement the stack using an array.
4. Write programs to implement a double ended queue ADT using i) array and ii) doubly linked list respectively.
5. Write a program that uses functions to perform the following: a) Create a binary search tree of characters. b) Traverse the above Binary search tree recursively in Postorder.
6. Write a program that uses functions to perform the following: a) Create a binary search tree of integers. b) Traverse the above Binary search tree non recursively in in-order.
7. Write programs for implementing the following sorting methods to arrange a list of integers in ascending order: a) Insertion sort b) Merge sort
8. Write programs for implementing the following sorting methods to arrange a list of integers in ascending order: a) Quick sort b) Selection sort
9. i) write a program to perform the following operation: A) Insertion into a B-tree ii) Write a C program for implementing Heap sort algorithm for sorting a given list of integers in ascending order.
10. Write a program to implement all the functions of a dictionary (ADT) using hashing.
11. Write a program for implementing Knuth-Morris- Pratt pattern matching algorithm.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

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

CO1. Design and analyze the time and space efficiency of the data structure.
CO2. Identify the appropriate data structure for given problem.
CO3. Understand the applications of data structures.
CO4. Understand which algorithm or data structure to use in different scenarios.

Course Name: **SPSS Software Lab**
Course Code: **MA-627**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To provide skills to use the SPSS Software.
- To provide skills for analyzing data with appropriate techniques.
- To enable the students to visualize data.

List of Experiments

1. An Overview of SPSS: Mouse and keyboard processing, frequently–used dialog boxes, editing output, Printing results, Creating and editing a data file.
2. Managing Data: Listing cases, replacing missing values, computing new variables, recording variables, exploring data, selecting cases, sorting cases, merging files.
3. Graphs: Creating and editing graphs and charts.
4. Frequencies: Frequencies, bar charts, histograms, percentiles.
5. Descriptive Statistics I: measures of central tendency, variability, deviation from normality, size and stability.
6. Descriptive Statistics II: Cross Tabulation and chi-square analyses, the means procedure.
7. Bivariate Correlation: Bivariate Correlation, Partial.
8. The T-test procedure: Independent –samples, paired samples, and one sample tests.
9. The one way ANOVA procedure: One way analysis of variance.
10. General Linear model: Two–way analysis of variance.
11. General Linear model: Simple Linear Regression.
12. General Linear model: Multiple Linear Regression.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

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

CO1. Import, review, manipulate and summarize data-sets in SPSS Software.
CO2. Explore data-sets to create testable hypotheses and identify appropriate statistical tests.
CO3. Perform appropriate statistical tests using SPSS software.
CO4. Create and edit visualizations with SPSS software.

Course Name: **Functional Analysis**
Course Code: **MA-631**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand basics of normed vector spaces and its applications in different fields.
- To have the idea of linear operator in normed vector spaces and the properties.
- To view basics of Hilbert spaces and discuss some theorem and its properties.
- To have the idea of linear operator in Hilbert spaces and the properties.

Course Content

Metric Spaces: Review of Hölder inequality, Minkowski inequality and vector spaces with examples of ℓ_p and L_p spaces.

Normed Spaces and Banach Space: Normed linear spaces, Banach spaces with examples, convergence and absolute convergence of series in a normed linear space. Inner product spaces, Hilbert spaces, relation between Banach and Hilbert spaces. Schwarz inequality.

Inner Product Spaces and Hilbert Spaces: Convex sets, existence and uniqueness of a vector of minimum length, projection theorem. Orthogonal and orthonormal system in Hilbert spaces with examples, Bessel's inequality, Parseval's identity, Characterization of complete orthogonal systems.

Fundamental Theorems for Normed and Banach Spaces: Continuity of linear maps on normed linear spaces, equivalent norms, conjugate and dual spaces, The Riesz Representation Theorem. Adjoint operators, self adjoint operators, normal operators, unitary operators on Hilbert spaces (H) and their properties. Isometric isomorphism of H onto itself under unitary operators and their importance. Projection operators on Banach spaces and Hilbert spaces. Orthogonal projections, The Closed Graph Theorem, The Uniform Boundedness Principle and its applications, The Hahn-Banach Extension and Separation theorems, Open Mapping Theorem and its applications.

Further Applications: Contraction mapping with examples, Banach-fixed point theorems and its applications. Eigenvalues, eigenvectors and eigen-spaces, invariant spaces, spectral theorem on finite dimensional Hilbert spaces.

Course Outcomes

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

CO1. Explain the fundamental concept of functional analysis and their role in modern mathematics and applied concepts.

CO2. Demonstrate accurate and efficient use of functional analysis techniques.

CO3. Demonstrate capacity for mathematical reasoning through analysis proving and explain concept from functional analysis.

CO4. Apply problem solving using functional analysis techniques applied to diverse situation in physics, engineering and other mathematical context.

Books and References

1. Introductory functional analysis with applications by E. Kreyszig, Wiley Classics Library, John Wiley & Sons, Inc., New York.
2. Functional Analysis: A First Course by M. T. Nair, PHI Learning Pvt. Ltd.
3. Functional Analysis by G. Bachman and L. Narici, Academic Press.
4. A course in functional analysis by J. B. Conway, Graduate Texts in Mathematics, 96, Springer-Verlag, New York.
5. Introduction to Hilbert Spaces with Applications by L. K. Debnath and P. Mikusiński, Academic Press.
6. Introduction to Topology and Modern Analysis by G. F. Simmons, McGraw Hill.

Course Name: **Numerical Analysis**
Course Code: **MA-632**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce the errors and various sources of erros in numerical computation.
- To impart knowledge about numerical methods for solving non-linear equations, interpolation, differentiation, and integration.
- To enable the students to implement the direct and iterative methods for solving system of equation.
- To enable the students to solve initial and boundary value problems numerically.
- To introduce the finite difference method to solve ordinary differential equation.

Course Content

Errors: Definition and sources of errors, Floating-point arithmetic and rounding errors, Loss of significance and Propagation of errors, Stability and accuracy.

Nonlinear Equations: Bisection method, Fixed point iteration method, secant method, Newton-Raphson method for simple and multiple root, Rate of convergence, Solution of a system of nonlinear equations.

Linear Systems and Eigen Values: Direct methods (Gauss elimination with pivoting strategy, LU decomposition), iterative methods (Jacobi and Gauss-Seidel) and their convergence analysis, Rayleigh's power, Jacobi's method, Given's method for eigen-values and eigen-vectors.

Interpolation: Lagrange interpolation, Newton interpolation, Hermite interpolation, Spline interpolation, B-splines, Bivariate interpolation, Error of the interpolating polynomials, Data fitting and least-squares approximation problem.

Differentiation and Integration: Difference operators (forward, backward and central difference), Newton-Cotes formula, Trapezoidal and Simpson's rules, Gaussian quadrature.

Initial Value Problems: Euler and modified Euler methods, Runge-Kutta methods, Multistep methods, Predictor-Corrector method.

Boundary Value Problems: Shooting methods, Finite difference methods for ODE.

Course Outcomes

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

CO1. Understand the errors, source of error and its effect on any numerical computations.
CO2. Learn how to obtain numerical solution of nonlinear equations.
CO3. Solve system of linear equations numerically using direct and iterative methods.
CO4. Learn how to solve definite integrals, initial and boundary value problems numerically.

Books and References

1. Elementary Numerical Analysis-An Algorithmic Approach by S.D. Conte, and Carl de Boor, Tata McGraw Hill.
2. Introduction to Numerical Analysis by K.E. Atkinson, John Wiley.
3. Numerical Analysis for Scientific and Engineering Computations by M.K. Jain, S.R.K. Iyengar and R.K. Jain, New Age international (P) Ltd.
4. Introduction Methods of Numerical Analysis by S.S. Sastry, Prentice Hall of India.
5. Numerical solution of partial differential equations: Finite difference methods by G.D. Smith, Clarendon Press.
6. Numerical solution for partial differential equations by K.W. Morton and D.F. Mayers, Cambridge University Press.
7. Numerical Methods for Engineers and Scientists by J.N. Sharma, Narosa Publishing House, New Delhi.

Course Name: **R Software Lab** Course Code: **MA-633**	
Contact Hours/Week: **4P**	Course Credits: **02**
Course Objectives • To provide skills to use the R interactive environment. • To provide skills for analyzing data with appropriate statistical techniques. • To enable the students to visualize data.	
List of Experiments 1. An Overview of R: Basic fundamentals, installation and use of software, data editing, use of R as a calculator, functions and assignments. 2. Managing Data: Listing cases, replacing missing values, computing new variables, recording variables, exploring data, selecting cases, sorting cases, merging files. 3. Graphs: Creating and editing graphs and charts. 4. Frequencies: Frequencies, bar charts, histograms, percentiles. 5. Descriptive Statistics I: measures of central tendency, variability, deviation from normality, size and stability. 6. Descriptive Statistics II: Cross Tabulation and chi-square analyses, the means procedure. 7. Bivariate Correlation: Bivariate Correlation, Partial. 8. The T-test procedure: Independent –samples, paired samples, and one sample tests. 9. The one way ANOVA procedure: One way analysis of variance. 10. General Linear model: Two–way analysis of variance. 11. General Linear model: Simple Linear Regression. 12. General Linear model: Multiple Linear Regression. ***Note:*** *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*	
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Import, review, manipulate and summarize data-sets in R Software. CO2. Explore data-sets to create testable hypotheses and identify appropriate statistical tests. CO3. Perform appropriate statistical tests using R Software. CO4. Create and edit visualizations with R Software.	

Course Name: **Numerical Methods Lab**
Course Code: **MA-634**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To impart the knowledge developing algorithm and MATLAB codes for above listed methods.
- To equip students with the skill create function files and call the same.
- To enable the students for efficient use of computers, laboratories and softwares to handle problems that are difficult to be solved manually.

List of Experiments

1. To develop algorithm and codes to solve algebraic and transental equations using
   a) Bisection method
   b) RegulaFalsi Method
   c) Newton Raphson method.
2. To develop algorithm and codes to solve system of linear equations by
   a) Gauss elimination method
   b) Gauss Seidal iteration method
   c) LU Decomposition method.
3. To develop codes for finding definite integrals using
   a) Trapezoidal rule
   b) Simpson's 1/3 and 3/8 rule
   c) Romberg Integration.
4. Developing codes to find numerical solution of ordinary differential equation using
   a) Euler's method,
   b) RungeKutta (4^{th} order) Method,
   c) Adam Bashforth predictor corrector method.
5. To develop codes for finding value of dependent variable at particular point by
   a) Newton's forward interpolation,
   b) Newton's backward interpolation,
   c) Gauss forward and Backward interpolation.
6. To find derivative of dependent variable using interpolation.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

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

CO1. Students will be able to develop algorithms and consequently codes for various numerical methods.
CO2. Students will learn to use inbuilt functions, create and call function files.
CO3. Students will also learn to control error in numerical computations
CO4. They will be able to use their computational skills efficiently with desired level of accuracy.

Course Name: **Viscous Fluid Dynamics**
Course Code: **MA-721**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the Fluid dynamics and basic equations of flow of viscous fluid.
- To introduce the fundamental concepts relevant to Dynamical Similarity and Inspection & Dimensional Analysis.
- To enable the students to understand the method of Exact Solutions of the Navier Stokes' Equations.

Course Content

Introduction to Fluid Dynamics: Fluid, Continuum hypothesis, Viscosity, Newton's Law of Viscosity, Some Cartesian Tensor Notations, Most general motion of a fluid element, Stokes' law of friction, Thermal Conductivity, Generalized law of Heat conduction.

Fundamental Equations of the Flow of Viscous Fluids: Equation of State, Equation of Continuity, Equation of Motions (Navier – Stokes (NS) Equations), Equation of Energy, Vorticity and Circulation in a viscous incompressible fluid motion.

Dynamical Similarity and Inspection & Dimensional Analysis: Dynamical Similarity (Reynold's Law),Inspection Analysis, Dimensional Analysis, Buckingham – π - Theorem, Method of finding out the π – products, Application of π – Theorem to viscous compressible motion, Physical importance of Non-dimensional parameters, Important non-dimensional coefficients in the dynamics of viscous fluids.

Exact Solutions of the Navier Stokes' Equations

- ***Study incompressible flow with constant fluid properties:*** Flow between parallel plates (a) Velocity distribution, (b) Temperature Distribution, Plane Couette flow, Plane Poiseuille flow, generalized plane Couette flow. Flow in a circular pipe (Hagen-Poiseuille flow (a) velocity distribution (b) Temperature distribution. Flow between two concentric Rotating Cylinders (Couette flow): (a) Velocity distribution (b) Temperature distribution.
- **Unstudy incompressible flow with constant fluid properties:** Flow due to a plane wall suddenly set in motion, flow due to an oscillating plane wall.
- **Study incompressible flow with fluid suction/injection on the boundaries:** Plane Couette flow with transpiration cooling.

Course Outcomes

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

CO1. Identify various physical problems related with solution of NavierStoke's Equations.
CO2. Describe the solution physically.
CO3. Solve some more physical problems related with steady incompressible flow with variable viscosity
CO4. Assess the results obtained by solving above problems.

Books and References

1. Viscous fluid dynamics by J. L. Bansal, Oxford and IBH Publishing Co. Pvt. Ltd.
2. Fluid mechanics by P. K. Kundu, I. M. Cohen and D. R. Dowling, Academic Press.
3. Introduction to fluid mechanics and fluid machines by S. K. Som, G. Biswas and S. Chakraborty, Tata McGraw-Hill Education.
4. Fluid Mechanics by F. M. White, McGraw-Hill.
5. Introduction to fluid mechanics by R. W. Fox and A. T. McDonald, John Wiley & Sons, New York.

Course Name: **Topology**
Course Code: **MA-722**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand Topological Space (product space and quotient space) and its applications in different fields.
- To have the idea of sequences and continuous function and the properties.
- To view some connected space and compact space and discussed some theorem and its properties.
- Students also learn about fundamental of algebraic topology.

Course Content

Introduction: Finite, countable, uncountable sets, functions, relations, axiom of choice, Zorn's Lemma.

Topological Spaces and Continuous Functions: Open sets, closed sets, basis for a topology, sub basis, T_1 and T_2 spaces, order topology, product topology, subspace topology, limit point, continuous function, general product topology, metric space and its topology, quotient topology.

Connectedness and Compactness: Connected spaces, connected subspaces, local connectedness, compact subspace, limit point compactness, local compactness.

Countability and Separation Axioms: Countability axioms, separation axioms, regular and normal spaces, Urysohn's Lemma, UrysohnMetrization Theorem, Tietze Extension Theorem, Tychonoff Theorem.

Course Outcomes

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

CO1. Students will know definition of standard term topology and variety of example and counter example in topology.

CO2. Students will understand computations and application in algebraic topology.

CO3. Students will be able to work with new ideas in mathematics.

Books and References

1. Topology by J. R. Munkres, Prentice-Hall, Inc., NJ.
2. Introduction to Topology and Modern Analysis by G. F. Simmons, McGraw Hill.
3. Introduction to Topology by T. W. Gamelin and R. E. Greene, Dover Publications, Inc., Mineola, NY.
4. Introduction to Topology by M. J. Mansfield, D. Van Nostrand Co., Inc., Princeton, NJ.
5. Introduction to Topology by B. Mendelson, Dover Books on Advanced Mathematics, Dover Publications, Inc., New York.

Course Name: **Advanced Operations Research**
Course Code: **MA-723**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide quantitative insight and understanding of fundamental methods of Non-linear, dynamic and quadratic programming problems.
- To demonstrate the powerful capabilities of optimization theory to enable reducing costs, improving efficiency, optimal usage of resources and providing benefits in many other key dimensions in engineering / industry / managerial / decision making problems.
- To have flavor of both sound theoretical foundation of various methods and their actual implementations in problems solving.

Course Content

Nonlinear Programming: One Dimensional Minimization Methods: Unimodel function, Elimination methods, unrestricted search, Exhaustive search, Dichotomous search, Fibonacci Method, Golden selection method. Unconstrained Optimization Techniques: Direct Search Method, Pattern search method, Descent methods, steepest descent method.

Dynamic Programming: Decision Tree and Bellman's principle of optimality, Concept of dynamic programming, minimum path problem, Mathematical formulation of multistage Model, Backward & forward Recursive approach, Application in linear programming.

Quadratic Programming: Formulation, converting into LPP, Simplex approach.

Stochastic Programming: Basic Properties of Probability theory, stochastic linear, nonlinear and dynamic programming.

Queuing Theory: Steady-state solution solutions of Markovian Queuing Models: M/M1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited space, M/G/1.

Course Outcomes

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

CO1. Understand the characteristics of different types of decision-making environments and the appropriate decision making approaches and tools to be used in each type.

CO2. Build and solve Non-linear programming, quadratic, dynamic and queuing models.

CO3. Design new simple models to improve decision –making and develop critical thinking and objective analysis of decision problems.

Books and References

1. Introduction to operations research by F. S. Hillier and G. J. Lieberman, Holden-Day, Inc., Oakland, CA.
2. Nonlinear and dynamic programming by G. Hadley, Addison-Wesley Publishing Co., Inc., Reading, MA.
3. Optimization: theory and applications by S. S. Rao, Wiley Eastern Ltd., New Delhi.
4. Numerical Optimization with Applications by S. Chandra, Jaydeva and A. Mehra, Narosa Publishing House.
5. Nonlinear programming by M. S. Bazaraa, H. D. Sherali and C. M. Shetty, Wiley-Interscience.
6. Operation Research: An Introduction by H.A. Taha, Prentice Hall of India.
7. Operation Research: Theory, Methods and Applications by S.D. Sharma and H. Sharma, Kedar Nath & Co.

Course Name: **Applied Linear Algebra**
Course Code: **MA-724**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce concepts of linear algebra and provide wide application of this discipline within scientific field.
- To impart knowledge about Vector Spaces, Linear Operators, Inner product spaces and Eigen decomposition.
- To enable the students with analytical ability to apply the theorems and results in real life engineering applications.

Course Content

Introduction: System of linear equations, Vector Spaces, Subspaces, Basis and dimension

Linear Operators: Functions, Linear operators, Null space and range, Rank and nullity theorem, Operator inverses, Application to matrix theory, Computation of the range and null space of a matrix, Matrix of an operator, Operator algebra, Change of basis, similar matrices, Applications.

Eigen Decomposition: Eigenvectors, Eigenvalues, Characteristic polynomial, Eigen spaces, Diagonalizability conditions, Cayley-Hamilton theorem, Invariant subspaces, The primary decomposition theorem, Cyclic subspaces and annihilators, Cyclic decomposition.

I**nner Product Spaces:** Inner product between two vectors, orthogonal and orthonormal vectors, Gram-Schmidt process for orthogonalization, projection theorem, adjoint of a linear operator, self-adjoint operators, Positive operators, Nonnegative operator, unitary operator, normal operators, spectral theorem, projection operator, positive definite forms, Bilinear forms.

Course Outcomes

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

CO1. Concepts of Vector Spaces and linear transformation.
CO2. Understand fundamental concepts of matrix representation of linear transformation, null space, range space and change of basis.
CO3. Learn details of Inner product space.
CO4. Theoretical concepts about projection theorem and positive definite forms.
CO5. Understand development and concepts of Eigen decomposition, spectral theorem.
CO6. Have an insight about application of linear Algebra.

Books and References

1. Linear algebra by K. Hoffman and R. Kunze, Prentice-Hall Mathematics Series, Prentice-Hall, Inc., Englewood Cliffs, NJ.
2. Matrix analysis and applied linear algebra by Society for Industrial and Applied Mathematics (SIAM), C. D. Meyer, Philadelphia, PA.
3. Applied linear algebra by B. Noble and J. W. Daniel, Prentice-Hall, Inc., Englewood Cliffs, NJ.
4. Applied linear algebra by P. J. Olver and C. Shakiban, Pearson Prentice Hall, Upper Saddle River, NJ.
5. Applied linear algebra and matrix analysis, Undergraduate Texts in Mathematics by T. S. Shores, Springer.

Course Name: **Mathematics Behind Machine Learning**
Course Code: **MA-725**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce the mathematical topics, techniques and results that form the backbone of some major ML algorithms.
- To make the student appreciate both the utility and aesthetics of the different fields in Mathematics.
- To provide a firm theoretical foundation for existing methods.
- To equip the students with the skills necessary to further their research in Machine Learning.

Course Content

Data Representation: Eigenvalues, Eigenvectors, linear regression, Principal Component Analysis (PCA), Singular value decomposition (SVD), Fischer Discriminant.

Functionals, Hilbert spaces, Riesz representation theorem, Kernel trick, Kernel PCA, Kernel SVM, Norm Minimization, Sparse representation theory, Dimensionality reduction.

Supervised Learning: Convex optimization, Primal-Dual transformations, Karush-Kuhn-Tucker conditions, Support vector machine (SVM), Probability and Measures, Types of convergences, Statistical learning theory, VC dimension and capacity, Blackwell's approachability.

Unsupervised Learning: Expectation maximization, EM-based clustering, C-means clustering, Fuzzy C-means clustering, Operator theory, Decomposition of operators and subspaces.

Course Outcomes

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

CO1. Understand mathematical concepts used in machine learning (ML) most algorithms.
CO2. Learn theoretical concept of supervised and unsupervised learning in ML algorithms.
CO3. Apply the skills necessary to do further research in the field of ML.

Books and References

1. The elements of Statistical learning, Data Mining, Inference and Prediction by T. Hatsei, R. Tibshirani, J. Friedman, Springer Series in Statistics.
2. Machine Learning by T.M. Mitchell, McGraw-Hill.

Course Name: **Theory of Stability** Course Code: **MA-726** Course Type: **Programme Elective-I**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives • To impart knowledge about the thermal instability of a layer of fluid heated from below (Bénard Problem), stability of superposed fluids. • To introduce the effect of rotation and magnetic field in various types of stability problems. • To enable the students to understand the fundamentals of hydrodynamic and Hydro magnetic stability.
Course Content
Basic Concepts: Basic concepts of linear theory, stability, instability, neutral curves, principle of exchange of stabilities, Marginal stability; over stability, thermal instability. **The Thermal Instability of a Layer of Fluid Heated from below:** • **Bénardproblem:** The nature of the physical problem, the basic hydrodynamic equations, the Boussinesq approximation, the perturbation equations and boundary conditions, the analysis into normal modes, the principle of exchange of stabilities, the equations governing the marginal state and the reduction to a characteristic value problem, Exact solution of the characteristic value problem. • **The effect of rotation:** The perturbation equations, the analysis into normal modes, the case when instability sets in as stationary convection (A variational principle), solution for the case when instability sets in as stationary convection, on the onset of convection as overstability (the solution for the case of two free boundaries). • **The effect of magnetic field:** The perturbation equations, boundary conditions, the analysis into normal modes, the case when instability sets in as stationary convection (A variational principle), solution for the case when instability sets in as stationary convection, on the onset of convection as overstability. **The Stability of Superposed Fluids:** • **The Rayleigh-Taylor instability:** The perturbation equations, the inviscid case (the case of two uniform fluids of constant density separated by a horizontal boundary, the case of exponentially varying density), the effect of rotation, the effect of vertical magnetic field. • **The Kelvin-Helmholtz instability:** The perturbation equations, the case of two uniform fluids in relative horizontal motion separated by a horizontal boundary, the effect of rotation, the effect of horizontal magnetic field.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify various physical problems related with thermal instability and stability of superposed fluids. CO2. Describe the solution physically. CO3. Solve some more physical problems for different type of fluids, which are physically occurred in engineering problems. CO4. Assess the results obtained by solving above problems.
Books and References 1. Hydrodynamic and hydromagnetic stability by S. Chandrasekhar, Dover Publications. 2. Convection in porous media by D. A. Nield and A. Bejan, Springer-Verlag, New York. 3. The energy method, stability, and nonlinear convection by B. Straughan, Applied Mathematical Sciences, Springer-Verlag, New York. 4. Studies in hydrodynamic and hydromagnetic stability by M. B. Banerjee and J. R. Gupta, Silver Line Publications, Shimla.

Course Name: **Database Management System**
Course Code: **MA-731**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- Understand the role of a database management system in an organization.
- Understand basic database concepts, including the structure and operation of the relational data model.
- Construct simple and moderately advanced database queries using Structured Query Language (SQL).
- Understand and successfully apply logical database design principles, including E-R diagrams and database normalization.
- Understand the concept of a database transaction and related database facilities, including concurrency control, journaling, backup and recovery, and data object locking and protocols.
- Describe and discuss selected advanced database topics, such as distributed database systems and the data warehouse.

Course Content

Basic Concepts: Introduction to File and Database systems- Database system structure – concepts and architecture, date models, schemas & instances, DBMS architecture & data independence, database languages & interfaces, Data Model, ER model.

Relational Models: SQL – Data definition- Queries in SQL-relational model concepts, relational model constraints, relational algebra, SQL- a relational database language: date definition in SQL, view and queries in SQL, specifying constraints and indexes in SQL; relational database management systems-Updates, Views, Integrity and Security, Relational Database design, Functional dependences and Normalization for Relational Databases, normal forms based on primary keys, (1NF, 2NF, 3NF & BCNF), lossless join and dependency preserving decomposition, converting ER-diagrams into relations.

Data Storage and Query Processing: Record storage and Primary file organization- Secondary storage Devices, Operations on Files, Heap File, Sorted Files, Hashing Techniques, Index Structure for files, Different types of Indexes-B-Tree - B+Tree.

Transaction Management: Transaction Processing, Need for Concurrency control, Desirable properties of Transaction, Schedule and Recoverability, Serializability and Schedules; Concurrency Control, Types of Locks, Two Phases locking, Deadlock.

Course Outcomes

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

CO1. Understand DBMS concept, data models and architecture.
CO2. Understand ER model and its mapping to relational model.
CO3. Use of relational algebra and SQP.
CO4. Apply normalization to build database and understand concurrency and recovery strategies for DBMS.

Books and References

1. An introduction to database concepts by B. Desai, Galgotia publications.
2. An introduction to database systems by C.J.Date, Addison Wesley.
3. Fundamentals of database systems by Elmsari and Navathe, Addison Wesley.
4. Database System Concepts by Abraham Silberschatz, Henry F. Korth and S. Sudarshan, McGraw-Hill.
5. Database System Implementation, Hector Garcia–Molina by Jeffrey D.Ullman and Jennifer Widom, Pearson Education.
6. Database System, Design, Implementation and Management by Peter Rob and Corlos Coronel, Thompson Learning Course Technology.

Course Name: **Text Mining & Analytics**
Course Code: **MA-732**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** | Course Credits: **04**

Course Objectives

- To provides an unique opportunity to learn key components of text mining and analytics aided by the real world datasets and the text mining toolkit.
- To give Hands-on experience in core text mining techniques
- To develop interesting text mining applications.

Course Content

Introduction: Definition, Objectives, Functional Overview, Relationship to DBMS, Digital libraries and Data Warehouses, organization, representation, and access to information, use of codes, formats, and standards, data structures for unstructured data; design and maintenance of such databases, indexing and indexes, retrieval and classification schemes.

Information Retrieval System Capabilities: Search, Browse, Miscellaneous, Cataloging and Indexing: Objectives, Indexing Process, Automatic Indexing, Information Extraction. Data Structures: Introduction, Stemming Algorithms, Inverted file structures, N-gram data structure, PAT data structure, Signature file structure, Hypertext data structure.

Automatic Indexing: Classes of automatic indexing, Statistical indexing, Natural language, Concept indexing, Hypertext linkages, Document and Term Clustering: Introduction, Thesaurus generation, Item clustering, Hierarchy of clusters.

User Search Techniques: Search statements and binding, Similarity measures and ranking, Relevance feedback, Selective dissemination of information search, Weighted searches of Boolean systems, Searching the Internet and hypertext, analysis, crowd sourcing search, construction and evaluation of search and navigation techniques; and search engines.

Information Visualization: Introduction, Cognition and perception, Information visualization technologies.

Text Search Algorithms: Introduction, Software text search algorithms, Hardware text search systems.

Information System Evaluation: Introduction, Measures used in system evaluation, Measurement example – TREC results, Evaluation of Asian language text retrieval, question answering and text summarization, cross-language information retrieval.

Query Expansion: Thesauri, Semantic Networks, Integrating Structured Data and Text.

Course Outcomes

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

CO1. Describe the history and development of text mining.
CO2. Identify the Automatic Indexing.
CO3. Apply principles of Document clustering and classification.
CO4. Assess the Natural language processing.

Books and References

1. Information Retrieval Systems: Theory and Implementation by G. Kowalski, Kluwer Academic Publishers.
2. Web Dragons: Inside the Myths of Search Engine Technology by I. Witten, M. Gori, T. Numerico, Morgan Kauffman.
3. Introduction to Information Retrieval by C. D. Manning, P. Raghavan and H. Schütze, Cambridge University Press.
4. Information Retrieval Data Structures and Algorithms by W.B. Frakes, R. B.Yates, Prentice Hall.
5. Information Storage &Retieval by R. Korfhage, John Wiley & Sons.

Course Name: **Digital Image Processing**
Course Code: **MA-733**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To study the image fundamentals and mathematical transforms necessary for image processing.
- To design and implement algorithms that perform basic image processing (e.g. noise removal and image enhancement) and advanced image analysis (e.g. image compression, image segmentation, Pattern Recognition).
- To assess the performance of image processing algorithms and systems.

Course Content

Introduction: Digital image representation, Fundamental steps in image processing, Elements of Digital Image processing systems, Elements of visual perception, Image model, Sampling and quantization, Relationship between pixels, Imaging geometry.

Image Enhancement: Enhancement by point processing, Sample intensity transformation, Histogram processing, Image subtraction, Image averaging, Spatial filtering, Smoothing filters, Sharpening filters, Frequency domain: Low- Pass, High-Pass, Homomorphic filtering.

Image Compression: Coding redundancy, Inter-pixel redundancy, fidelity criteria, Image compression models, Error-free compression, Variable length coding, Bit-plane coding, Loss-less predicative coding, Lossy compression, Image compression standards, Fractal Compression, Real-Time image transmission, JPEG and MPEG.

Image Segmentation: Detection of discontinuities, Edge linking and boundary detection, Thresholding, Region oriented segmentation, Use of motion in segmentation, Spatial techniques, and Frequency domaintechniques.

Spatial Operations and Transformations: Spatially dependent transform template and convolution, Window operations, 2- Dimensional geometric transformations.

Pattern Recognition: Classification and description, Structure of a pattern recognition system, feature extraction, Classifiers, Decision regions and boundaries, discriminate functions, Supervised and Unsupervised learning, PR-Approaches statistics, syntactic and neural.

Statistical Pattern Recognition: Statistical PR, Classifier Gaussian Model, Classifier performance, Risk and error, Maximum likelihood estimation, Bayesian parameter estimation approach, clustering for unsupervised learning and classifiers.

Course Outcomes

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

CO1. Learn different techniques employed for the enhancement of images.
CO2. Understand the need for image compression and to learn the spatial and frequency domain techniques of image compression.
CO3. Learn different feature extraction techniques for image analysis and recognition.
CO4. Understand the rapid advances in Machine vision.

Books and References

1. Digital Image Processing by R. Gonzalez and R. E. Wood, Prentice Hall of India.
2. Introductory Computer Vision and Image Procession by A. Low, McGraw Hill.
3. Pattern Recognition-Statistical, Structural and neural approach by R. Schalkoff, John Willey & Sons.
4. Digital Image Processing by W.K. Pratt, McGraw Hill.
5. Fundamentals of Image Processing by A. K. Jain, Pearson.

Course Name: **Computer Graphics**
Course Code: **MA-734**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce the use of the components of a graphics system and become familiar with building approach of graphics system components and algorithms related with them.
- To learn the basic principles of 3-dimensional computer graphics and provide an understanding of how to scan convert the basic geometrical primitives, how to transform the shapes to fit them as per the picture definition.
- To provide an understanding of mapping from a world coordinates to device coordinates, clipping, and projections.
- To be able to discuss the application of computer graphics concepts in the development of computer games, information visualization, and business applications.

Course Content

Introduction to Computer Graphics: Overview of Graphics Systems, Display Devices, Hard copy Devices. Interactive Input Devices, Display Processors, The Graphical Kernel System, Output Primitives, Line drawing algorithms, Circle Generation algorithms, Character Generation.

Raster Scan Graphics: Line Drawing Algorithms, Circle Generation, General Function Rasterization, Scan Conversion- Generation of the display, Image Compression, Polygon Filling, Fundamentals of Antialiasing.

Two-Dimensional Geometric Transformation & Viewing: Basic Transformation, Translation, Rotation, Scaling, Other Transformation Reflection, Shear, Transformation functions, Window to viewport co-ordinate transformation, Clipping Operations, Point Clipping, Line Clipping, Polygon Clipping.

Three- Dimensional Concepts & Object Representations: Three Dimensional Display Methods, Parallel Projection, Perspective Projection, Translation, Rotation, Scaling, Composite Transformation, Three dimensional Transformation function, Polygon Surfaces, Curved Lines and surfaces, Bezier Curves and surfaces, B-Spline Curves and surfaces.

Graphics Hardware: Display technology, random scan, raster scan display processing, input devices for interaction.

Visible Lines and Visible Surfaces: Visual Realism, Hidden line and hidden surface removal: depth buffer algorithm, geometric computations, scan line coherence algorithms, area coherence algorithms, priority algorithm, shading and color models, Modeling methods.

Rendering: A simple illumination model, Transparency, Refraction effects in transparent materials, Simple Transparency Models, Z-Buffer Transparency, Shadows, Texture.

Course Outcomes

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

CO1. Understand the computer graphics display technologies.
CO2. Implement various 2D transformations.
CO3. Apply the clipping algorithms to 2D primitives.
CO4. Demonstrate the 3D transformation concepts to model an object.
CO5. Understand and implement various rendering algorithms.

Books and References

1. Procedural Elements for Computer Graphics by D.F. Rogers, McGraw Hill.
2. Computer Graphics by Hearn and Baker, PHI.
3. Computer Graphics - A programming approach by S. Harrington, McGraw Hill.
4. Mathematical Elements for Computer Graphics by D.F. Rogers, McGraw Hill.

Course Name: **Parallel Algorithms**
Course Code: **MA-735**
Course Type: **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the parallel computing models, design and analyze parallel algorithms for PRAM machines and Interconnection networks.
- To introduce the fundamental concepts relevant to parallel computing, including parallel architectures, parallel programming methods and techniques, parallel algorithm designs, and parallel performance analysis.
- To enable the students to understand the factors that cause the various parallel programming models.

Course Content

Introduction: Introduction to parallel algorithms: EREW, CREW, CRCW PRAMs and interconnection network models, Need for Parallel Processing , Data and Temporal Parallelism, Models of Computation, RAM and PRAM Model, Shared Memory and Message Passing Models, Processor Organizations, PRAM Algorithms, Analysis of PRAM Algorithms

Parallelization of Algorithm: Different Parallel Programming Models, Brent's Theorem, Message passing algorithm, Load balancing and termination detection, programming with shared memory, programming for Distributed shared memory.

Basic Parallel Algorithmic Techniques: Divide-and-Conquer, Partitioning, pipelining, Accelerated Cascading, Symmetry Breaking, Synchronization (Locked, Lock-free) Parallel Algorithms and Data organization for shared/distributed memory, Min/Max, Sum Searching, Merging, Sorting, Various Parallel Sorting and Sorting Networks, Introduction to Graphics Processing Units (GPUs), CUDA Programming Model, Various operation in CUDA. Optimization Techniques: Understanding thread and blocks execution, Memory Bank Conflicts, Parallel Thread Execution, Control Flow, Precision, Optimizing CPU-GPU usage.

Course Outcomes

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

CO1. Identify difference between sequential and parallel algorithms.
CO2. Describe and use various parallel algorithms and CUDA programming model.
CO3. Apply principles of computing and mathematics appropriate to the discipline.
CO4. Design, implement and analyze various efficient parallel algorithms and its applications.

Books and References

1. Parallel Programming by B. Wilkinson & M. Allen, Pearson.
2. Parallel Programming in C with MPI and OpenMP by M. J. Quinn, Tata McGraw Hill.
3. Using MPI: Portable Parallel Programming with the Message passing Interface by W. Groop, E. Lusk & A. Skjellum, MIT Press.
4. Fundamentals of Parallel Processing by H. F. Jordan and G. Alaghband, Pearson.
5. Practical Parallel Programming by G. V. Wilson & G. Wilson, MIT Press.

Course Name: **Numerical Methods for Differential Equations** Course Code: **MA-741** Course Type: **Program Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To design and analyze numerical techniques to approximate solutions to differential equations for which finding a closed-form (analytic) solution is not possible.
- To devlop understanding about convergence, stability and consistency of a numerical method.
- To impart knowledge about error estimation and problem solving.

Course Content

Numerical Solution of Ordinary Differential Equations: Initial-value problems: linear multistep methods, Runge-Kutta methods, large systems and method of lines; error estimation and control; continuous output; event location.

Boundary-value Problems: The shooting method, finite difference methods, Stiffness.

Numerical Solution of Partial Differential Equations: Introduction to PDE's, classification and characteristics, Initial/ boundary value problems for parabolic and hyperbolic PDEs (one space and one time dimension). Explicit finite-difference schemes. Implicit finite-difference schemes, Numerical Instabilities.

Convergence Theory: Consistency, stability and convergence, Lax's equivalence theorem Parabolic and hyperbolic PDEs in two and three space dimensions, Boundary value problems for elliptic PDEs, Finite-element method for one and two dimensional problem.

Course Outcomes

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

CO1. Solve ODE and PDE using the various numerical scheme.

CO2. Understand the key ideas, concepts and definitions of the computational algorithms, sources of errors, convergence theorems.

CO3. Choose the best numerical method to apply to solve a given differential equation and quantify the error in the numerical (approximate) solution.

CO4. Analyze an algorithm's accuracy, efficiency and convergence properties.

Books and References

1. Applied numerical analysis by C.F. Gerald and P.O. Wheatley, Pearson.
2. Applied numerical methods for engineers and scientists by S.S. Rao, Prentice Hall.
3. Numerical Analysis by L. Burden and J.D. Faires, Brooks/Cole.
4. Numerical Methods for Engineers by S.C. Chapra, R.P. Canale, McGraw Hill Education (India).

Course Name: **Advanced Statistical Modeling**	
Course Code: **MA-742**	
Course Type: **Program Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge about the areas of spatial and spatio-temporal statistics.
- To apply the concepts of spatial and temporal statistics to rea data sets.
- To enable the students to assimilate data applied to real, scientic and interesting problems.

Course Content

Background and Motivation: Background, Types of Data, Taxonomies, Basic Properties, Preliminary Concepts (Spatial Structures and Modeling). Motivation: Objectives and Applications. Challenges. Software.

Review of Types of Data with Applications: Point level models. Spatial point processes. Areal (lattice) models.

Estimation and Modeling of Spatial correlations: Estimating variogram. Fitting parametric models: Matern class. Maximum likelihood estimation. Restricted maximum likelihood.

Prediction and Kriging: Lagrange multiplier approach. Conditional inference approach. Predicting at multiple sites. Model misspecification in kriging.

Spatial-Temporal Models: Separable vs non-separable models. Continuous time models when spatial dependence is nuisance. Spatial models when time dependence is nuisance. Misalignment. Data integration.

Bayesian Spatial Statistics: Bayesian estimation. Bayesian kriging. Bayesian priors for covariance parameters. Hierarchical Bayesian methods.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Identify and source data for use in evidence-based decision making in spatial and temporal statistics.
CO2. Distinguish different types of spatial data (geostatistical, areal, point process) and understand how spatial autocorrelation plays a role in statistical modeling.
CO3. Determine which spatial methods to use to in their own research.
CO4. Read and discuss new methods in the spatial and temporal statistics literature based on an understanding of the basic spatial statistics approaches, principles and main assumptions.
CO5. Demonstrate the concepts through examples and applications.

Books and References

1. Hierarchical Modeling and Analysis for Spatial Data by Banerjee, S.; Carlin, B.P. &Gelfand, A.E., Chapman and Hall/CRC.
2. Statistics for Spatial Data by Cressie, N., Wiley-Blackwell.
3. Statistics for Spatio–Temporal Data by Cressie, N. &Wikle, C.K., Wiley-Blackwell.
4. Interpolation of spatial data: Some theory for Kriging by M. L. Stein, Springer, first edition.
5. Statistical methods for spatial data analysis by O. Schabenberger and C. A. Gotway, Chapman and Hall/CRC.
6. Spatial data analysis: Theory and practice by R. Haining, Cambridge University Press.
7. Geostatistics with applications in earth sciences by D. D. Sharma, Springer.

Course Name: **Soft Computing**	
Course Code: **MA-743**	
Course Type: **Program Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- Develop the skills to gain a basic understanding of neural network theory and fuzzy logic theory.
- Introduce students to artificial neural networks and fuzzy theory from an engineering perspective.
- To understand the basics of an evolutionary computing paradigm known as genetic algorithms and its application to engineering optimization problems.
- To provide the mathematical background for carrying out the optimization associated with neural network learning.

Course Content

Neural Networks: Introduction, Biological Neuro-system, Neurons and its Mathematical Models, ANN architecture, Learning rules, Supervised and Unsupervised Learning Model, Reinforcement Learning, ANN training Algorithms-perceptions, Training rules, Delta, Back Propagation Algorithm, Multilayer Perceptron Model, Hopfield Networks, Associative Memories, Applications of Artificial Neural Networks.

Fuzzy Logic: Introduction, Classical and Fuzzy Sets, Membership Function, Fuzzy rule generation, Operations on Fuzzy Sets: Compliment, Intersections, Unions, Combinations of Operations, Aggregation Operations. Fuzzy Arithmetic: Fuzzy Numbers, Linguistic Variables, Arithmetic Operations on Intervals & Numbers, Lattice of Fuzzy Numbers, Fuzzy Equations. Fuzzy Logic: Classical Logic, Multivalued Logics, Fuzzy Propositions, Fuzzy Qualifiers, Linguistic Hedges.

Genetic Algorithm: Concept of "Genetics" and "Evolution" and it's applications to probabilistic search techniques, Basic GA framework and different GA architectures, GA operators: Encoding, Crossover, Selection, Mutation etc., Single objective Optimization problem using GA, Convergence theory of GA, Traveling Sales Man Problem .

Swarm Intelligence: Introduction and characteristics of Swarm Intelligence, Ant Colony Optimization (ACO) system, Practice Swarm Optimization (PSO) system: Parameter selection, Topologies (SPSO, APSO, stochastic star, TRIBES, and C-PSO), Applications of ACO & PSO in field of: Routing, Assignment, Scheduling, Subset.

Course Outcomes

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

CO1. Comprehend the fuzzy logic and the concept of fuzziness involved in various systems and fuzzy set theory.

CO2. Understand the fundamental theory and concepts of neural networks, Identify different neural network architectures, algorithms, applications and their limitations.

CO3. Understandgenetic algorithms and other random search procedures useful while seeking global optimum in self-learning situations.

CO4. Reveal different applications of these models to solve engineering and other problems.

Books and References

1. Fuzzy Logic: A Practical approach by F. Martin McNeill, E. Thro, AP Professional.
2. An Introduction to Neural Networks by J. A. Anderson, PHI.
3. Introduction to the Theory of Neural Computation by J. K. Hertz, R. G. Palmer, Addison-Wesley.
4. Fuzzy Sets & Fuzzy Logic by G. J. Klir& B. Yuan, PHI.
5. An Introduction to Genetic Algorithm by M. Mitchell, PHI.
6. Neural Networks: Algorithms, Applications and Programming Techniques by J. A. Freeman & D. M. Skapura, Addison Wesley.

Course Name: **Orthogonal Polynomials and Special Functions**
Course Code: **MA-744**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide an introduction to the study of orthogonal polynomials and special functions.
- To learn important problems in approximation theory of functions, the theory of differential, difference and integral equations.
- To develop an understanding of the structural, analytical and geometrical properties of orthogonal polynomials and special functions.

Course Content

Orthogonal Polynomials: Definition, their zeros, expansion in terms of orthogonal polynomials, three term recurrence relation, Christofel-Darboux formula. Bessel's inequality. Relationship with chain sequences and continued fractions. Gauss Quadrature. Hermite, Laguerre, Jacobi and Ultraspherical polynomials: Definition and elementary properties. Generating functions of some standard forms including Boas and Buck type. Sister Celine's techniques for finding pure recurrence relations. Characterization: Appell, Sheffes and s-type characterization of polynomial sets.

Gamma Function: Definition in the complex domain. Weierstrass's definition. Psi function and its series expansion. Difference equation. Order symbols o and O. Relationship with Beta function and its elementary properties. Infinite products, duplication formula, multiplication formula and reflection formula.

Hyper-geometric Functions: Solution of homogeneous linear differential equations of second order near an ordinary and regular singular point, their convergence and solutions for large values. Differential Equations with three regular singularities, hyper-geometric differential equations. Gauss hyper-geometric function, elementary properties, contiguous relations, integral representation, linear and quadratic transformation and summation formulae. Confluent hyper-geometric function and its elementary properties. Generalized hyper-geometric function ${}_pF_q$ and its elementary properties - linear and quadratic transformations, summation formulae.

Asymptotic Series: Definition, elementary properties, term by term differentiation, integration, theorem of uniqueness, Watson's lemma. Asymptotic expansion of ${}_1F_1$ and ${}_2F_1$.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Apply basic mathematical tools, such as inequalities, in proving classic results of the real analysis.

CO2. Describe mathematical properties of some special functions and orthogonal polynomials which are used in connection with practical problems.

CO3. construct best approximations of functions in terms of special functions/polynomials or other explicit formulae.

Books and References

1. Special functions, Encyclopedia of Mathematics and its Applications by G. E. Andrews, R. Askey and R. Roy, Cambridge University Press, Cambridge.
2. An introduction to orthogonal polynomials by T. S. Chihara, Gordon and Breach Science Publishers.
3. Classical and quantum orthogonal polynomials in one variable, Encyclopedia of Mathematics and its Applications by M. E. H. Ismail, Cambridge University Press.
4. Special functions by E. D. Rainville, The Macmillan Co., New York.
5. A course of modern analysis by E. T. Whittaker and G. N. Watson, Cambridge University Press.

Course Name: **Artificial Intelligence**
Course Code: **MA-745**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To present an overview of artificial intelligence (AI) principles and approaches.
- To develop a basic understanding of the building blocks of AI as presented in terms of intelligent agents: Search, knowledge representation, Knowledge acquisition.
- To implement knowledge of AI in some applications.

Course Content

Introduction: Introduction to AI, AI techniques, level of model, criteria for success, Turing test

Problems, Problem Spaces &Search: Defining problem as a space, search, production system, problem characteristics, production system characteristics, issues in the design of search programs.

Intelligent Agents: Reactive, deliberative, goal-driven, utility-driven, and learning agents Artificial Intelligence programming techniques

Problem-solving Through Search: Forward and backward, state-space, blind, heuristic, problem-reduction, A, A*, AO*, minimax, alpha-beta cut off, constraint propagation, neural, stochastic, and evolutionary search algorithms, genetic algorithm, PSO.

Knowledge Representation and Reasoning: Ontologies, foundations of knowledge representation and reasoning, representing and reasoning about objects, relations, events, actions, time, and space; frame representation, semantic network, predicate logic, resolution, natural deduction, situation calculus, description logics, reasoning with defaults, reasoning about knowledge.

Representing and Reasoning with Uncertain Knowledge: Probability, connection to logic, independence, Bayes rule, bayesian networks, probabilistic inference

Machine Learning and Knowledge Acquisition: Learning from memorization, examples, explanation and exploration. Learning nearest neighbor, naive Bayes, and decision tree classifiers.

Course Outcomes

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

CO1. Design a knowledge based system.
CO2. Analyze and formalize the problem as a state space, graph, design heuristics and select amongst different search or game based techniques to solve them.
CO3. Formulate and solve problems with uncertain information using Bayesian approaches.
CO4. Apply knowledge representation, reasoning, and machine learning techniques to real-world problems.

Books and References

1. Artificial Intelligence by S. Kaushik, Cengage Learning India Pvt Ltd.
2. Principles of Artificial Intelligence by N.J. Nilsson, Narosa Publishing House.
3. Artificial Intelligence by E. Rich and Knight, McGraw Hill International.
4. Artificial Intelligence – A Modern Approach by S. Russell, P. Norvig, Pearson Education / Prentice Hall of India.
5. Logic and Prolog Programming by S. Kaushik, New Age International Pvt Ltd.

Course Name: **Dynamical Systems**
Course Code: **MA-746**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To enhance the understanding of the theory, properties and applications of various dynamical systems
- To provide an introduction to discrete and continuous nonlinear dynamical systems and analysis of such systems for the stability of equilibrium points.
- To improve problem-solving skills.

Course Content

Linear Dynamical Continuous Systems: First order equations, existence uniqueness theorem, growth equation, logistic growth, constant harvesting, Planner linear systems, equilibrium points, stability, phase space, n-dimensional linear systems, stable, unstable and center spaces.

Nonlinear Autonomous Systems: Motion of pendulum, local and global stability, Liapunov method, periodic solution, Bendixson's criterion, Poincare Bendixson theorem, limit cycle, attractors, index theory, Hartman Grobman theorem, nonhyperbolic critical points, center manifolds, normal forms, Gradient and Hamiltonian systems.

Local Bifurcation: Fixed points, saddle node, pitchfork trans-critical bifurcation, Hopf bifurcation, co-dimension.

Discrete Systems: Logistic maps, equilibrium points and their local stability, cycles, period doubling, chaos, tent map, horse shoe map.

Deterministic Chaos: Duffing's oscillator, Lorenz system, Liapunov exponents, routes to chaos, necessary conditions for chaos.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Understand the important aspects of dynamical systems such as mathematical modeling, well-posedness (existence, uniqueness, and stability) of the considered problem.
CO2. Conversant with the controllability, stabilizability and optimal control aspects of a dynamical system.
CO3. Understand the dynamics and the structure of the phase-plane of linear systems.

Books and References

1. Differential equations, dynamical systems, and an introduction to chaos by M. W. Hirsch, S. Smale and R. L. Devaney, Elsevier/Academic Press, Amsterdam.
2. Discrete dynamical systems: Theory and applications, by J. T. Sandefur, Oxford University Press, New York.
3. Nonlinear dynamics and chaos: With applications to physics, biology, chemistry, and engineering by S. H. Strogatz, Westview Press.
4. Introduction to applied nonlinear dynamical systems and chaos by S. Wiggins, Texts in Applied Mathematics, 2, Springer-Verlag, New York.

Course Name: **Computer Networks**
Course Code: **MA-751**
Course Type: **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- Understand the basic network infrastructure to learn the overall function of networking systems and to classify various wired and wireless transmission media for data communication networks.
- To apply knowledge of different techniques of error detection and correction to detect and solve error bit during data transmission and compare various routing algorithm and select an appropriate one for a routing design.
- To design a network routing for IP networks and understand the internal functionalities of main protocols such as HTTP, FTP, SMTP, TCP, UDP, IP.

Course Content

Introductory Concepts: Goals and Applications of Networks, LAN, WAN, MAN, Wireless network, Network software: Protocol hierarchies, design issues of layers, Interfaces and services. Reference Model: The OSI reference model, TCP/IP reference model, Example networks: The ARPANET, The Internet.

Physical Layer: Fourier Analysis, Maximum data rate of a channel, Transmission media, Wireless transmission, Virtual circuits, Circuit switching.

Data Link Layer: Data link layer design issues, services provided to network layers, Framing, Error control, Flow control, Error detection and correction, Elementary data link protocols, An unrestricted Simplex protocol, A Simplex Stop-and-Wait protocol, Simplex Protocol for a noisy channel, Sliding Window protocols, A one-bit Sliding protocol, A protocol using go-back-N, A protocol using selective repeat.

Medium Access Sublayer: Channel Allocations, Static and dynamic allocation in LAN and MAN, Multiple Access protocols, ALOHA, Carrier Sense multiple access protocols, Wireless protocols, Collision free protocols, Limited contention protocols, IEEE standard 802.3 and Ethernet, IEEE standard 802.4, Token bus IEEE standard 802.5, Token Ring, Distributed Queue Dual bus, Logical link control, bridges, High speed LAN.

Network Layer: Network Layer design issue, Routing algorithms, Congestion Control Algorithms, Internetworking.

Transport Layer: Transport services, Design issues, elements of transport protocols, simple transport protocols, Connection management, TCP, UDP.

Session, Presentation and Application Layer: Session Layer - Design issues, remote procedure call.
Presentation Layer - Design issues. Application Layer - File Transfer, Access and Management, Electronic mail.

Course Outcomes

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

CO1. Understand network models and architectures.
CO2. Identify the pros and cons of choosing a suitable MAC layer protocol.
CO3. Analyze the performance of various routing protocols and design of new routing protocol.
CO4. Solve basic network design problems using knowledge of common local and wide area network architectures.
CO5. Apply knowledge of computers, software, networking technologies and information assurance to an organization's management, operations, and requirements.

Books and References

1. Computer Networks by A.S. Tanenbaum, Prentice Hall of India.
2. Computer Networking:A Top-Down Approach Featuring the Internet by J. Kurose and K.W. Ross, Addison-Wesley.
3. Data and Computer Communication by W. Stallings, Prentice Hall of India.

Course Name: **Software Engineering**
Course Code: **MA-752**
Course Type: **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand the need of Software Life Cycle Models and to demonstrate the Requirements of the Software Systems process.
- To summarize the system models of software engineering and choose appropriate software architecture style for real-time software projects.
- To analyze various testing techniques and to analyze Risk management and Software quality of the software products.

Course Content

Introduction: Problem domain, software engineering challenges, software engineering approach.
Software Processes: Software process, characteristics of software process, software development process models, and other processes.
Software Requirements Analysis and Specification: Software requirements, problem analysis, requirements specification, functional specification with use cases, validation, matrices.
Software Architecture: Role of software architect, architecture views, component and connector view, architecture style for C & C view, discussion and evaluating architectures.
Planning a Software Project: Effort estimation, project scheduling and staffing, software configuration management plan, quality assurance plan, risk management, project monitoring plan.
Function Oriented Design: Design principles, module level concepts, design notation and specification, structured design methodology, verification, metrics.
Object Oriented Design: OO concepts, design concept, Unified Modeling Language, design methodology, metrics.
Detailed Design, Software Measurements, Metrics and Models: Detailed design and PDL, verification, Metrics and their scope, Qualities of a good Software metrics, classification of metrics, Cost estimation models COCOMO, Quality attributes, SQA, Quality Standards, ISO 9000 and CMM.
Coding: Programming principles and guidelines, coding process, refactoring, verification, and metrics.
Testing: Testing fundamentals, black-box testing, white-box testing, testing process, defect analysis and prevention, metrics - reliability estimation.
CASE Tools: Types of CASE tools, advantages and components of CASE tools, Unified Modeling Language.

Course Outcomes

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

CO1. Understand and analyze the concept of software development and software engineering.
CO2. Compare and comprehend different software engineering process models.
CO3. Design of software projects and do the cost estimation.
CO4. Apply different software testing techniques.

Books and References

1. Computer Networks by A.S. Tanenbaum, Prentice Hall of India.
2. Computer Networking: A Top-Down Approach Featuring the Internet by J. Kurose and K.W. Ross, Addison-Wesley.
3. An integrated approach to software engineering by W. P. Jalote, Narosa Publishing.
4. Software Engineering: A Practitioner’s Approach by R. R. Pressman, TMH.

Course Name: **Web Development**
Course Code: **MA-753**
Course Type: **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand how to plan and conduct user research related to web usability.
- To learn the language of the web: HTML and CSS.
- To learn techniques of responsive web design, including media queries.
- To learn CSS grid layout and flexbox.

Course Content

Introduction to Web: Course Overview, The Internet and World Wide Web, Introduction to Markup, Essential HTML document structure, Essential HTML for content, HTML forms.

CSS: CSS mechanics and basic selectors, CSS text properties, CSS block model, Colors and Images, CSS and lists, Multiple CSS stylesheets, The cascade and specificity of CSS, Fonts, CSS and Layouts, CSS frameworks, CSS Loose Ends, Image types (PNG, JPEG, GIF), features, properties and typical use, Tools for image creation and manipulation.

JavaScript: JavaScript Events, DOM, jQuery, Focus on using and integrating JavaScript functionality, Slideshows, form validation, navigation, social media widgets, JSON, Ajax, JavaScript templates, Server Side, HTTP Overview, Caching, Compressing, Custom Error Pages, Redirects, HTTPS / TLS, Cookies.

PHP: PHP Overview, PHP File Includes, PHP Web Applications, Example: Web Application Using Database and Templates, Web Content Management Systems (Web CMS).

XML: Introduction, Tree, Syntax, Elements, Attributes, Namespaces, HTTP Requests, Parser, XPath, XQuery.

Course Outcomes

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

CO1. Develop and implement solutions to problems encountered in all phases of the design process.
CO2. Create visual communications through the application of design theories and principles to develop effective design solutions.
CO3. Apply typographic skills and knowledge to create effective visual communications.

Books and References

1. Learning Web Design by J. Robbins, O'Reilly Media.
2. Internet and world wide web – How to Program by P. Deitel , H. Deitel, A. Deitel , Prentice Hall.

Course Name: **Cloud Computing**
Course Code: **MA-754**
Course Type: **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To learn about the uses of Cloud Services.
- To implement Virtualization.
- To implement Task Scheduling algorithms.
- To apply Map-Reduce concept to applications.
- To build Private Cloud and its applications.

Course Content

Introduction to Cloud Computing: Roots of Cloud Computing, Layers and Types of Clouds, Features of a Cloud, Cloud Infrastructure Management, Infrastructure as a Service Providers, Platform as a Service Providers, and Challenges and Opportunities.

Virtualization and Resource Provisioning in Clouds: Introduction and Inspiration, Virtual Machines (VM), VM Provisioning and Manageability, VM Migration Services, VM Provisioning in the Cloud Context, and Future Research Directions.

Cloud Computing Architecture: Cloud Benefits and Challenges, Market-Oriented Cloud Architecture, SLA-oriented Resource Allocation, Global Cloud Exchange; Emerging Cloud Platforms, Federation of Clouds.

Programming Enterprise Clouds Using Aneka: Introduction, Aneka Architecture, Aneka Deployment, Parallel Programming Models, Thread Programming using Aneka, Task Programming using Aneka, and Map Reduce Programming using Aneka, Parallel Algorithms, Parallel Data mining, Parallel Mandelbrot, and Image Processing.

Advanced Topics and Cloud Applications: Integration of Private and Public Clouds, Cloud Best Practices, GrepTheWeb on Amazon Cloud, ECG Data Analysis on Cloud using Aneka, Hosting Massively Multiplayer Games on Cloud, and Content Delivery Networks Using Clouds, and Hosting Twitter and Facebook on Cloud.

Course Outcomes

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

CO1. Identify Roots of Cloud Computing, Layers and Types of Clouds.
CO2. DescribeCloud Benefits and Challenges, Market-Oriented Cloud Architecture.
CO3. Apply principles of Parallel Data mining, Parallel Mandelbrot, and Image Processing.
CO4. Assess theIntegration of Private and Public Clouds.

Books and References

1. Cloud Computing: Principles and Paradigms by R. Buyya, J. Broberg and A. Goscinski, Wiley Press, New York, USA.
2. Cloud Computing: A Practical Approach by A. T. Velte, T. J. Velte, Robert Elsenpeter, The McGraw-Hill.
3. Cloud Computing Bible by B. Sosinsky, Wiley Publishing.
4. Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, &IaaS) by M. J. Kavis, Wiley Publishing.

Course Name: **Data Mining** Course Code: **MA-755** Course Type: **Program Elective-IV**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge about the basic concepts and techniques of Data Mining
- To introduce the fundamental concepts relevant to the methodology of engineering legacy databases for data warehousing and data mining to derive business rules for decision support systems
- To enable the students to understand the factors that cause the Develop and apply critical thinking, problem-solving, and decision-making skills.

Course Content

Introduction: Types of data mining problems. The process of data mining. Statistical evaluation of big data: statistical prediction, performance measures, pitfalls in data-mining evaluation.

Data Preparation: data models, data transformations, handling of missing data, time-dependent data, textual data.

Data Reduction: feature selection, principal components, smoothing data, case subsampling.

Predictive Modeling: mathematical models, linear models, neural nets, advanced statistical models, distance solutions, logic solutions, decision trees, decision rules, model combination.

Solution Analyses: graphical trend analyses, comparison of methods. Future trends: text mining, visualization, distributed data. Case studies.

Course Outcomes

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

CO1. Identify the data mining principles and techniques: Introduce DM as a cutting edge business intelligence method.

CO2. Describing and demonstrating basic data mining algorithms, methods, and tools.

CO3. Apply principles of DM techniques for building competitive advantage through proactive analysis, predictive modelling, and identifying new trends and behaviours.

CO4. Assess the perform data mining tasks with relevant tools.

Books and References

1. Data Mining Concepts and Techniques by Jiawei Han and Michelien Kamber, Morgan Kaufmann.
2. Data Warehousing, Data mining and OLAP by Alex Berson and Stephen Smith, McGraw Hill.

Course Name: **Statistical Data Analysis**
Course Code: **MA-811**
Course Type: **Open Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the different types of data sets and forming the questionnaire.
- To apply the concepts of correlation and regression and ANOVA to the data sets.
- To enable the students to assimilate data applied to real, science and interesting problems.

Course Content

Introduction: Definition of statistics – Scope and limitations of statistics – Types of data – Nominal, Ordinal, Ratio, Interval scale data - Primary and Secondary data – Data presentation tools –One dimensional, two dimensional data presentation – line diagram – Box plots – stem and Leaf plots – Scatter plots.

Statistical Measures: Collection and presentation of data – summarizing data – frequency distribution – Measures of location, Measures of dispersion, and Skewness, Kurtosis and their measures.

Probability: Events - Sample Space - Mathematical and Statistical definitions of Probability – Axiomatic definition of Probability –Addition and multiplication theorems - Conditional probability –Bayes' Theorem - Simple problems.

Correlation and Regression: Partial and Multiple correlation coefficients (three variables only) – regression – Curve fitting by least squares – linear and quadratic.

Hypothesis Testing: Types of errors and power - most powerful tests, Test for equality of means and variances – t and F test; Chi-square test for goodness of fit and independence of attributes, Analysis of variance with one–way and two–way classifications.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Identify and source data for use in evidence-based decision making in statistics.
CO2. Distinguish different types of data and understand how the data plays an important role in statistical decision making.
CO3. Determine which hypothesis testing to use to in their own research.
CO4. Demonstrate the concepts through examples and applications.

Books and References

1. Fundamentals of Mathematical Statistics by Gupta S.C. & Kapoor V.K., Sultan Chand and Sons.
2. Fundamentals of Applied Statistics by Gupta .S.C. and Kapoor.V.K, Sultan Chand.
3. Statistical Inference – Testing of Hypotheses by Manoj Kumar Srivastava and NamitaSrivastava, Prentice Hall of India.
4. An Introduction to Probability and Statistics, Rohatgi by V.K. and Saleh, A.K, John Wiley.
5. Introduction to Mathematical Statistics by Hogg, R.V., Mc Kean J W and Craig, A.T, Pearson Edition.
6. Introducing Probability and Statistics by Bansilal, Sanjay Arora and Sudha Arora,Satya Prakashan Publications, New Delhi.
7. Basic statistics by Agarwal. B. L, New Age International (P) Ltd.

Course Name: **Numerical and Statistical Methods**
Course Code: **MA-812**
Course Type: **Open Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide the student with numerical methods of solving the non-linear equations, interpolation, differentiation, and integration.
- To improve the student's skills in numerical methods. Demonstrate understanding of common numerical methods.

Course Content

Error in Numerical Computations: Accuracy and precision; error analysis, Propagation of error

Solution of Nonlinear and Transcendental Equations: Basic concepts on polynomial equations, Roots of equations by Bisection method, iterative method, Regula- falsi method, Newton- Raphson method, Secant method. Solution of system of nonlinear equations.

Interpolation: Least square curve fit and trigonometric approximations, Finite differences and difference operators, Newton's interpolation formulae, Gauss forward and backward formulae, Sterling and Bessel's formulae, Lagrange's interpolation. Bessel and Spline interpolation.

Numerical Differentiation: Numerical differentiation, errors in numerical differentiation,

Numerical Integration: Trapezoidal, Simpson's 1/3 and 3/8 rules, Romberg integration- recursive formulae, Evaluation of double integrals by Trapezoidal and Simpson's rules.

Linear System of Simultaneous Algebraic Equations: Matrix inversion: solution system linear equations- , Jacobi's method and Gauss- Seidal method. Eigen values and Eigen vectors-Jacobi's method

Numerical Solution of Ordinary Differential Equations: Picard's method, Euler's method, Modified Euler's method, Runge- Kutta method. Finite difference method.

Numerical Solution of Partial Differential Equations: Classification of Partial differential equations, Finite Difference representation of derivatives, Solution of one dimensional heat and wave equation and two dimensional Laplace and Poisson equation.

Descriptive Statistics: Discrete and Continuous Probability Distributions-Binomial, Exponential. Poisson, Normal, Uniform and their properties.

Course Outcomes

Upon successful completion of the course, the student will be able to:

CO1. Apply numerical methods to obtain approximate solutions to mathematical problems.
CO2. Analyse and evaluate the accuracy of common numerical methods.
CO3. Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations.

Books and References

1. Numerical Methods for Scientific and Engineering Computations by M K Jain, S R K Iyenger and R K Jain, New Age International Publishers, New Delhi.
2. Numerical Methods for Engineers and Scientists by J N Sharma, Narosa Publishers, New Delhi.
3. Numerical Methods for engineers by S C Chapra and R P Canale, TMH.
4. Introductory Methods of Numerical Analysis by S SSastri, PHI New Delhi.
5. Applied Numerical Methods using MATLAB by W Y Yang, W Chao, T S Chung and J Morris, WILEY.
6. Numerical Methods for Engineers and Scientists by J D Hoffman, CRC Press.