Master of Science
in
Mathematics and Computing

Course Structure, Curriculum and Syllabi

Department of Mathematics and Scientific Computing,
National Institute of Technology Hamirpur,
Hamirpur – 177 005, Himachal Pradesh.

Revised Curriculum Structure for M. Sc. (Mathematics and Computing) Program

SEMESTER-I

Course No.	Course Name	Credits	Course Type
XX-6MN	Programme Core Courses	20	Core courses
XX-6MN	Programme Core (Lab) Courses	03	Lab courses
	Total	**23**	

SEMESTER-II

Course No.	Course Name	Credits	Course Type
XX-6MN	Programme Core Courses	20	Core courses
XX-6MN	Programme Core (Lab) Courses	05	Lab courses
	Total	**25**	

SEMESTER-III

Course No.	Course Name	Credits	Course Type
XX-6MN	Programme Core Courses	10	Core courses
XX-6MN	Programme Core (Lab) Courses	02	Lab courses
XX-7MN	Programme Electives*	08	Elective courses
XX-796	Summer Internship/Industrial Training	01	Experiential Learning Course
XX-798	M.Sc. Project	04	Research Work
	Total	**25**	

SEMESTER-IV

Course No.	Course Name	Credits	Course Type
XX-7MN	Programme Electives*	12	Elective courses
XX-701-709	Institute Elective (Interdisciplinary)	04	Open Elective
XX-797	Community Connect	01	Community Learning
XX-799	M.Sc. Project	06	Research Work
	Total	**23**	

* Programme Electives: Any course listed in scheme as Annexure – A (List of Electives).

SEMESTER-I

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
XX-611	Programme Core Course	4	0	0	4	4
XX-612	Programme Core Course	4	0	0	4	4
XX-613	Programme Core Course	4	0	0	4	4
XX-614	Programme Core Course	4	0	0	4	4
XX-615	Programme Core Course	4	0	0	4	4
XX-616	Programme Core (Lab) Course	0	0	4	4	2
XX-617	Programme Core (Lab) Course	0	0	2	2	1
	Total	**20**	**0**	**6**	**26**	**23**

SEMESTER-II

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
XX-621	Programme Core Course	4	0	0	4	4
XX-622	Programme Core Course	4	0	0	4	4
XX-623	Programme Core Course	4	0	0	4	4
XX-624	Programme Core Course	4	0	0	4	4
XX-625	Programme Core Course	4	0	0	4	4
XX-626	Programme Core (Lab) Course	0	0	4	4	2
XX-627	Programme Core (Lab) Course	0	0	4	4	2
XX-628	Programme Core (Lab) Course	0	0	2	2	1
	Total	**20**	**0**	**10**	**30**	**25**

SEMESTER-III

Course No.	Subject	Teaching Schedule			Hours /Week	Credits
		L	T	P		
XX-631	Programme Core Course	4	0	0	4	4
XX-632	Programme Core Course	4	0	0	4	4
XX-633	Programme Core Course	2	0	0	2	2
XX-633	Programme Core (Lab) Course	0	0	2	2	1
XX-634	Programme Core (Lab) Course	0	0	2	2	1
XX-7MN	Programme Elective-I*	4	0	0	4	4
XX-7MN	Programme Elective-II*	4	0	0	4	4
XX-796	Summer Internship/ Skill based Training	–	–	–	–	1
XX -798	MSc Project	–	–	–	–	4
	Total	**18**	**0**	**4**	**22**	**25**

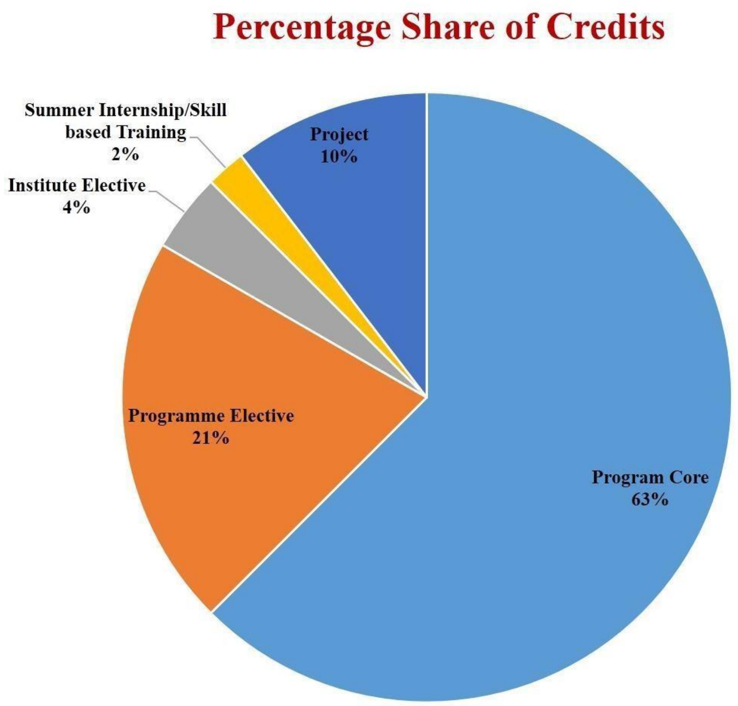
SEMESTER-IV

Course No.	Subject	Teaching Schedule			Hours/ week	Credits
		L	T	P		
XX-7MN	Programme Elective-III*	4	0	0	4	4
XX-7MN	Programme Elective-IV*	4	0	0	4	4
XX-7MN	Programme Elective-V*	4	0	0	4	4
XX-70N	Open Elective/Institute Elective**	4	0	0	4	4
XX -797	Community Connect***	–	–	–	–	1
XX -799	MSc Project	–	–	–	–	6
	Total	**16**	**0**	**0**	**16**	**23**

*Programme Electives: Any course listed in scheme as Annexure – A (List of Electives).

Types of Courses and credits in each Semester

	1st	2nd	3rd	4th	Total Credits
Program Core	23	25	12	0	60
Programme Elective	0	0	8	12	20
Institute Elective	0	0	0	4	04
Summer Internship/Skill based Training	0	0	1	1	02
Project	0	0	4	6	10
Total					**96**



Curriculum Structure of MSc (Mathematics and Computing) Program (2 Years) in Consonance with NEP-2020

SEMESTER – I

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-611	Real Analysis	4	0	0	4	4
MA-612	Differential Equations	4	0	0	4	4
MA-613	Abstract Algebra	4	0	0	4	4
MA-614	Probability and Statistics	4	0	0	4	4
MA-615	Computer Programming	4	0	0	4	4
MA-616	Computer Programming Lab	0	0	4	4	2
MA-617	SPSS Software Lab	0	0	2	2	1
	Total	**20**	**0**	**6**	**26**	**23**

SEMESTER – II

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-621	Linear Algebra	4	0	0	4	4
MA-622	Complex Analysis	4	0	0	4	4
MA-623	Operations Research	4	0	0	4	4
MA-624	Data Structure and Algorithms	4	0	0	4	4
MA-625	Database Management Systems	4	0	0	4	4
MA-626	Operations Research Lab	0	0	4	4	2
MA-627	Data Structure and Algorithms Lab	0	0	4	4	2
MA-628	Database Management Systems Lab	0	0	2	2	1
	Total	**20**	**0**	**10**	**30**	**25**

SEMESTER – III

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-631	Numerical Analysis	4	0	0	4	4
MA-632	Functional Analysis	4	0	0	4	4
MA-633	Indian Knowledge System	2	0	0	2	2
MA-634	R and Python Lab	0	0	2	2	1
MA-635	Numerical Methods Lab	0	0	2	2	1
MA-7MN	Programme Elective-I*	4	0	0	4	4
MA-7MN	Programme Elective-II*	4	0	0	4	4
MA-796	Summer Internship/ Skill based Training	–	–	–	–	1
MA -798	MSc Project	–	–	–	–	4
	Total	**18**	**0**	**4**	**22**	**25**

- Summer Internship/Skill based Training undertaken by the students just after second semester during summer vacations and its evaluation will be done in third semester

SEMESTER – IV

Course No.	Subject	Teaching Schedule			Hours/ week	Credits
		L	T	P		
MA-7MN	Programme Elective-III*	4	0	0	4	4
MA-7MN	Programme Elective-IV*	4	0	0	4	4
MA-7MN	Programme Elective-V*	4	0	0	4	4
MA-70N	Institute Elective**	4	0	0	4	4
MA -797	Community Connect***	–	–	–	–	1
MA -799	MSc Project	–	–	–	–	6
	Total	**16**	**0**	**0**	**16**	**23**

Total Program Core Course Credits = 50; Total Program Core Lab Credits = 10; Total Program Elective Course Credits = 20; Total Institute Elective Course Credits = 04, Industrial Training/Summer Internship Credits =1, Community Connect Credits = 1; Project Credit = 10

Total Credit of the Programme = 23+25+25+23 = 96

Annexure – A

(List of Program Electives and Institute Electives)

List of Program Elective-I*

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-711	Cryptography	4	0	0	4	4
MA-712	Computer Networks	4	0	0	4	4
MA-713	Digital Image Processing	4	0	0	4	4

List of Program Elective-II*

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-721	Statistics in Decision Makings	4	0	0	4	4
MA-722	Financial Mathematics	4	0	0	4	4
MA-723	Advanced Optimization Techniques	4	0	0	4	4

List of Program Elective-III*

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-731	Mathematical Methods	4	0	0	4	4
MA-732	Topology	4	0	0	4	4
MA-733	Finite Element Methods	4	0	0	4	4

List of Program Elective-IV*

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-741	Numerical Methods for PDE	4	0	0	4	4
MA-742	Soft Computing	4	0	0	4	4
MA-743	Multivariate Statistical Analysis	4	0	0	4	4

List of Program Elective-V*

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-751	Software Engineering	4	0	0	4	4
MA-752	Time Series Analysis	4	0	0	4	4
MA-753	Measure Theory and Integration	4	0	0	4	4

List of Institute Elective**

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
MA-701	Numerical and Statistical Methods	4	0	0	4	4
MA-702	Statistical Data Analysis	4	0	0	4	4

Course Name: **Real Analysis**
Course Code: **MA-611**
Course Credits: **04**
Contact Hours/Week: **4L**
Course Type: **Core**

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.

Course Content

Set Theory and Real Number System: Elementary set theory, finite, countable and uncountable sets, Real number system as a complete ordered field, Nested Intervals Property, Archimedean property, supremum, infimum. Sequences and Series: Sequences and series, convergence, monotonic sequence, Subsequences, Bolzano-Weierstrass theorem, Cauchy Criterion, Heine Borel theorem, Comparison test, Ratio test. Limit and Continuity: Cluster point, Limit of a function, Limit theorems, Sequential criterion, Continuity, uniform continuity, continuity on intervals, minimum maximum theorem, types of discontinuity. Differentiability: differentiability, Caratheodory's Theorem, Chain rule, Mean value theorems, L'Hospital rule, Monotonic functions, Sequences and series of functions, uniform convergence. Riemann Integration: Tagged partition, Riemann sums and Riemann integral, Improper Integrals, Cauchy Criterion, Squeeze Theorem, Fundamental Theorems of Calculus. Functions of several variables: directional derivative, partial derivative, derivative as a linear transformation, inverse and implicit function theorems. Metric spaces: compactness, connectedness. Normed linear Spaces. Spaces of continuous functions as examples.

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. Introduction to Real Analysis, R.G. Bartle & D.R. Sherbert, Wiley.
3. Mathematical Analysis by T. M. Apostol, Addison-Wesley Publishing Company.
4. Introduction to Topology and Modern Analysis by G. F. Simmons, Tata McGraw-Hill.

Course Name: **Differential Equations**
Course Code: **MA-612**
Course Credits: **04**
Contact Hours/Week: **4L**
Course Type: **Core**

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, Picard's Method of successive approximation, Dependence of solutions on initial conditions, singular solutions of first order ODEs, system of first order ODEs. Higher Order ODEs: Second order linear ordinary differential equations with constant and variable coefficients; Cauchy-Euler equation, method of variation of parameters, method of Laplace transforms for solving ordinary differential equations. Series Solution: Review of Linear second order differential equations and Power series solutions, Legendre and Bessel differential equations, generating functions, 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, Linearized stability, Lyapunov functions, 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, Method of Separation of Variable for Solution of hyperbolic, Parabolic and elliptic equations, d'Alembert formula.

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

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.

Course Name: **Abstract Algebra**
Course Code: **MA-613**
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

Number Theory: Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø- function, primitive roots. Groups: Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems. Ring and Ideals: Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain. Polynomial rings and irreducibility criteria, Eisenstein's irreducibility criterion. Field: Fields, finite fields, field extensions, Introduction to Galois Theory.

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: **Probability and Statistics**
Course Code: **MA-614**
Course Credits: **04**
Contact Hours/Week: **4L**
Course Type: **Core**

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.

Course Content

Probability: σ field; measurable space; construction of measure probability and properties; definitions, scope and examples of probability; sample spaces and events; axiomatic definition of probability; joint and conditional probabilities; independence, total probability; Bayes' rule and applications. Random Variables: Definition of random variables, continuous and discrete random variables; cumulative distribution function (cdf) for discrete and continuous random variables; probability mass function (pmf); probability density functions (pdf) and properties; expectation: mean, variance and moments of a random variables. Theoretical Distributions: Discrete Uniform, Bernoulli, Binomial, Poisson, Negative Binomial, Geometric distributions, Continuous Uniform, Normal, Exponential, Gamma, Weibull, and Beta distributions. Law of large numbers; Central limit theorem and its significance.
Bivariate Random Variable: Function of a random variable, problems. Joint distributions. Marginal and conditional distribution. Transformation of random variables. Covariance and correlation, bivariate normal distribution, problems. Estimation: Problem of estimation; point and interval estimation, criteria for a good estimator, unbiasedness, consistency, efficiency and sufficiency with examples. Method of moments and maximum likelihood and application of these methods for obtaining estimates of parameters of binomial, Poisson and normal distributions, properties of MLE's (without proof), merits and demerits of these methods.

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 and linear models.
CO2. Identify an appropriate theoretical distribution to fit the empirical data and find out the properties of data.
CO3. Understand the concept of estimation theory and its properties.

Books and References

1. An introduction to probability theory and its applications by w Feller. John Wiley& Sons (2008)
2. Introduction to Probability and Statistics for Engineers and Scientists by Sheldon M. Ross, Academic Press, (2009).
3. An Introduction to Probability and Statistics, Rohtagi by V.K. & Saleh, A.K.M.E., Wiley.
4. Introduction to Probability and Statistics by J.S. Milton & J.C. Arnold. McGraw Hill Education.

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

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

Introduction to the C Language – Algorithm, Pseudo code, Flow chart, Background, C Programs, Identifiers, Data Types, Variables, Constants, Input / Output, Operators(Arithmetic, relational, logical, bitwise etc.), Expressions, Precedence and Associativity, Expression Evaluation, Type conversions. Statements- Selection Statements(making decisions) – if and switch statements, Repetition statements (loops)-while, for, do-while statements, Loop examples, other statements related to looping – break, continue, go to, Simple C Program examples. Functions- Introduction to Structured Programming, Functions- basics, user defined functions, inter function communication (call by value, call by reference), Standard functions. Storage classes-auto, register, static, extern, scope rules, arrays to functions, recursive functions, example C programs. Arrays and Pointers– Basic concepts, one-dimensional arrays, two – dimensional arrays, multidimensional arrays, C programming examples Pointers – Introduction (Basic Concepts), pointers to pointers, compatibility, Pointer Applications, Arrays and Pointers, Pointer Arithmetic, memory allocation functions, array of pointers, pointers to void, pointers to functions, command –line arguments, Introduction to structures and unions. Basic concepts of Object-Oriented Programming- Object Oriented Programming Paradigm, Basic concepts of OOP, 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, Classes, Objects, Inheritance and Polymorphism.

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, Josee Lajoie, Barbara E. Moo, Pearson Education.

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

Course Objectives

- To provide skills to use the C/C++ Programming Software.
- Apply logical and algorithmic thinking to solve programming problems.
- Develop skills to debug programs and handle runtime errors.

List of Experiments

1. Write a C program to find sum and average of three numbers, the sum of individual digits of a given positive integer, and to generate the first n terms of the Fibonacci sequence.
2. Write a C program to generate prime numbers between 1 to n and also to check whether given number is Armstrong Number or Not.
3. Write a C program to check whether given number is perfect number or Not and also to check whether given number is strong number or not.
4. Write a C program to find the roots of a quadratic equation and also perform arithmetic operations using switch statement.
5. Write a C program to find factorial of a given integer using non-recursive function and also find factorial of a given integer using recursive function.
6. Write C program to find GCD of two integers by using recursive function and also find GCD of two integers using non-recursive function.
7. Write a C program to find both the largest and smallest number in a list of integers, write a C program to Sort the Array in an Ascending Order, and also find whether given matrix is symmetric or not.
8. Write a C program to perform addition of two matrices and also write a program that uses functions to perform Multiplication of Two Matrices.
9. Write a C program to use function to insert a sub-string in to given main string from a given position and also write a C program that uses functions to delete n Characters from a given position in a given string.
10. Write a C program using user defined functions to determine whether the given string is palindrome or not? And then also write to displays the position or index in the main string S where the sub string T begins, or - 1 if S doesn't contain T.
11. Read and print students detail using class and object.
12. Demonstrate use of function by i) To swap numbers in cyclic order using call by reference and to check prime number by creating a function, ii) To find the multiplication values and the cubic values using inline function, iii) To calculate the area of circle, rectangle and triangle using function overloading.

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 and abstract the programming task involved for a given problem.
CO2. Design and develop c programming skills.
CO3. Trace and debug a program.

Course Name: **SPSS Software Lab**
Course Code: **MA-617**
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: **Linear Algebra**
Course Code: **MA-621**
Course Type: **Core**
Contact Hours/Week: **4L**
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, linear dependence, basis, dimension, algebra of linear transformations. Algebra of matrices, rank and determinant of matrices, linear equations. Linear Transformation: Linear Transformation, 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, Jordan forms and annihilators, Cyclic decomposition. Inner 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, Quadratic forms, reduction and classification of quadratic 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. Learn details of Inner product space.
CO3. Theoretical concepts about projection theorem and positive definite forms.
CO4. Understand development and concepts of Eigen decomposition, spectral theorem. 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.

Course Name: **Complex Analysis**
Course Code: **MA-622**
Contact Hours/Week: **4L**
Course Credits:**04**
Course Type: **Core**

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, Harmonic functions, Cartesian and polar form of Cauchy-Riemann equation. Complex Integration: Cauchy's fundamental theorem, Cauchy's integral formula, Poisson's integral formula for a circle, Morera's theorem, Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem, Taylor's theorem, Laurent's theorem, Argument principle, 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, continuity of sum function, term by term differentiation, term by term integration. 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.

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. S. Ponnuswamy, Foundation of Complex Analysis, Narosa.

Course Name: **Operations Research**
Course Code: **MA-623**
Course Type: **Core**
Contact Hours/Week: **4L**
Course Credits: **04**

Course Objectives:

- Develop the ability to formulate real-world problems into mathematical models, focusing on linear programming. Gain proficiency in various optimization methods, including the Simplex method, duality theory.
- Apply techniques to solve transportation and assignment problems, including the Hungarian method and traveling salesman problem.
- Utilize inventory control models, game theory, and network analysis methods like PERT and CPM for strategic decision-making and project management.

Course Content

Operations Research: Origin, Definition and scope. Mathematical Foundations: Hyperplane and hyperspheres, Convex sets and their properties, Convex functions. *Linear Programming:* Formulation and examples, Basic feasible and optimal solutions, Extreme points, Graphical Method, Simplex Method, Big-M Method, Degeneracy. Duality in Linear Programming: Duality and Dual LPP and its properties, Dual simplex Algorithm and sensitivity analysis. Assignment and Transportation Problems: *Assignment problem*: mathematical formulation, solution by Hungarian Method, unbalanced problem, Traveling Salesman problem and its solution. *Transportation Problem:* Basic feasible solutions, Optimum solution by stepping stone and modified distribution methods, Unbalanced and degenerate problems, Transhipment problem. Game Theory: Two- person Zero-sum games, Pay-off Matrix , the Maximum Minimal Principle, Saddle Point and Value of the Game, Rule for determining a Saddle Point, Games without Saddle Points, Mixed Strategies, Graphic solution of 2 x n and m x 2 games, Dominance Property- General rule for Dominance, Modified Dominance Property. 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. Inventory control models: Economic order quantity (EOQ) model with uniform demand, EOQ when shortages are allowed, EOQ with uniform replenishment, Inventory control with price breaks.

Course Outcomes

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

- CO1. Gain comprehensive knowledge of operations research origins, definitions, and scope.
- CO2. Master mathematical concepts like hyperplanes, convex sets, and functions for effective problem-solving.
- CO3. Develop the ability to formulate and solve linear programming, transportation, and assignment problems.

Books and References

1. V. Chvatal (1983), Linear Programming, W.H. Freeman, New York.
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 theory and application by J. K. Sharma, MACMILAN Publishers.
5. Operations Research by P.K. Gupta and D.S. Hira, S. Chand & Co.

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: **Database Management Systems**
Course Code: **MA-625**
Contact Hours/Week: **4L**
Credits: **04**
Course Type: **Core**

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, concepts and architecture, date models, schemas and 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 dependencies 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 and 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.

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

Course Objectives

- To grasp basic programming principles, enabling them to comprehend and apply algorithmic concepts effectively.
- To acquire the skill to identify, characterize, and define complex problems, laying the foundation for systematic problem-solving approaches.
- To develop the ability to design programs tailored to solve specific problems, demonstrating aptitude in algorithm development and implementation.
- To apply learned concepts to develop algorithmic solutions, fostering a deeper understanding of optimization principles and their practical applications.

List of Experiments

1. To solve Linear Programming Problem using Graphical Method with (i) Unbounded solution (ii) Infeasible solution (iii) Alternative or multiple solutions.
2. Solution of LPP with Simplex method.
3. Problem solving using Charnes-M method.
4. Problem solving using Two Phase method.
5. Illustration of following special cases in LPP using Simplex method (i) Unrestricted variables (ii) Unbounded solution (iii) Infeasible solution (iv) Alternative or multiple solutions.
6. Solution to the Transportation Problem.
7. Solution of Assignment problem.
8. Solution to the Travelling Salesman Problem.
9. Write a program to find the EOQ with and without shortages.
10. Project Planning (Deterministic Case- CPM, Probabilistic Case- PERT).
11. Solution of Two-Person-zero-sum pure and mixed strategy game.
12. Linear Programming solution to game problems.

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on the 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. Understand various optimization techniques.
CO3. Solve optimization problems using MATLAB, Excel Solver, and LINGO.
CO4. Demonstrate efficient problem-solving abilities.
CO5. Bridge theory and practice in solving real-world optimization challenges.

Course Name: **Data Structure and Algorithms Lab**
Course Code: **MA-627**
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 BFS and DFS 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.
- CO2. Understand the applications of data structures.
- CO3. Understand which algorithm or data structure to use in different scenarios.

Course Name: **Database Management Systems Lab**
Course Code: **MA-628**
Contact Hours/Week: **2P**
Course Credits: **01**

Course Objectives

- To present an introduction to database management systems using programming.
- To provide skills for writing programs.
- Familiar with basic database storage structures and access techniques.

List of Experiments

1. Introduction to DBMS software (e.g., MySQL, PostgreSQL, Oracle).
2. Implement basic SQL commands: CREATE, DROP, ALTER.
3. Implement Data types and constraints in SQL.
4. Implement Data Manipulation and Retrieval using INSERT, UPDATE, DELETE commands, Simple SELECT queries, WHERE clause, Advanced SELECT queries: ORDER BY, GROUP BY, HAVING.
5. Implement Complex Queries and Joins using SQL functions: aggregate functions (COUNT, SUM, AVG, MIN, MAX), and Joins: INNER JOIN, LEFT JOIN, RIGHT JOIN, FULL JOIN.
6. Create and manage views and Use views in SELECT statements.
7. Design and implement databases based on Entity-Relationship diagrams.
8. Normalize a given database schema to 1NF, 2NF, 3NF, and BCNF.
9. Write and execute stored procedures for complex operations.
10. Write programs to demonstrate the use of transaction control commands: COMMIT, ROLLBACK, and SAVEPOINT.
11. Write and execute stored procedures for complex operations.
12. Write programs to connect to a database using JDBC (Java Database Connectivity).
13. Design and implement a small database application. Example projects: Library Management System, Student Information System, Online Retail Store Database.

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

Course Outcomes

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

CO1. Describe the fundamental elements of relational database management systems.
CO2. Design ER-models to represent simple database application scenarios.
CO3. Improve the database design by normalization.

Course Name: **Numerical Analysis**
Course Code: **MA-631**
Contact Hours/Week: **4L**
Credits: **04**
Course Type: **Core**

Course Objectives

- To introduce the errors and various sources of errors 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 and Boundary Value Problems: Euler and modified Euler methods, Runge-Kutta methods, Multistep methods, Predictor- Corrector method, 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.

Course Name: **Functional Analysis**
Course Code: **MA-632**
Contact Hours/Week: **4L**
Credits: **04**
Course Type: **Core**

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

Normed Spaces and Banach Space: Review of Hölder inequality, Minkowski inequality and vector spaces with examples of $\mathcal{P}$p and Lp spaces. 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 B V Limaye, New Age International.
4. A course in functional analysis by J. B. Conway, Graduate Texts in Mathematics, 96, Springer-Verlag, New York.

Course Name: **Indian Knowledge System**
Course Code: **MA-633**
Course Credits: **02**
Contact Hours/Week: **2L**
Course Type: **Core**

Course Objectives

- To create awareness among the students about the history and culture of our land.
- Ushering new areas of research in the field of Vedic Mathematics.
- To acknowledge the contributions of Indian Mathematicians in Vedic Arithmetic.

Course Content

Bhāratīya Civilization and Philosophy: Genesis of the land, Antiquity of civilization, Traditional Knowledge System, The Vedas, Main Schools of Indian Philosophy, Ancient Education System: Gurukulas, Takṣaśilā University and Nālandā University, Knowledge Export from Bhārata, Panchkosh concept of education. Multiplication Methods: Fundamentals such as base addition, subtraction, complementation, Ekadhikenpurven, Eknuenpurven, Urdhavatriagbhyam, Nikhilam Navtashcharamam Dashtaha, Combined Operations such as squaring, cubing etc. Division and Divisibility: Nikhilam Navtashcharamam Dasthaha, Paravartya Yojyet; Ekadhikenpurven method, Eknuenpurven. Contributions of Indian Mathematician (in light of arithmetic): Aryabhatt, Brahamgupt, Mahaveeracharya, Bharti Krishan Tritha. Vedic Algebra: Multiplication (Quadratic expressions of single variable), Urdhvatiragbhyam Method, Combined Operations. Division and Factorization: Division (Divisor: Linear expression of single variable), Factorization (Quadratic expression of single variable). Contribution of Indian Mathematicians (In light of Algebra): Varahmihir, Bhaskaracharya, Neelkanth Somayya, Bharti Krishna Tirtha. Vedic Geometry: Concept of Bhaudhayana Number (BN) – BN of an angle, Multiplication of a constant in a BN, BN of complementary angles, BN of sum and difference ($\alpha \pm \beta$) of an angle, BN of half angle. Trigonometry: Definitions of trigonometric ratios, Trigonometric Identities. Contribution of Bharatiya Mathematicians (In the light of Geometry): Bhaskaracharya, Madhavan, Parmeshvaran, Bharti Krishna Tirtha, Baudhayana. Contribution of Indian Mathematicians; Ancient Bharatiya Mathematical Work (Leelavati, Sulba Sutra, Ganita Kaumudi)

Course Outcomes

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

CO1. Acknowledge the contributions of Indian Mathematicians in Vedic Algebra.
CO2. Develop the understanding of objectives and features of Vedic Arithmetic.
CO3. Recognize the meaning of mathematical sutras of vedic arithmetic in Sanskrit.

Books and References

1. Textbook on The Knowledge System of Bhārata by Bhag Chand Chauhan,
2. Vedic Mathematics, Motilal Banarsi Das, New Delhi (2022).
3. Vedic Ganita Praneta, Siksha Sanskriti Uthana Nyasa, New Delhi.
4. Vedic Mathematics: Past, Present and Future, Siksha Sanskriti Uthana Nyasa, New Delhi.
5. Beejganitam, Chokhambba Vidya Bhavan, Varanasi.
6. Bharatiya Mathematicians, Sharda Sanskrit Sansthan, Varanasi

Course Name: **R and Python Lab**
Course Code: **MA-634**
Contact Hours/Week: **2P**
Course Credits: **01**

Course Objectives

- To provide skills to use the R interactive environment.
- To read more Python code
- To provide skills for analyzing data with appropriate statistical techniques.
- To enable the students to visualize data.

List of Experiments

R Software

1. An Overview of R and Python: Basic fundamentals, installation and use of software, data editing, use of R as a calculator, functions and assignments. Managing Data: Listing cases, replacing missing values, computing new variables, recording variables, exploring data, selecting cases, sorting cases, merging files.
2. Graphs: Creating and editing graphs and charts. Frequencies: Frequencies, bar charts, histograms, percentiles.
3. Descriptive Statistics: measures of central tendency, variability, deviation from normality, size and stability. Cross Tabulation and chi-square analyses, the means procedure.
4. Bivariate Correlation: Bivariate Correlation, Partial. Hypothesis Testing: Independent –samples, paired samples, and one sample tests.
5. ANOVA procedure: One-way and Two–way analysis of variance.

Python Software

1. To read two numbers and perform an arithmetic operation based on the option chosen by the user.
2. Write a NumPy program to create a 2D array with 1 on the border and 0 inside, program to get the number of nonzero elements in an array, program to compute the multiplication of two given matrixes, and program compute the inverse of a given matrix.
3. Write a program to calculate factorial of a given number and store result into variable, and write a function that tests if a number is prime. Test it by writing out all prime numbers less than 50.
4. Generate two array of same length and plot on x axis and y-axis, and write a NumPy program to get the element-wise remainder of an array of division.
5. Write a program to generate a multiplication table for a given number, program to find the distance between two points, area of a circle, and write a program to find the factorial of a number using recursion. And also find the GCD of two numbers using recursion.

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.
CO5. Write python basic programs using conditional and looping structures.
CO6. Execute programs in python for string handling, functions, create modules and work with packages.

Course Name: **Numerical Methods Lab**
Course Code: **MA-635**
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 (4th 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. Develop algorithms and consequently codes for various numerical methods.
CO2. Use inbuilt functions, create and call function files.
CO3. Learn to control error in numerical computations
CO4. Use their computational skills efficiently with desired level of accuracy.

Program Elective – I

Course Name: **Cryptography**
Course Code: **MA-711**
Contact Hours/Week: **4L**
Credits: **04**
Course Type: **Program Elective-I**

Course Objectives

- Understand the basic concepts of cryptography, including encryption, decryption, and cryptographic protocols.
- Study symmetric key algorithms (e.g., DES, AES) and asymmetric key algorithms (e.g., RSA, ECC).
- Understand techniques for assessing and ensuring the security of cryptographic systems.

Course Content

Introduction and Classical Ciphers: Cryptography, Cryptosystem, Cryptanalysis, CIA Triad: Confidentiality, Integrity, Availability; Attacks: Passive, Security Services: Access Control, Nonrepudiation. Classical Cryptosystems: Substitution Techniques: Monoalphabetic: Ceasar Cipher, Hill; Polyalphabetic: Vigenere Cipher, Playfair; Transposition Techniques: Rail Fence Cipher; Modern Ciphers: Block Ciphers, Stream Ciphers, Symmetric Ciphers, Asymmetric Ciphers. Symmetric Ciphers: Fiestel Cipher Structure, Data Encryption Standards (DES), Double DES, Triple DES; International Data Encryption Standard (IDEA): Key Generation, Encryption and Decryption Process, Advanced Encryption Standards (AES): Key Generation, Encryption and Decryption Process, Modes of Block Cipher Encryptions (Electronic Code Book, Cipher Block Chaining, Cipher Feedback Mode, Output Feedback Mode, Counter Mode). Asymmetric Ciphers: Discrete Logarithms, Public Key Cryptosystems, Applications of Public Key Cryptosystems, Distribution of public key, Distribution of secret key by using public key cryptography, Diffie-Hellman Key Exchange, RSA Algorithm: Key Generation, Encryption and Decryption Process, Elgamal Cryptographic System: Key Generation, Encryption and Decryption Process. Cryptographic Hash Functions and Digital Signatures: Message Authentication, Message Authentication Functions, Message Authentication Codes, Hash Functions, Properties of Hash functions and applications, Message Digests: Details of MD4 and MD5 algorithms, Secure Hash Algorithms (SHA-1 and SHA-2), Digital Signatures, Digital Signature Standard: The DSS Approach, Digital Signature Algorithm (DSA), Digital Signature Standard: The RSA Approach. Authentication: Authentication System, Password Based Authentication, Dictionary Attacks (Online and Offline), Mutual Authentication, Biometric System, Needham-Schroeder Scheme, Kerberos Protocol, Digital Certificates and X.509 certificates, PGP and Firewall.

Course Outcomes

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

CO1. Demonstrate a solid understanding of the fundamental principles and concepts of cryptography, including encryption, decryption, and cryptographic protocols.

CO2. Analyze and evaluate the strengths and weaknesses of various cryptographic algorithms, including symmetric key algorithms (e.g., DES, AES) and asymmetric key algorithms (e.g., RSA, ECC).

CO3. Learn and understand about various cryptographic protocols and their applications in securing communication and techniques for assessing and ensuring the security of cryptographic systems

Books and References

1. Cryptography and Network Security: Principles and Practice by William Stallings.
2. Handbook of Applied Cryptography by Alfred J. Menezes, Paul C. van Oorschot, and Scott A.
3. Understanding Cryptography: A Textbook for Students and Practitioners by Christof Paar and Jan Pelzl.
4. Cryptography and Network Security by Behrouz A. Forouzan and Debdeep Mukhopadhyay.

Course Name: **Computer Networks**
Course Code: **MA-712**
Contact Hours/Week: **4L**
Credits: **04**
Course Type: **Program Elective-I**

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 algorithms 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

Introduction: Network hardware, Network software, OSI, TCP/IP Reference models, Example Networks: ARPANET, Internet. Physical Layer: Guided Transmission media: twisted pairs, coaxial cable, fiber optics, Wireless transmission. Data Link Layer: Design issues, framing, Error detection and correction. Elementary data link protocols: simplex protocol, A simplex stop and wait protocol for an error-free channel, A simplex stop and wait protocol for noisy channel. Sliding Window protocols: A one-bit sliding window protocol, A protocol using Go-Back-N, A protocol using Selective Repeat, Example data link protocols. Medium Access sub layer: The channel allocation problem, Multiple access protocols: ALOHA, Carrier sense multiple access protocols, collision free protocols. Network Layer: Design issues, Routing algorithms: shortest path routing, Flooding, Hierarchical routing, Broadcast, Multicast, distance vector routing, Congestion Control Algorithms, Quality of Service, Internetworking. Transport Layer: Transport Services, Elements of Transport protocols, Connection management, TCP and UDP protocols. Application Layer: Domain name system, SNMP, Electronic Mail; the World WEB, HTTP.

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.
4. An Engineering Approach to Computer Networks-S. Keshav, 2nd Edition, Pearson Education.

Course Name: **Digital Image Processing**
Course Code: **MA-713**
Contact Hours/Week: **4L**
Credits: **04**
Course Type: **Program Elective-I**

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, Lossless 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 domain techniques. 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.

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.

Program Elective – II

Course Name: **Statistics in Decision Makings**
Course Code: **MA-721**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective -II**

Course Objectives

- To introduce the elementary concepts relevant to Statistical decision making methods.
- To learn various available statistical tests and its importance with the data different sets.
- To develop the ability to perform hypothesis testing and interpret results.
- Integrate statistical decision theory into practical decision-making processes.

Introduction to Statistics: Definition and importance of statistics in decision making; Types of data: qualitative vs. quantitative; Scales of measurement: nominal, ordinal, interval, ratio. Sampling and Sampling Distributions: Population vs. sample; Sampling methods: random, stratified, cluster; Central Limit Theorem; Sampling distributions of sample mean and proportion. Estimation and Confidence Intervals: Point estimation and properties of estimators; Constructing confidence intervals for means and proportions; Margin of error and sample size determination. Hypothesis Testing: Null and alternative hypotheses; Type I and Type II errors; p-values and significance levels; Tests for means, proportions, and variances. Comparing Two Groups: Independent and paired sample t-tests; Comparing proportions; Non-parametric tests: Mann-Whitney U test, Wilcoxon signed-rank test, Kruskal-Wallis test. Analysis of Variance (ANOVA): One-way ANOVA; Assumptions and interpretations; Post-hoc tests: Tukey, Bonferroni. Regression Analysis: Simple linear regression; Multiple regression; Assumptions of regression models; Model diagnostics and validation. Statistical Decision Theory: Decision-making under uncertainty; Loss functions and risk; Bayesian decision theory; Applications in business and engineering.

Course Outcomes

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

CO1. Distinguish different types of data and understand how the data plays an important role in statistical decision making

CO2. Apply statistical techniques to analyze data and make informed decisions

CO3. Understand and make conclusions about the different types of data sets

Text and Reference Books

1. Fundamentals of Mathematical Statistics by Gupta S.C. & Kapoor V.K., Sultan Chand and Sons
2. An Introduction to Probability and Statistics, Rohatgi by V.K. and Saleh, A.K, John Wiley
3. D. C. Montgomery, Introduction to Statistical Quality Control, John Wiley & Sons.
4. Fundamentals of Applied Statistics by S.C. Gupta and V.K.Kapoor, Sultan Chand and Sons.
5. Mittage, H.J and Rinne, H, Statistical Methods of Quality Assurance, Chapmann Hall, London, UK, 1993.
6. Edward G. Schilling, Dean V. Neubauer, Acceptance Sampling in Quality Control, Second Edition, Taylor & Francis, 2009.
7. Probability and Statistics for Engineers and Scientists" by Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers, and Keying Ye

Course Name: **Financial Mathematics**
Course Code: **MA-722**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-II**

Course Objectives

- To provide an introduction to Financial Mathematics.
- To have an idea of various Portfolio Modelling and their Analysis.
- To introduce Stochastic Process under Finance.
- To introduce Stochastic Calculus for the problems of Financial Mathematics.

Course Content

Introduction: Introduction and main theme of mathematical finance, financial markets and terminology, time value of money, interest rate, discount rate, bonds and bonds pricing, term structure of interest rates, spot and forward rates, net present value, net future value, financial instruments, underlying and derivative securities, types of derivatives, options, forwards, futures, swaps, concept of arbitrage. Discrete-Time Finance: Pricing by arbitrage, risk-neutral probability measures, valuation of contingent claims, and fundamental theorem of asset pricing, Cox-Ross-Rubinstein (CRR) model, pricing and hedging of European and American derivatives as well as fixed-income derivatives in CRR model, general results related to prices of derivatives. Portfolio Modelling and Analysis: Portfolios, returns and risk, risk-reward analysis, asset pricing models, mean variance portfolio optimization, Markowitz model and efficient frontier calculation algorithm, Capital Asset Pricing Models (CAPM). Stochastic Process: Definitions and Simple Stochastics Processes, Brownian Motion and its Properties, Processes Derived from Brownian Motion, Filtration and Martingale. Stochastics Calculus: Introduction, variation of real-valued function, variation of Brownian Motion, Stochastic Integral and its Properties, Ito-Doeblin Formula and its variants, Stochastic differential equation. Continuous-Time Finance: Black-Scholes-Merton model of stock prices as geometric Brownian motion, derivation of the Black-Scholes-Merton partial differential equation, the Black-Scholes formula and simple extensions of the model, self-financing strategies and model completeness, risk neutral measures, the fundamental theorems of asset pricing, continuous time optimal stopping and pricing of American options, forwards and futures in Black-Scholes-Merton model.

Course Outcomes

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

CO1. To understand the fundamentals of financial markets.
CO2. To apply and analyses various Portfolio Models.
CO3. Gain familiarity in the knowledge of Markov property and Martingale property its applications in the problems involving Mathematical Finance.
CO4. Gain knowledge in the solution of stochastic differential equations and Ito Calculus.

Books and References

1. D.G. Luenberger Investment Science, Oxford University Press-2009.
2. B. Oksendal, Stochastic Differential Equations An Introduction with Application, Springer-Verlag-2003
3. S. M. Ross, An Introduction to Mathematical Finance, Cambridge University Press, 1999.
4. Mathematics for finance. An Introduction by M. Capinski & T. Zastawniak, Springer (2003).

Course Name: **Advanced Optimization Techniques**
Course Code: **MA-723**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-II**

Course Objectives

- Enumerate the fundamental knowledge of Linear Programming, Dynamic Programming problems and Integer programming. To provide quantitative insight and understanding of fundamental methods of Nonlinear and quadratic programming problems.
- Formulate and solve problems with conflicting objectives using the weight sum approach, goal programming, and various solution methodologies. Apply probability theory to solve stochastic linear and nonlinear programming problems.

Course Content

Linear Programming and Dynamic programming: Revised Simplex Method, Karmarkar' Method for linear 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. Integer Programming: Graphical Representation, Gomory's Cutting Plane Method, Balas' Algorithm for Zero–One Programming, Branch-and-Bound Method. Nonlinear Programming: Single variable optimization without constraints, Multi variable optimization without constraints, Multivariable optimization with constraints – method of Lagrange multipliers, Kuhn-Tucker conditions, Quadratic Programming, Wolfe's Method. Multi-objective programming: Conflicting objectives and Tradeoffs, Various Solutions concepts, Weight sum Approach, Formulation of Goal programming, Solution Methodologies for Linear programming Problems. Stochastic Programming: Basic Properties of Probability theory, stochastic linear and nonlinear programming.

Course Outcomes

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

CO1. Solve complex linear and dynamic programming problems using advanced methods like Revised Simplex and Karmarkar's Method.
CO2. Build and solve Integer Programming, Nonlinear with constraints and without constraint programming problems.
CO3. Address conflicting objectives using goal programming and weight sum approach, developing solutions for multi-objective problems.
CO4. Utilize probability theory to formulate and solve stochastic linear and nonlinear programming problems.

Books and References

1. Introduction to operations research by F. S. Hillier and G. J. Lieberman, Holden-Day, Inc., CA.
2. Nonlinear and dynamic programming by G. Hadley, Addison-Wesley Publishing Co., Inc., 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.

Program Elective – III

Course Name: **Mathematical Methods**
Course Code: **MA-731**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-III**

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 analyses 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, Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema. Variational methods for boundary value problems in ordinary and partial differential equations. Generalized coordinates, Lagrange's equations. Integral Equations: Definition and classification of linear integral equations. Conversion of initial and boundary value problems into integral equations. Green's function approach. Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigen functions, resolvent kernel.

Course Outcomes

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

CO1. Explain fundamental mathematical concepts or analyses 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: **Topology**
Course Code: **MA-732**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-III**

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, T1 and T2 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: **Finite Element Methods**
Course Code: **MA-733**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-III**

Course Objectives

- To provide the student with the finite element method of solving the linear and nonlinear differential equations.
- To improve the student's skills in the finite element method.
- To impart the knowledge of FEM implementation using MATLAB.

Course Content

Introduction: Overview – Basic ingredients of the FEM, Early comparison with alternative solution methodologies like finite difference methods. The concepts in FEM: One-dimensional problems (2-point 2nd-order BVP), Axial deformations of a bar, Strong and weak forms, Essential vs. natural boundary conditions, Variational formulations (Principle of virtual work, principle of minimum potential energy), Approximations (Rayleigh-Ritz & Galerkin), Accuracy – error measures, discretization, interpolation, and approximation, Finite element basis functions (linear and quadratic elements), Assembly, Problems with smooth and non-smooth solutions, Convergence. Generalization to two dimensions: Membrane, plane strain and plane stress problems, Triangular and quadrilateral elements, Generalization to higher-order BVP. Mesh Generation and Solvers: Introduction to mesh generation techniques, Structured and unstructured meshes, Quality measures and refinement strategies, Linear static analysis using FEM. Applications: Steady-state and transient heat conduction, Convection and radiation boundary conditions, Application of FEM to heat transfer problems and reaction diffusion equations.

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 Finite element methods.
CO3. Understand the use and significance of finite element methods for computation.

Books and References

1. J. N. Reddy, An introduction to the Finite Element Method, 3rd edition, McGraw-Hill, 2006.
2. O. C. Zienkiewicz and R. L. Taylor, The Finite Element Method, 7th edition, Butterworth Heinemann, 2013.
3. T. J. R. Hughes, The Finite Element Method, Prentice-Hall, 1986.
4. Vidar Thomee, Galerkin Finite Element Methods for Parabolic Problems, Springer Verlag, 2006.

Program Elective – IV

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

Course Objectives

- To provide the student with the numerical methods of solving the linear and nonlinear partial differential equations.
- To impart the knowledge of implementation of numerical methods using MATLAB.
- To introduce FDM and FEM methods, inter alia, for linear and nonlinear PDEs

Course Content

Introduction to PDEs: Classification of PDEs: Elliptic, Parabolic, and Hyperbolic equations, Examples and physical interpretations, Initial and boundary conditions. Finite Difference Methods (FDM): Discretization of spatial and temporal domains, Derivation of finite difference schemes, Forward, backward, and central differences, Local truncation error, Consistency analysis, Stability analysis: von Neumann method, Convergence and Lax Equivalence Theorem, Finite difference method for Poisson and Laplace equations, Explicit and implicit methods for heat equation, Crank-Nicolson scheme, Finite difference methods for wave equation. Finite Element Methods (FEM): Introduction to finite element analysis, Weak formulation of PDEs, Shape functions and element matrices, Assembly of the global system, Implementation of FEM, 1D finite element methods, Error analysis and convergence. Higher-Dimensional Problems: Finite difference methods in 2D and 3D, Finite element methods for 2D problems, Stability, Consistency, Errors analysis, Meshing. Spectral Methods: Fourier series and transforms, Chebyshev polynomials. Implementation of spectral methods, Wavelet Methods: Wavelets, Fundamental Properties, Wavelets for Partial Differential Equations, Implementation.

Course Outcomes

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

CO1. Apply numerical methods to obtain approximate solutions to partial differential equations.
CO2. Analyze and evaluate the accuracy of Finite element methods.
CO3. Understand the use and significance of finite difference methods for computation.

Books and References

1. G. D. Smith, Numerical Solution of Partial Differential Equations: Finite Difference Methods, Clarendon Press, 1985
2. J. N. Reddy, An introduction to the Finite Element Method, 3rd edition, McGraw-Hill, 2006.
3. Vidar Thomee, Galerkin Finite Element Methods for Parabolic Problems, Springer-Verlag, 2006.
4. Silvia Bertoluzza, Silvia Falletta, Giovanni Russo, Chi-Wang Shu Numerical Solutions of Partial Differential Equations, Birkhäuser, 2009.

Course Name: **Soft Computing**
Course Code: **MA-742**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-IV**

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 its 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 Salesman Problem. Swarm Intelligence: Introduction and characteristics of Swarm Intelligence, Ant Colony Optimization (ACO) system, Practice Swarm Optimization (PSO) system: Parameter selection, Applications of ACO & PSO.

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. Understand genetic 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: **Multivariate Statistical Analysis**
Course Code: **MA-743**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-IV**

Course Objectives

- To impart knowledge about the multivariate statistical analysis, both theory and methods.
- To introduce the fundamental concepts relevant to multivariate distributions.
- To enable the students to understand the classification problem in context of multivariate data.

Course Content

Introduction: Multivariate descriptive statistics, statistical distance, mean and covariance matrix, partition of covariance matrix, linear combination of random variables. Simple Geometry and random sampling: Geometry of sample, random samples and expected values of sample mean and covariance matrix, generalized variance, Sample mean, Covariance and Correlation as a matrix operations. Multivariate random variables: Joint multivariate distribution function, mass and density functions, joint and marginal functions, Moment generating function for multivariate random variable and its properties. Multivariate Normal Distribution: Multivariate normal distribution and its properties. Random sampling from multivariate normal distribution. Maximum likelihood estimators of parameters, distribution of sample mean vectors. Hotelling T2 Distribution: Hotelling T^2 statistic, derivation and its distribution –Uses of T^2 statistic - relation between T^2 and D^2 – Mahalanobis D^2 statistic and its distribution. Classification problems: Classification into one of two populations and one of several populations – Fisher's Linear discriminant function. Principle Component Analysis: Population principle components, sample variation, large sample inferences, monitoring quality with principle components. Factor Analysis: Mathematical mode, Estimation of Factor Loadings, Concept of factor rotation – Varimax criterion

Course Outcomes

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

CO1. Derive various multivariate sampling distributions.
CO2. Understand how the distribution arises in multivariate sampling and how to use it
CO3. Understand how to use the classification methods
CO4. Assess the multivariate nature of the data sets and dimension reduction techniques.

Books and References

1. T.W. Anderson, An Introduction to Multivariate Statistical Analysis, John Wiley and Sons, 2003.
2. R.A. Johnson and D.W. Wichern, Applied Multivariate Statistical Analysis, 6th Edition, Prentice Hall of India, 2007.
3. J.F. Hair, W.C. Black, B.J. Babin, R.E., Multivariate data analysis, Anderson, Pearson.
4. N.C. Giri, Applied Multivariate Statistical Analysis, Academic Press

Program Elective – V

Course Name: **Software Engineering**
Course Code: **MA-751**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-V**

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 and Testing: 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: **Time Series Analysis**
Course Code: **MA-752**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-V**

Course Objectives

- To learn about important time series models and their applications in various fields.
- To able to formulate real-life problems using time series models.
- To able to use statistical software to estimate the models from actual data, and draw conclusions and develop solutions from the estimated models.

Course Content

Exploratory Time Series Analysis: Components of time series, Measurements of trend, Measurement of seasonal fluctuation, Measurement of cyclic movement, tests for trend and seasonality, exponential and moving average smoothing. Holt and Winters smoothing, forecasting smoothing. Introduction: Time-series as discrete parameter stochastic process, auto covariance and auto-correlation functions and their properties. Stationary Process and ARMA Models: Moving average (MA), Auto regressive (AR), ARMA and (4) AR integrated MA (ARIMA) models, Choice of AR and MA periods, Properties of sample mean and autocorrelation function, Forecasting stationary time series, ARMA(p, q) processes, ACF and PACF, Forecasting of ARMA processes. Spectral Analysis: Spectral densitie, Time-invariant linear filters, The spectral density of an ARMA process. Nonstationary and Seasonal Time Series Models: ARIMA models, Identification techniques, Unit roots in time series, Forecasting ARIMA models, Seasonal ARIMA models, Regression with ARMA errors. Multivariate Time Series: Second-order properties of multivariate time series, Estimation of the mean and covariance, Multivariate ARMA processes, Best linear predictors of second-order random vectors, Modeling and forecasting.

Course Outcomes

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

CO1. Understand and analyse the theoretical & practical aspects of time series data.
CO2. Understand the components of time series and measure these components.
CO3. Identify an appropriate time series model to fit the empirical data and use it for forecasting.
CO4. Understand the genesis of the multivariate time series analysis.

Books and References

1. Brockwell, Peter J. and Davis, Richard A. (2002). Introduction to Time Series and Forecasting, 2nd edition. Springer-Verlag, New York.
2. Box, G.E.P., Jenkins, G.M. and Reinsel, G.C. (1994). Time Series Analysis: Forecasting and Control, 3rd Edition, Prentice Hall, New Jersey.
3. Chatfield, C. (1996). The Analysis of Time Series, 5th edition, Chapman and Hall, New York.
4. Shumway, R.H., Stoffer, D.S. (2006). Time Series Analysis and Its Applications (with R examples). Springer-Verlag, New York.
5. James D. Hamilton (1994). Time Series Analysis, 1st Edition, Princeton University Press,

Course Name: **Measure Theory and Integration**
Course Code: **MA-753**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Program Elective-V**

Course Objectives

- The modern notion of measure, developed in the late 19th century, is an extension of the notions of length, area or volume.
- The objective of this course is to introduce the concepts of measure and integral with respect to a measure, to show their basic properties, and to provide a basis for further studies in Analysis.

Course Content

Lebesgue outer measure, measurable sets, Algebra and sigma-algebra of sets, Borel measure, Measurable functions, simple functions, Egoroff's theorem. Integration of Non-negative function, the general integral, integration of series, Riemann and Lebesgue integrals**.** Monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem, various modes of convergence and their relations. Signed measures, Hahn and Jordan decomposition theorems, Lebesgue-Radon-Nikodym theorem, Lebesgue decomposition theorem, the representation of positive linear functionals on C_c(X), Product measures, iterated integrals, Fubini's and Tonelli's theorems.

Course Outcomes

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

CO1. Understand the abstract measure theory and definition and main properties of integral.
CO2. Construct Lebesgue's measure on the real line and in n-dimensional Euclidean space.
CO3. Use the concept of measure theory to solve the problems related to functional analysis.

Books and References

1. G. D. Barra, Measure Theory and Integration, 2nd Edition, Woodhead Publishing, 2003.
2. Terence Tao, An Introduction to Measure Theory, Graduate Studies in Mathematics, AMS, 2011.
3. K. Rana, An Introduction to Measure and Integration, 2nd Edition, Narosa, 2004.
4. H. L. Royden, Real Analysis, Third edition, Prentice-Hall of India, 1995.

Institute Electives

Course Name: **Numerical and Statistical Methods**
Course Code: **MA-701**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Institute Elective**

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. Analyze 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.Basic statistics by Agarwal. B. L, New Age International (P) Ltd.

Course Name: **Statistical Data Analysis**
Course Code: **MA-702**
Contact Hours/Week: **4L**
Course Credits: **04**
Course Type: **Institute Elective**

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.