Discrete Mathematics for Computing					
Prerequisite: None		L	T	P	C
Total hours: 42		3	0	0	3
Course Content					Hrs.
Unit 1	Logic: Syllogism in Nyay (Logic in India). Well-formed formula, interpretations, propositional logic, predicate logic, theory of inference for propositional logic and Proof techniques.				9
Unit 2	Set Theory: Review of Basic Set Operations, cardinality of a set, relations, equivalence relations, partially ordered sets, functions, countability. Halayudha commentary. Paravartya sutra method for division of polynomials, lattices and Boolean algebras.				9
Unit 3	Combinatorics: Permutations, combinations, Pigeon Hole principle, inclusion exclusion principle, recurrences, generating functions, partitions, Virahanka Fibonacci sequence, Recurrence relations, special numbers.				12
Unit 4	Group Theory: Modular Arithmetic, Kuttaka problem. Groups-Binary operation, and its properties, Definition of a group, Groups as symmetries, cyclic, dihedral, symmetric, matrix groups, Subgroups, Cosets, normal subgroups and quotient groups, Conjugacy classes, Lagrange's theorem, Historical evolution of algebra and symmetry: Bhaskara II, development of group theory, and applications in modern computing, Monoids. Introduction to rings and fields.				12

Course outcomes:

- Apply the concepts of sets, relations, functions, logic, and proof techniques to solve discrete mathematical problems.
- Use combinatorial methods and recurrence relations to analyze and solve computational problems.
- Analyze algebraic structures such as groups, monoids, rings, and fields and their applications in computing.
- Appreciate the historical development of discrete mathematics, including significant Indian contributions, and their relevance to modern computing.

Text Books

1.	Herstein I. N., Abstract Algebra. 3rd ed. John Wiley & Sons, 1996.
2.	Tremblay J. P., and Manohar R., Discrete Mathematics with Applications to Computer Science. Tata McGraw-Hill, 1997.

3.	Raju C. K., Cultural Foundations of Mathematics: The Nature of Mathematical Proof and the Transmission of the Calculus from India to Europe in the 16th c. CE. Pearson Longman, 2007.
Reference books	
1.	Huth M., and Ryan M., Logic in Computer Science: Modelling and Reasoning about Systems. Cambridge University Press, 2004.
2.	Gallian J. A., Contemporary Abstract Algebra. 9th ed. Cengage Learning, Boston, 2017.
3.	Liu C. L., and Mohapatra D.P., Elements of Discrete Mathematics. 4th ed. Tata McGraw-Hill Education, 2012.
4.	Rosen K. H., Discrete Mathematics and Its Applications. 6th ed. Tata McGraw-Hill, 2007.
5.	Joseph G. G., The Crest of the Peacock: Non-European Roots of Mathematics. 3rd ed. Princeton University Press, 2011.

Linear Algebra					
Pre-requisite: None		L	T	P	C
Total hours: 42		3	0	0	3
Course Content					Hrs.
Unit 1	Introduction: Algebra in ancient India. Review of set theory and fields. Vector spaces and subspaces, linear independence and dependence, spanning set, basis and its existence, sums and direct sum of subspaces.				10
Unit 2	Linear transformations: Linear transformations and their basic properties, Rank-Nullity theorem and its consequences, ordered basis, coordinate matrix, change of basis, matrix representation of a linear transformation, vector space of linear transformations, linear functional.				8
Unit 3	Inner product spaces: Cauchy-Schwartz inequality, orthogonality, Gram-Schmidt orthogonalization, orthonormal basis, QR-factorization, least square approximation, best approximation, orthogonal complement, Adjoint of an operator, Hermitian, unitary and normal operators.				12
Unit 4	Eigen-values and Eigen-vectors of a linear operator: Characteristic polynomials, minimal polynomials, Cayley Hamilton's theorem for operators, Schur's theorem (Statement Only), diagonalizability, Spectral theorem for normal operators, Singular Value Decomposition.				12

Course Outcomes

- Understand the concepts of vector spaces, subspaces, bases, dimension and their properties.
- Relate matrices and linear transformations, compute Eigen values and Eigen vectors of linear transformations and use these notions in diagonalization.
- Learn properties of inner product spaces and properties of some special operators on such spaces.
- Learn to apply geometric and algebraic notions of linear algebra to determine best approximations in vector spaces.

Text Books

1.	Axler S., Linear Algebra Done Right, Springer UTM, 1997.
2.	Anton H., Rorres C., Elementary Linear Algebra: Applications, 11th edition, Wiley, 2013.

Reference Books

1.	Strang G., Linear Algebra and Its Applications, 4th edition, Cengage Learning, 2006.
2.	Hoffman K. and Kunze R., Linear Algebra, 2nd edition, PHI Learning, 2009.
3.	Lang S., Introduction to Linear Algebra, 2nd Edition, Springer India, 2005.
4.	Kumaresan S., Linear Algebra: A Geometric Approach, PHI Learning, 2000.
5.	VaradarajanV. S., Algebra in ancient and modern times, American Mathematical Soc., 1998

Graphs and Matrices					
Prerequisite: Mathematics II		L	T	P	C
Total hours: 42		3	0	0	3
Course Content					Hrs.
Unit 1	Graphs: Vertex degrees, isolated/pendant vertices, and the Handshaking Lemma, walks, trails, Paths, Cycles, connectivity, special types of graphs, subgraphs, isomorphism, trees and their properties, Spanning tree and minimum number of spanning trees, Eulerian and Hamiltonian graphs				12
Unit 2	Matrices: Eigenvalues of symmetric matrices, Generalized Inverse, Moore Penrose Inverse, Schur Complement, Interlacing Inequality, Weyl's Inequality, Positive Definite and Positive Semi-Definite Matrices				6
Unit 3	Representation of graphs: Incidence matrix, Matchings in bipartite graphs, Adjacency Matrix, Eigenvalues of some special graphs, Determinant, Bounds, Energy of a graph, Anti-Adjacency matrix of a directed graph, Non-singular trees				8
Unit 4	Laplacian matrix: Basic properties, Computing Laplacian Eigenvalues, Matrix-tree theorem, Bounds of Laplacian spectral radius, Signless Laplacian matrix, Regular graphs, strongly regular graphs, and the friendship theorem, Graph with maximum Energy				8
Unit 5	Algebraic connectivity: Classification of trees, Monotonicity properties of Fielder vector, Bounds of algebraic connectivity. Distance matrix of a graph, Distance and Laplacian matrix of a tree.				8

Text Books	
1.	R. Balakrishnan and K. Ranganathan, A Text Book of Graph Theory, Springer, 2000.
2.	R. A. Horn and C. R. Johnson, Matrix Analysis, Second Edition, Cambridge University Press, 2012.
3.	R. Bapat, Graphs and Matrices, Text and Readings in Mathematics, Second Edition, Hindustan Book Agency, New Delhi, 2014.

Reference books	
1.	J. M. Aldous. Graphs and Applications. Springer, LPE, 2007.
2.	J. A. Bondy and U. S. R. Murty. Graph Theory with Applications. North-Holland, 1976.
3.	West D. B., *Introduction to Graph Theory*, Second Edition, Pearson, 2001.
4.	R. J. Wilson, *Introduction to Graph Theory,* Fourth Edition, Prentice Hall, 1996.
5.	D. R. Cvetkovic, S. Simic, An introduction to the theory of Graph Spectra, First Edition, Cambridge University press, 2010.

6.	N. Biggs, Algebraic Graph Theory, Second Edition, Cambridge University press, 1993.

Numerical Methods and Computations					
Prerequisite: Mathematics - II, Real Analysis		L	T	P	C
Total hours: 42		3	0	0	3
Course Content					Hrs.
Unit 1	Errors in Numerical Computations: Representation of numbers in computers and their accuracy, floating point arithmetic, Machine epsilon, errors in computations, types of errors, propagation of errors, conditioning and stability of numerical computations, approximations of functions: Taylor's series.				6
Unit 2	Solution of Simultaneous Linear Equations: Direct methods: Gauss and Gauss-Jordan elimination method, Pivoting strategies, LU-decomposition, Operations count. Iterative methods: Jacobi and Gauss-Seidel iteration methods. Review of vector and matrix norms, condition number, and convergence analysis.				8
Unit 3	Numerical Solution of Algebraic and Transcendental Equations: Iterative algorithms: Ancient Indian Algorithms for Square Root Computation, Bisection method, Secant method, Newton-Raphson method, and Fixed-point iteration, Convergence and error analysis, Multiple Roots. Solution of a system of nonlinear equations using Newton's method.				8
Unit 4	Numerical Interpolation: Forward, backward and central differences operators, Second difference approximations in Ancient Indian Astronomy, Newton's forward and backward difference interpolation formulae. Central difference formulae: Gauss, Stirling, and Bessel's formula. Lagrange's and Newton's divided difference interpolation formulae, Error in polynomial interpolation. Hermite and Cubic-spline interpolation.				11
Unit 5	Numerical Differentiation and Integration: Numerical differentiation through an interpolating polynomial, the Method of Undetermined Coefficients. Numerical integration: Newton-Cotes formulae, Error estimates. Romberg integration and Gaussian quadrature. Extension to multiple integrals.				9

Course Outcomes:

- Understanding of fundamental numerical methods for solving mathematical problems (linear and nonlinear equations) approximately.
- Demonstrate proficiency in applying numerical techniques to analyze and approximate tabulated functions.

• Ability to examine the accuracy and efficiency of numerical algorithms and computations. • Utilize numerical methods to evaluate numerical differentiation and integration of functions	
Text Books	
1.	Burden R. L. and Faires J. D., Numerical Analysis, 9th Edition, Cengage Learning, 2011.
2.	Jain M.K., Iyengar S.R.K., and Jain R.K., Numerical Methods for Scientific and Engineering Computation, Wiley Eastern Limited, 2012.
Reference books	
1.	Gerald C.F and Wheatly P.O., Applied Numerical Analysis, Seventh Edition, Pearson Addison-Wesley Pub. Co, 1985.
2.	Kincaid D.R. and Cheney W., Numerical Analysis: Mathematics of Scientific Computing, Third Edition, AMS, Providence, Rhode Island, 2002.
3.	Sastry S.S., Introductory Methods of Numerical Analysis, Prentice Hall of India, 2012.
4.	Sharma J.N., Numerical methods for Engineers and Scientists, 2nd edition, Narosa Publishing House, New Delhi, 2008.
5.	Divakaran P. P., The Mathematics of India: Concepts, Methods and Connections, Springer (with Hindustan Book Agency, New Delhi), 2018.

<table>
<tr><td colspan="6">Probability and Stochastic Processes</td></tr>
<tr><td colspan="2">Pre-requisite: None</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Total hours: 42</td><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td colspan="5">Course Content</td><td>Hrs.</td></tr>
<tr><td>Unit 1</td><td colspan="4">Historical development of probability: Early concepts of counting, chance and uncertainty; combinatorial foundations in Pingala's Chandashastra, Meru Prastara (Pascal's Triangle), Hemachandra sequence, and Narayana Pandita's combinatorial methods; emergence of probability theory through the correspondence between Pascal and Fermat, leading to Kolmogorov's axiomatic framework. Probability: Classical and axiomatic definitions of probability, addition rule, conditional probability, multiplication rule, total probability, and Bayes' theorem.</td><td>7</td></tr>
<tr><td>Unit 2</td><td colspan="4">Random Variables: Discrete, continuous, and mixed random variables, probability mass, probability density and cumulative distribution functions, mathematical expectation, moments, and moment generating function,</td><td>7</td></tr>
<tr><td>Unit 3</td><td colspan="4">Special Distributions: Discrete: uniform, binomial, negative binomial, hypergeometric, Poisson.
Continuous: Uniform, Exponential, Weibull, Normal. Historical evolution of probability distributions and statistical thinking, including Indian contributions to combinatorial enumeration and the emergence of probability models in science and engineering.</td><td>10</td></tr>
<tr><td>Unit 4</td><td colspan="4">Pairs of Random Variables: Joint Cumulative Distribution Function, Joint Probability Mass Function(PMF), Marginal PMF, Joint Probability Density Function, Marginal PDF, Functions of two random variables, expected values, Conditioning by an event, and conditioning by Random Variables.</td><td>8</td></tr>
<tr><td>Unit 5</td><td colspan="4">Stochastic Process: Classification and properties of stochastic processes, Stationary process, Markov process, Poisson process, Birth and death process, The Brownian motion process, Expected value and Correlation.</td><td>10</td></tr>
<tr><td colspan="6">Course Outcomes
• Understand and analyze the theoretical and practical aspects of the theoretical distributions of random variables.
• Identify an appropriate theoretical distribution to fit the empirical data and find out the properties of the data.</td></tr>
</table>

• Understand and apply the concept of stationarity to the stochastic processes in various contexts.	
Text Books	
1.	Ross S.M., Introduction to Probability and Statistics for Engineers and Scientists, Academic Press, 2014.
2.	Papoulis A. and Pillai S.U., Probability, Random Variables and Stochastic Processes, 4th edition, McGraw-Hill, 2002.
Reference books	
1.	Medhi J., Stochastic Processes, New Age International Publishers, 2009.
2.	Chung K.L. and Ait Sahlia F., Elementary Probability theory: With Stochastic Processes and an Introduction to Mathematical Finance, Springer, 2010.
3.	Gupta S. C. and Kapoor V. K., Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 2014.
4.	Veerajan T., Probability, Statistics and Random Processes, Tata McGraw–Hill, 2017.
5.	Raju C.K., Cultural Foundations of Mathematics, Pearson Longman, 2007.
6.	Montgomery D. C. and Runger G. C., Applied Statistics and Probability for Engineers, 7th Ed., John Wiley & Sons, 2018.

Optimization Methods and Applications					
Pre-requisite: Linear Algebra		L	T	P	C
Total hours: 42		3	0	0	3
Course Content					Hrs.
Unit 1	Introduction to Optimization: Historical development of optimization from geometric constructions in the Śulba Sūtras, algebraic and computational methods developed by Aryabhata, Brahmagupta, and Bhāskara II, including Bhāskara II's ideas related to maxima and minima, followed by the evolution of optimization through the works of Fermat, Euler, Lagrange, Kantorovich, and Dantzig, leading to modern linear programming. Linear Programming Problems (LPP): Formulation of LPP, notion of an optimal solution, graphical interpretation of optimality, convex sets and convex functions, applications of convexity in linear programming, extreme points, basic feasible solutions (BFS), Fundamental Theorem of Linear Programming (statement only), and the relationship between extreme points of the feasible region and basic feasible solutions.				8
Unit 2	Canonical form of LPP, initial BFS and a method of improving current BFS, simplex algorithm, artificial variable and its interpretation in the context of feasibility, case of unbounded LPP, two-phase method.				6
Unit 3	Introduction to duality, formulation of dual LPP, duality theorems and their interpretations. Complementary slackness theorem (statement only), economic interpretation and applications of duality, dual-simplex method.				6
Unit 4	Linear integer program and Gomory cut algorithm, Transportation programming problems (TPP), optimal solution of TPP, assignment problems and Hungarian Method. Introduction to Game Theory: Two-person zero-sum games, payoff matrix, pure and mixed strategies.				8
Unit 5	Applications of LPP to problems such as Network optimization problems like shortest path and Network flows, PERT-CPM. Historical evolution of optimization in transportation, logistics and scheduling with emphasis on ancient Indian trade-route optimization, architectural planning, and modern developments in Operations Research after World War II.				7
Unit 6	Non-linear Programming: Lagrange multipliers and Kuhn - Tucker conditions. Historical development of constrained optimization from				7

	geometric methods to Lagrange multipliers, Karush-Kuhn-Tucker theory and their role in modern Artificial Intelligence, Machine Learning and Engineering.	

Course Outcomes

- Understand the theoretical foundations of nonlinear programming, including convex and non-convex optimization problems, and optimization algorithms.
- Understand the fundamental principles and concepts of optimization techniques in various domains.
- Analyze and formulate linear programming problems mathematically, identifying objective functions, constraints, and decision variables.
- Understand the principles and methodologies of Duality, Critical Path Method (CPM), and Program Evaluation and Review Technique (PERT), and their applications in project management and resource allocation.

Text Books

1.	Taha H. A., Operations Research: An Introduction, 10th Ed., Pearson, 2017.
2.	Rao S., Engineering optimization theory and practice, New Age International publishers, 2013.

Reference books

1.	Boyd S. and Vandenberghe L., Convex Optimization, Cambridge University Press, 2004.
2.	Bertsimas D., Introduction to Linear Optimization, Athena Scientific, 1997.
3.	Joseph G.G., The Crest of the Peacock: Non-European Roots of Mathematics, 3rd Ed., Princeton University Press, 2011.
4.	Raju C. K., Cultural Foundations of Mathematics, Pearson Longman, 2007.
5.	Swarup K., Gupta P.K. and Man Mohan, Operations Research, Sultan Chand & Sons, Latest Edition.