<table>
<tr><th colspan="5">Probability and Stochastic Processes</th></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.

Complex Analysis				
Pre-requisite: Real analysis	L	T	P	C
Total hours: 42	3	1	0	4

Course Content		Hrs.
Unit 1	Historical development of complex analysis: Contributions of Brahmagupta and Bhāskara II to algebra and the theory of equations; transmission of methods for solving polynomial equations from India to Arabia and Europe; evolution of complex numbers through Cardano, Bombelli, Euler, and Gauss, leading to the development of the complex plane and its applications. Complex numbers and elementary properties, polar representation, stereographic projection, functions of a complex variable, graphical representation, single-valued and multi-valued functions, elementary complex functions and inverse functions, topology of the complex plane, and completeness.	8
Unit 2	Limits, continuity and differentiation, Cauchy-Riemann equations, holomorphic and harmonic functions, harmonic conjugate, analytic functions, power series, holomorphicity of power series, Line Integrals, and Green's Theorem.	8
Unit 3	ML-inequality, Cauchy-Goursat theorem, Cauchy's integral formula, Taylor series, Morera's theorem, Liouville's theorem, mean value property, maximum modulus principle,. Historical evolution of complex function theory.	8
Unit 4	Zeros of analytic functions, Fundamental theorem of algebra, classification of singularities, Laurent series, residues, Cauchy's Residue theorem and applications in solving improper real integrals, application to inverse Laplace transform, Rouche's theorem (statement only) and argument principle (statement only).	10
Unit 5	Conformal maps, standard transformations, bilinear transformations, group properties, automorphism, cross-ratio theorem, fixed points, simple bilinear transformations, Riemann mapping theorem (statement only), Schwarz-Christoffel transformation, Poisson integral for circle and plane, Dirichlet problem.	8

Course Outcomes

- Represent complex numbers algebraically and geometrically

• Analyze limit, continuity and differentiation of functions of complex variables. • Understand Cauchy-Riemann equations, analytic functions and various properties of analytic functions. • Understand Cauchy theorem and Cauchy integral formulas and apply these to evaluate complex contour integrals. • Represent functions as Taylor and Laurent series; classify singularities and poles; find residues and evaluate complex integrals using the residue theorem. • Understand conformal mapping and apply the techniques regarding conformal mappings to various fields.

Text Books	
1.	Ponnusamy S., Silverman H., Complex Variable with Applications, Birkhauser, 2006.
2.	Brown J. W. and Churchill R. V., Complex Variables and Applications, 7th Ed., Mc-Graw Hill, 2004.
Reference books	
1.	Conway, J. B. Functions of One Complex Variable I. 2nd ed. Graduate Texts in Mathematics, Vol. 11. New York: Springer-Verlag, 1995. ISBN: 978-0-387-94234-6.
2.	Kasana H.S., Complex Variables: Theory and Application, PHI Intl Ltd, 2nd Edition, 2017.
3.	Zills, D. G., and Shanahan, P. D., A First Course in Complex Analysis with Applications. Jones & Bartlett Publishers, Inc., 2003.
4.	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 Century, Pearson Longman, 2007.
5.	Spiegel, M. R., Lipschutz, S., Schiller, J. J., & Spellman, D. Schaum's Outline of Complex Variables. 2nd ed. New York: McGraw-Hill Professional, 2009.

<table>
<tr><th colspan="6">Differential Equations</th></tr>
<tr><td colspan="2">Prerequisite: Basic knowledge of Real Analysis</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>1</td><td>0</td><td>4</td></tr>
<tr><td colspan="5">Course Content</td><td>Hrs.</td></tr>
<tr><td>Unit 1</td><td colspan="4">Overview of the contributions of Indian mathematicians to mathematical astronomy and modern differential equations.
First-order non-linear differential equations: Existence and Uniqueness problem, fixed-point theorem(statement only), Picard existence and uniqueness theorem.</td><td>10</td></tr>
<tr><td>Unit 2</td><td colspan="4">Linear dependence and Wronskian, Dimensionality of space of solutions, Abel-Liouville formula, Method of Undetermined coefficients for linear differential equations of constant coefficients, Series solutions of linear differential equations, System of linear differential equations.
Two-point boundary value problems of the Sturm-Liouville type, Sturm Separation Theorem (statement only), Sturm Comparison Theorem (statement only), Green's functions.</td><td>12</td></tr>
<tr><td>Unit 3</td><td colspan="4">Introduction to PDE and the classification of PDEs (Linear, Nonlinear, Semi-linear, Quasi-linear), Formation of partial differential equations, Integral surfaces passing through a given curve, Method of characteristics.
Classification of second-order PDEs (elliptic, parabolic, hyperbolic) and reduction to canonical form and their solutions.</td><td>8</td></tr>
<tr><td>Unit 4</td><td colspan="4">Cauchy's problem for second-order PDEs, Characteristic equations and characteristic curves of second-order PDEs, Review of Fourier Series, Method of separation of variables: Solution of Wave equation, Heat equation, and Laplace equation.</td><td>12</td></tr>
<tr><td colspan="6">Course Outcomes:
Analyze the existence, uniqueness, and continuity of solutions of first-order ordinary differential equations.
Explain the fundamental concepts of ordinary differential equations, including linear dependence, Wronskians, and the Abel–Liouville formula.
Apply power series methods to solve linear differential equations and solve systems of linear differential equations.
Classify second-order partial differential equations and identify their canonical forms.</td></tr>
</table>

• Apply the method of separation of variables to solve classical partial differential equations such as the wave, heat, and Laplace equations.	

Text Books

1.	Simmons G.F. and Krantz S.G., Differential Equations Theory, Techniques and Practice, McGraw Hill, 2006.
2.	Ross, S. L., Differential Equations, 3rd edition, Wiley 1984.
3.	Rao, K. Sankara, Introduction to Partial Differential Equations, PHI Learning Pvt. Ltd., 2010

Reference books

1.	Deo S. G, Raghvendra V., Kar R. and Lakshmikantham V., Textbook of Ordinary Differential Equations, McGraw-Hill Education, 2018.
2.	Coddington E.A. and Levison N., Theory of Ordinary Differential Equations, McGraw Hill, 2017.
3.	Zill D. and Wright W., Advanced Engineering Mathematics, Fourth Edition, Jones and Bartlett Student Edition, 2011 (Indian Edition).
4.	O'Neil P., Advanced Engineering Mathematics, Seventh Edition, Cengage Learning, 2012 (Indian Edition).
5.	Plofker, K.. Indian Mathematics. Princeton University Press, 2009

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.

<table>
<tr><td colspan="2">Optimization Methods and Applications Lab</td><td></td><td></td><td></td></tr>
<tr><td>Pre-requisite: Linear Algebra</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>Total hours: 24</td><td>0</td><td>0</td><td>2</td><td>1</td></tr>
<tr><td colspan="4">Course Content</td><td>Hrs.</td></tr>
<tr><td colspan="4">
1. Introduction to the programming language/package and setting up a Data File
2. Setting up the problem and solving simple LP problems
3. Solution of Transportation programming problems (TPP)
4. Solution of Assignment problems, Hungarian Method.
5. Solution of Travelling Salesman Problem
6. Applications of LPP to Network optimization problems like shortest path and Network flows
7. Linear Integer program and Gomory cut algorithm
8. Project Planning: PERT
9. Project Planning: CPM
10. Solution of shortest path problem
11. Solution of resource allocation problem

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of the semester based on the above generic list.
</td><td>24</td></tr>
<tr><td colspan="5">Course Outcomes
• Gain hands-on experience in implementing optimization algorithms discussed in theory classes, including linear programming, and nonlinear programming techniques.
• Develop proficiency in using computational tools and software packages or commercial optimization software to solve optimization problems efficiently.
• Acquire skills in formulating optimization problems, defining objective functions, constraints, and decision variables, and translating them into code for algorithm implementation.
• Develop critical thinking and problem-solving skills by troubleshooting algorithm implementations, debugging code, and refining optimization strategies.
</td></tr>
</table>

Text Books	
1.	Hamdy A. Taha, Operations research: An introduction, Pearson Education, 2006
2	Rao S., Engineering optimization theory and practice, New Age International publishers, 2013.
Reference book	
1.	Boyd S. and Vandenberghe L., Convex Optimization, Cambridge University Press, 2004.
2.	Bertsimas D., Introduction to Linear Optimization, Athena Scientific, 1997.
3.	Vanderbei R., Linear Programming: foundations and extension, Springer, 2001.
4.	Srinivasan G., Operations research principles and applications, PHI Learning Private Limited, 2010.
5.	Chvatal V., Linear Programming, W. H. Freeman Publishers, 1983.

Theory of Computations					
Prerequisite: None		L	T	P	C
Total hours: 42		3	0	0	3
Course Content					Hrs.
Unit 1	Basic foundation: Review of Set Theory, Automata Theory, Alphabet, Power of Alphabet, Kleen Closure, Positive Closure, String, Empty String, Concatenation, Language. Finite Automata (FA): Introduction, Deterministic Finite Automata (DFA) -Formal Definition, Simpler Notations (State Transition Diagram, Transition Table), Language of A DFA. Nondeterministic Finite Automata (NFA)- Definition of NFA, Language of an NFA, Equivalence of Deterministic and Nondeterministic Finite Automata, Applications of Finite Automata, Finite Automata with Epsilon Transitions, Eliminating Epsilon Transitions, Minimization of Deterministic Finite Automata, Finite Automata with Output (Moore and Mealy Machines) and Inter Conversion.				10
Unit 2	Regular Expressions (RE): Introduction, Identities of Regular Expressions, Finite Automata and Regular Expressions- Converting from DFA's to Regular Expressions, Converting Regular Expressions to Automata, Minimization of Finite Automata, Applications of Regular Expressions. Regular grammars: Chomsky Classification of Languages, Regular Grammars and FA, FA for Regular Grammar, Regular Grammar for FA. Proving Languages to be Non-Regular -Pumping Lemma, Applications, Closure Properties of Regular Languages.				8
Unit 3	Context free grammar (cfg): Derivation Trees, Sentential Forms, Rightmost and Leftmost Derivations of Strings. Ambiguity in CFGs, Minimization of CFGs, Normal Forms (CNF, GNF), Pumping Lemma for CFLs.				8
Unit 4	Pushdown automata theory: Push Down Automata, Deterministic and Nondeterministic PDA, PDA And Languages, Construction of PDA, Acceptance of CFL, Acceptance by Final State and Acceptance by Empty Stack and its Equivalence, Equivalence of CFG and PDA.				8

	Turing machines (tm): formal Definition and Behaviour, Languages of a TM, TM as Accepters, TM as a Computer of Integer Functions, TM with Storage in its State, TM as Subroutine, Minsky's Theorem, Types of TMs, Multitrack, Multitape, Nondeterministic TM, Encoding of TM, Computability and Acceptability.	
Unit 5	Recursive and Recursively Enumerable Languages (REL): Properties of Recursive and Recursively Enumerable Languages. Undecidability and undecidable problems: Post's Correspondence Problem (PCP), Universal Turing Machine, The Halting Problem, Undecidable Problems about TMs. Context Sensitive Language and Linear Bounded Automata (LBA), Chomsky Hierarchy, Decidability.	8

Course Outcomes:

- Develop a solid understanding of the theoretical foundations of computation, including formal languages and automata theory.
- Analyze and classify computational problems using formal models such as finite automata, regular expressions, and context-free grammars.
- Explore advanced topics in the theory of computation, such as Recursive and Recursively Enumerable Languages and Chomsky Hierarchy.
- Apply theoretical concepts to solve computational problems and analyze the computational complexity of algorithms, and understand the limits of computation.

Text Books

1.	Hopcroft J.E., Motwani R., Ullman J.D., Introduction to Automata Theory, Languages and Computation, Pearson Education, India, 2007
2.	Cohen, D. I. A. Introduction to Computer Theory. 2nd ed. New York: John Wiley & Sons, 1997.

Reference books

1.	Martin J.C., Introduction to Languages and the Theory of Computation. 4th ed., McGraw-Hill, 2010
2.	Lewis H. R., & Papadimitriou, C. H. Elements of the Theory of Computation. 2nd ed., Prentice Hall, 1998

3.	Linz P. An Introduction to Formal Languages and Automata. Jones & Barlett Learning, 2016.
4.	Sipser, M. Introduction to the Theory of Computation. 3rd ed., Cengage Learning, 2013.