B.Tech. IV (Mathematics and Computing), Semester – VII TOPOLOGY AND FUNCTIONAL ANALYSIS MA-407	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	explain the concept of topology and the intrinsic properties of topological spaces.
CO2	apply the knowledge of compactness, countability and separation axioms in other branches of mathematics.
CO3	understand the fundamental concepts of normed linear spaces, including their topological properties, and apply key results like the Riesz lemma to solve problems related to these spaces.
CO4	analyze bounded linear maps on normed linear spaces, including finite-dimensional spaces, and apply essential theorems such as the Hahn-Banach theorem, Open Mapping theorem, and Banach-Steinhaus theorem to various functional analysis problems.
CO5	analyze bounded operators on Hilbert spaces, including self-adjoint, normal, and unitary operators, and apply the Riesz representation theorem to practical scenarios.

2.	Syllabus	
	TOPOLOGY: INTRODUCTION	**(10 Hours)**
	Topological Spaces, Examples of topological spaces, Bases, and sub-bases for a topology, Subspace topology, Product topology, Metric topology, Limit point, closure, interior, Continuous function, and Homeomorphism.	
	TOPOLOGY: COMPACTNESS, COUNTABILITY AND SEPARATION AXIOMS	**(08 Hours)**
	Compact spaces, Heine-Borel theorem; Countability axioms, Separation axioms, Regular spaces, Normal spaces.	
	FUNDAMENTALS OF NORMED LINEAR SPACE	**(05 Hours)**
	Normed linear spaces, examples, and their topological properties, Riesz lemma	
	BOUNDED LINEAR MAPS ON NORMED LINEAR SPACES	**(10 Hours)**
	Definition and examples, linear maps on finite-dimensional spaces, operator norm, Banach Spaces, Hahn-Banach theorem, and its applications, Open mapping and Closed Graph theorems, Banach-Steinhaus theorem (or the Uniform Boundedness Principle).	
	HILBERT SPACES	**(07 Hours)**
	Inner product spaces, orthonormal sets, Gram-Schmidt orthogonalization process, Schwarz's inequality, Bessel's inequality, orthonormal basis, Separable Hilbert spaces, projection, and Riesz representation theorem.	

	BOUNDED OPERATORS ON HILBERT SPACE	**(05 Hours)**
	Adjoint of an operator on a Hilbert space, Self-adjoint and normal operators, unitary operators on a Hilbert space.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial-1 and Tutorial-2 will be based on Topology: Introduction.
2	Tutorial-3 and 4 will be based on topology: compactness, countability and separation axioms.
3	Tutorial-5 and 6 will be based on fundamentals of normed linear space.
4	Tutorial-7 and 8 will be based on bounded linear maps on normed linear spaces.
5	Tutorial-9 will be based on Hilbert spaces.
6	Tutorial-10 will be based on bounded operators in Hilbert space.

4.	**Books Recommended**
1	J. R. Munkres, Topology, 2nd Edition, Pearson Education (India), 2015.
2	G. F. Simmons, Introduction to Topology and Modern Analysis, 1st Edition McGraw-Hill Education, New York, 2017.
3	S. Ponnusamy, Foundations of Functional Analysis, Narosa Publishing House, New Delhi, 2002.
4	E. Kreyszig, Introductory Functional Analysis with Applications, 1st edition, John Wiley & Sons, New York, 1989.
5	B. V. Limaye, Functional Analysis, 3rd Revised Edition, New Age International Private Limited, 2014.

ADDITIONAL REFERENCE BOOKS	
1	K. D. Joshi, Introduction to General Topology, New Age International, New Delhi, 2000.
2	M. A. Armstrong, Basic Topology, Springer (India), 2004.
3	C. W. Patty, Foundations of Topology, Second Edition, Jones & Barlett Student Edition, 2010.
4	W. Rudin, Functional Analysis, 2nd Edition, McGraw-Hill, New York, 1991.
5	J. B. Conway, A Course in Functional Analysis, 2nd Edition, Springer-Verlag, New York, 1990.

B.Tech. IV (Mathematics and Computing), Semester – VII AUTOMATA THEORY MA-468	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	gain knowledge of basic kinds of finite automata and their capabilities.
CO2	understand regular and context-free languages.
CO3	understand the time and space complexity for p and np problems.
CO4	gain the knowledge of describing and changing the language to regular expressions and grammar.
CO5	constructing the Turing machine for Recursive languages.

2.	Syllabus	
	PRELIMINARIES	**(09 Hours)**
	Set theory, propositions, predicate logic, relation, one-to-one function, onto function, bijection function, Direct proof, proof by contradiction, proof by contrapositive, Principle of mathematical induction, Recursive Definition	
	REGULAR LANGUAGES	**(05 Hours)**
	Symbol, Alphabet, String, Language, Regular expression and Language, Pumping Lemna.	
	FINITE STATE MACHINE	**(08 Hours)**
	Basics of Automata theory, Finite automata, Deterministic and Nondeterministic finite Automata, Equivalence of Deterministic and Nondeterministic finite Automata, Conversion RE (Regular Expression) to Non-Deterministic Finite Automata, Subset Algorithm to convert Non DFA to DFA, Finite automata minimization, Moore and Mealey machine and their Conversion.	
	CONTEXT-FREE GRAMMAR (CFG)	**(08 Hours)**
	Context-free language, Chomsky normal forms, Greibach normal forms (GNF), derivation - derivation tree with their relation, Ambiguous and unambiguous CFG, Algebraic expression, Closure properties of Context Free Language.	
	PUSH DOWN AUTOMATA (PDA):	**(07 Hours)**
	Introduction about PDA, equivalence between CFG and PDA, Deterministic PDA, Pumping Lemna for Context Free Language, Acceptance of Empty and Final state.	
	TURING MACHINE AND REL	**(04 Hours)**
	Basics of Turing machine, Language acceptor, Turing machine variations, Church Turing thesis, Universal Turing machine, Looping vs Halting, Recursively and Enumerable Languages.	

	COMPUTABILITY	**(04 Hours)**
	Partial function, Primitive recursive functions, undecidable problem, Class P and NP, Np Completeness	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial-1 and Tutorial-2 will be based on Preliminaries.
2	Tutorial-3 and 4 will be based on Regular Languages.
3	Tutorial-5 and 6 will be based on Finite state machine.
4	Tutorial-7 and 8 will be based on Context-Free Grammar (CFG).
5	Tutorial-9 will be based on Push Down Automata (PDA).
6	Tutorial-10 will be based on Turing Machine and REL.
7	Tutorial-11 and 12 will be based on Computability.

4.	**Books Recommended**
1	John E Hopcroft, Rajeev Motwani, Jeffrey D. Ullman, Introduction to Automata Theory Languages and Computation, 3rd Edition, Pearson Education India, 2011.
2	J. Martin, Introduction to Languages and the Theory of Computation, 3rd Edition, McGraw-Hill Education, 2007.
3	Peter Linz, An introduction to Formal Languages and Automata, 6th Edition, Jones & Bartlett, 2016.
4	Mishra and Chandrasekaran, Theory of Computer Science– Automata Languages and Computation, 3rd Edition, PHI, 2009.
5	K. V. N. Sunitha, N. Kalyani, Formal Languages and Automata Theory, 1st Edition, TMH, 2010.

ADDITIONAL REFERENCE BOOKS	
1	Michel Sipser, Introduction to Theory of Computation, 3rd Edition, Cengage India Private Limited, 2014
2	Bernard M. Moret, Theory of Computation, Ist Edition, Pearson Education, 2002.

B.Tech. IV (Mathematics and Computing), Semester – VII INNOVATION, INCUBATION AND ENTREPRENEURSHIP MG-110	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	explain the concepts of Entrepreneurship
CO2	develop skills related to various functional areas of management (Marketing Management, Financial Management, Operations Management, Personnel Management, etc.)
CO3	develop skills related to Project Planning and Business Plan development
CO4	demonstrate the concept of Innovation, Intellectual Property Rights (IPR) and Technology Business incubation
CO5	build knowledge about Sources of Information and Support for Entrepreneurship

2.	Syllabus	
	CONCEPTS OF ENTREPRENEURSHIP	**(10 Hours)**
	Scope of Entrepreneurship, Definitions of Entrepreneurship and Entrepreneur, Entrepreneurial Traits, Characteristics and Skills, Entrepreneurial Development models and Theories, Entrepreneurs Vs managers, Classification of Entrepreneurs; Major types of Entrepreneurship – Techno Entrepreneurship, Women Entrepreneurship, Social Entrepreneurship, Intrapreneurship (Corporate entrepreneurship), Rural Entrepreneurship, Family Business etc.; Problems for Small Scale Enterprises and Industrial Sickness; Entrepreneurial Environment – Political, Legal, Technological, Natural, Economic, Socio-cultural etc.	
	FUNCTIONAL MANAGEMENT AREA IN ENTREPRENEURSHIP	**(14 Hours)**
	Marketing Management: Basic concepts of Marketing, Development of Marketing Strategy and Marketing Plan **Operations Management:** Basic concepts of Operations Management, Location problem, Development of Operations strategy and plan **Personnel Management:** Main operative functions of a Personnel Manager, Development of H R strategy and plan **Financial Management:** Basics of Financial Management, Ratio Analysis, Investment Decisions, Capital Budgeting and Risk Analysis, Cash Flow Statement, Break Even Analysis	
	PROJECT PLANNING	**(08 Hours)**
	Search for Business Idea, Product Innovations, New Product Development – Stages in Product Development; Sequential stages of Project Formulation; Feasibility analysis – Technical, Market,	

	Economic, Financial, etc.; Project report; Project appraisal; Setting up an Industrial unit – procedure and formalities in setting up an Industrial unit; Business Plan Development	
	PROTECTION OF INNOVATION THROUGH IPR	**(02 Hours)**
	Introduction to Intellectual Property Rights – IPR, Patents, Trademarks, Copy Rights	
	INNOVATION AND INCUBATION	**(06 Hours)**
	Innovation and Entrepreneurship, Creativity, Green Technology Innovations, Grassroots Innovations, Issues and Challenges in Commercialization of Technology Innovations, Introduction to Technology Business Incubations, Process of Technology Business Incubation.	
	SOURCES OF INFORMATION AND SUPPORT FOR ENTREPRENEURSHIP	**(05 Hours)**
	State level Institutions, Central Level institutions, and other agencies	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial-1 and Tutorial-2 will be based on Concepts of Entrepreneurship.
2	Tutorial-3 and 4 will be based on Marketing Management and Operations Management.
3	Tutorial-5 and 6 will be based on Personnel Management and Financial Management.
4	Tutorial-7 and 8 will be based on Project Planning.
5	Tutorial-9 and 10 will be based on Innovation and Incubation.

4.	**Books Recommended**
1	V. Desai, Dynamics of Entrepreneurial Development and Management, Himalaya Publishing House, India, 6th Revised Edition, 2020
2	P. M. Charantimath, Entrepreneurial Development and Small Business Enterprises, Pearson Education, 3rd Edition, 2018
3	David H. Holt, Entrepreneurship: New Venture Creation, Pearson Education, 2016
4	P. Chandra, Projects: Planning, Analysis, Selection, Financing, Implementation and Review, Tata McGraw Hill, 9th Edition, 2019
5	T. R. Banga and S. C. Sharma, Industrial Organisation & Engineering Economics, Khanna Publishers, 25th Edition, 2015

B.Tech. IV (Mathematics and Computing), Semester – VII NEURAL NETWORK MA-467	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	learn different types of neural networks and different types of learning models.
CO2	determine the mathematical foundations of neural network models.
CO3	implement of neural networks using training algorithms such as the feed-forward, back-propagation algorithm.
CO4	design neural networks for practical purposes.
CO5	build neural networks for practical purposes.

2.	Syllabus	
	INTRODUCTION	**(13 Hours)**
	'Neurons' and their basic function- Math review- Mathematical Machinery and Review- How and Why Perceptrons Can Compute Logic Statements- Training Perceptrons Using Supervised Learning Techniques- Training Multi-layer	
	NEURAL NETWORKS USING SUPERVISED LEARNING TECHNIQUES	**(11 Hours)**
	Recurrent Neural Networks and Unsupervised Learning: Optimization Techniques-Implementation and Performance Considerations-Variations on the Hopfield Network-A Stochastic Version of the Hopfield Network	
	THE BOLTZMANN MACHINE-A STOCHASTIC VERSION OF THE BINARY ASSOCIATIVE MEMORY	**(08 Hours)**
	Restricted Boltzmann Machines-Competitive Learning and Self-Organizing Maps-Neural Network Modifications and Applications-Cellular Neural Networks and the Future of Massively Parallel Computation	
	INTRODUCTION TO MACHINE LEARNING TECHNIQUES	**(5 Hours)**
	Types of learning, hypothesis space and inductive bias, evaluation, cross-validation. Linear regression, Decision trees, overfitting. Support Vector Machine, Kernel function and Kernel SVM. Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural network.	
	Practicals will be based on the coverage of the above topics separately.	**(15 Hours)**
		(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)

3.	Practicals
1	Training Perceptrons Using Supervised Learning Techniques
2	Stochastic Version of the Hopfield Network
3	Exploring Restricted Boltzmann Machines and Competitive Learning, along with Self-Organizing Maps
4	Neural Network modifications and Cellular Neural Networks
5	Linear regression
6	Decision trees
7	Neural network: Perceptron, multilayer network, backpropagation
8	Deep neural network

4.	Books Recommended
1	Raul Rojas, Neural Networks - A Systematic Introduction, Springer-Verlag, Berlin, New - York,1996.
2	Christof Koch, Biophysics of Computation: Information Processing in Single Neurons, 1st Ed., Oxford University Press, 2004.
3	S. Rajasekaran and G. A and Vijayalakshmi Pai, Neural Networks, Fuzzy Logic, and Genetic Algorithms: Synthesis and Applications, 2nd Ed., PHI, 2003.
4	Satish Kumar, Neural Networks, A classroom approach, 2nd Ed., Mc Graw Hill 2018.
5	Kosko, Bart, Neural networks and fuzzy systems: a dynamical systems approach to machine intelligence, PHI India, 1994.

ADDITIONAL REFERENCE BOOKS	
1	Simon Haykin, Network N. A comprehensive foundation. Neural Networks, 2nd Ed., PHI, 1998.
2	Simon Haykin, Neural Networks & Learning Machines, 3rd Ed., Pearson Education India, 2016.
3	T.J. Ross, Fuzzy Logic with Engineering Applications, 3rd Ed, John Wiley & Sons, 2011.
4	N. K. Kasabov, Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering, MIT Press, 1996.
5	J. S. R. Jang, C. T. Sun and E. Mizutani Neuro-Fuzzy & Soft Computing, Ist Ed., Pearson, 2015.

M.Sc. V (Mathematics), Semester – IX ADVANCED NUMERICAL ANALYSIS AND COMPUTATION MA-480	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, the students will be able to
CO1	solve the initial value problems using multistep methods.
CO2	develop a finite difference scheme for ODEs and PDEs.
CO3	analyze the stability and convergence of difference schemes.
CO4	determine the solution for ODEs and PDEs using finite difference methods.
CO5	assess the suitability and effectiveness of finite difference schemes.

2.	Syllabus	
	REVIEW OF THE SYSTEM OF LINEAR EQUATIONS	**(05 Hours)**
	Condition number and ill-conditioned systems. Matrix and vector norms. Error bounds, tridiagonal and pentagonal system of equations.	
	INITIAL VALUE PROBLEMS IN ODES	**(08Hours)**
	Review single step methods, explicit multistep methods, implicit multistep methods, Predictor and corrector methods, Stability and convergence analysis.	
	FINITE DIFFERENCE METHODS FOR BVPS IN ODES	**(08 Hours)**
	Review on numerical approximation to derivatives, Approximation of boundary conditions of different kinds, Solution of linear and non-linear boundary value problems, and Convergence of difference schemes.	
	FINITE DIFFERENCE METHODS FOR HYPERBOLIC PDES	**(08 Hours)**
	Difference schemes in one space dimension with constant coefficient, Convergence, and consistency, Stability, The Lax-Richtmyer theorem, The CFL condition, Analysis of difference schemes: Fourier and Von Neumann analysis, Stability condition, Order of accuracy of difference schemes	
	FINITE DIFFERENCE METHODS FOR PARABOLIC PDES	**(08 Hours)**
	Explicit and implicit Difference schemes in one, two, and three space dimensions. Two level and multilevel schemes, Solution of convection-diffusion equation. Consistency, stability, and convergence of difference scheme.	

	FINITE DIFFERENCE METHODS FOR ELLIPTIC PDES	**(08 Hours)**
	Approximation to ∇^2 and ∇^4. Five-point and nine-point approximation for Laplace and Poisson equations, Dirichlet problem, ADI method, Neumann Problem, Mixed boundary value problems.	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours= 75 Hours)	

3.	**Practicals**
1	Compute and analyze the condition number of a given matrix.
2	Solve a tridiagonal system of linear equations using an appropriate algorithm.
3	Develop a method to solve pentagonal systems of linear equations.
4	Apply explicit multistep methods to solve ODEs and analyze their stability.
5	Analyze the stability and convergence of various ODE solvers.
6	Approximate derivatives using finite difference methods and validate the accuracy
7	Solve linear boundary value problems using finite difference methods.
8	Apply finite difference methods to solve nonlinear boundary value problems.
9	Implement a finite difference scheme for the 1D wave equation and analyze its stability using the CFL condition.
10	Solve a one-dimensional heat equation using an explicit difference scheme and investigate the stability and consistency.
11	Solve a parabolic PDE using an explicit difference scheme in two space dimensions.
12	Develop a five-point approximation scheme for the Laplace equation.
13	Develop a nine-point approximation scheme for solving the Poisson equation.

4.	**Books Recommended**
1	G. D. Smith, Numerical Solutions of Partial Differential Equations, 3rd Edition, Clarendon Press, Oxford, 1985.
2	M. K. Jain, Numerical Solution of Differential Equations, New Age Publication, New Delhi, 2018.
3	R. Mitchell and S. D. F. Griffiths, The Finite Difference Methods in Partial Differential Equations, Wiley and Sons, NY, 1980.
4	J. C. Strikwerda, Finite Difference Schemes for Partial Differential Equations, 2nd Edition, SIAM, 2007.
5	R. J. LeVeque, Finite Difference Methods for Ordinary and Partial Differential Equations: Steady State and Time-Dependent Problems, SIAM, 2007.

B.Tech. IV (Mathematics and Computing), Semester – VII FINITE ELEMENT METHODS AND COMPUTATIONS MA-471	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	understand the historical development and foundational principles of the Finite Element Method (FEM) and its advantages over other numerical methods.
CO2	apply variational methods and the weak form of PDEs to formulate and solve engineering problems using FEM.
CO3	develop and analyze finite element meshes, ensuring quality and refinement for accurate solutions.
CO4	utilize FEM to solve heat transfer problems and reaction-diffusion equations.
CO5	explore advanced topics such as applying FEM to solve fluid flow problems and understand the basics of optimization using FEM.

2.	Syllabus	
	INTRODUCTION	**(12 Hours)**
	Overview of numerical methods in engineering, Historical background and development of the Finite Element Method, Advantages of FEM over finite difference method	
	FINITE ELEMENT FORMULATION	**(10 Hours)**
	Review of weighted residual methods, Variational methods and calculus of variations, Weak form of partial differential equations (PDEs), Basic concepts of FEM: discretization, interpolation, and approximation, Shape functions and numerical integration	
	MESH GENERATION	**(07 Hours)**
	Introduction to mesh generation techniques, Structured and unstructured meshes, Quality measures and refinement strategies, Linear static analysis using FEM, Application to truss and frame structures, Introduction to dynamic analysis: eigenvalue problems	
	HEAT TRANSFER ANALYSIS	**(08 Hours)**
	Steady-state and transient heat conduction, Convection and radiation boundary conditions, Application of FEM to heat transfer problems and reaction-diffusion equations.	
	ADVANCED TOPICS	**(08 Hours)**
	Basics of fluid mechanics, Navier-Stokes equations and their weak form, Finite Element Method for fluid flow problems, Nonlinear finite element analysis, Introduction to optimization using FEM, Applications in other engineering disciplines	

	Practicals will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Practicals**
1	**Advantages of FEM over Finite Difference Method:** Solve a simple boundary value problem using both FEM and the finite difference method, and compare the accuracy and computational efficiency of the two methods.
2	**Variational Methods:** Apply variational methods to solve a boundary value problem.
3	**Weak Form of PDEs:** Convert a strong form PDE into its weak form and explain its importance in FEM.
4	**FEM Discretization**: Discretize a 1D domain into finite elements and set up the corresponding system of linear equations.
5	Interpolation and Shape Functions
6	**Introduction to Mesh Generation:** Generate a simple structured mesh for a 2D domain and explore how mesh quality affects the solution accuracy.
7	**Linear Static Analysis Using FEM:** Analyze a simple 2D truss structure using FEM and compare the results with hand calculations.
8	Dynamic Analysis: Eigenvalue Problems
9	**Steady-State Heat Conduction Using FEM:** Solve a 2D steady-state heat conduction problem using FEM and visualize the temperature distribution.
10	**Transient Heat Conduction:** Solve a transient heat conduction problem in a rod using FEM, and plot the temperature variation over time.
11	FEM for Fluid Flow Problems
12	Introduction to optimization using FEM

4.	**Books Recommended**
1	J. N. Reddy, An introduction to the Finite Element Method, 4th Edition, McGraw-Hill, 2018.
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, 2nd Edition Springer-Verlag, 2006.
5	Daryl L. Logan, A First Course in the Finite Element Method, 6th Edition, Cengage Learning India Private Limited, 2012

ADDITIONAL REFERENCE BOOKS	
1	T. J. R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publications, 2000.
2	George R. Buchanan, Schaum's Outline of Finite Element Analysis, 1st Edition, McGraw-Hill, 1994.

B.Tech. IV (Mathematics and Computing), Semester – VII THEORETICAL AND COMPUTATIONAL NEUROSCIENCE MA-482	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	understand the fundamental structures and processes of neurons, including membrane potentials, synapses, and neural activity.
CO2	apply and analyze point models of neurons, particularly the Hodgkin-Huxley Equations.
CO3	explore encoding and decoding techniques in neural systems.
CO4	examine the principles and types of plasticity in neural networks.
CO5	apply theoretical approaches to understand plasticity and explore current research topics in neuroscience.

2.	Syllabus	
	INTRODUCTION	**(07 Hours)**
	Neuron structure, Networks of Neurons and Synapses, System of neural processing, Basic structures in the brain, sensory-executive - Behavior systems, Membrane Potential and All or None Spike, Patch-Clamp Techniques, Membrane Potential, Ion Channels, Current Injection – Synapses, Single neuron activity.	
	POINT MODELS: HODGKIN HUXLEY EQUATIONS (HHE), ANALYSIS OF NEURAL MODELS	**(06 Hours)**
	Point and Compartmental Models of Neurons, Hodgkin Huxley Equations – I, Hodgkin Huxley Equations – II, Reducing the HHE and Moris-Lecar Equations (MLE), Properties of MLE, Phase Plane Analysis – I, Phase Plane Analysis – II, Analyzing HHE, Bifurcations, Other Point Models.	
	SPIKE TRAINS: ENCODING AND DECODING - I	**(06 Hours)**
	Random Variables and Random Processes, Spike Train Statistics and Response Measure, Receptive fields and Models of Receptive Fields, The Spike Triggered Average (Coding), Stimulus Reconstruction (Decoding).	
	SPIKE TRAINS: ENCODING AND DECODING - II	**(06 Hours)**
	Nonlinear approaches: Basics of Information Theory, Maximally Informative Dimensions, Discrimination-based approaches, Measuring Spike Train Distances, Statistical Methods in Discrimination.	
	SPIKE TRAINS: ENCODING AND DECODING - III	**(05 Hours)**

	Examples-I: Encoding/Decoding in Neural Systems, Examples-II: Encoding/Decoding in Neural Systems, Neural Population-Based Encoding/Decoding – I, Neural Population-Based Encoding/Decoding – II, Examples: Population-Based Encoding/Decoding.	
	PLASTICITY	**(05 Hours)**
	Synaptic Transmission and Synaptic Strength, Ways of Modification of Synaptic Strength, Types of Plasticity, Short Term Plasticity – I, Short Term Plasticity – II, Implications of Short-Term Plasticity, Long Term Plasticity – I, Long Term Plasticity – II, Modeling Long Term Plasticity, Computational Implications.	
	MODELING PHENOMENA WITH PLASTICITY	**(05 Hours)**
	Adaptation, Attention, Learning, and Memory – I, Learning and Memory – II, Developmental Changes, Conditioning and Reinforcement Learning, Reward Prediction (Error), Decision Problems, Learning and Memory – II, Developmental Changes.	
	THEORETICAL APPROACHES AND CURRENT RESEARCH	**(05 Hours)**
	Optimal Coding Principles – I, Optimal Coding Principles – II, Theoretical Approaches to Understanding Plasticity, Current Topics	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
		(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)

3.	**Tutorials**
1	Tutorial-1 and Tutorial-2 will be based on Introduction to Neurons.
2	Tutorial-3 and 4 will be based on Point models: Hodgkin Huxley Equations (HHE), Analysis of Neural Models.
3	Tutorial-5, 6 and 7 will be based on Spike Trains: Encoding and Decoding.
4	Tutorial-8 and 9 will be based on Plasticity.
5	Tutorial-10 and 11 will be based on Modeling Phenomena with Plasticity.
6	Tutorial-12 will be based on Theoretical Approaches and Current Research.

4.	**Books Recommended**
1	P. Dayan and L. F. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, The MIT Press, 2005.
2	E. Kandel and J. Schwartz, Principles of Neural Science, 5th Edition, McGraw-Hill, 2012.
3	G. Bard Ermentrout and David H. Terman, Mathematical Foundations of Neuroscience, Springer, 2010.
4	Fabrizio Gabbiani and Steven James Cox, Mathematics for Neuroscientists, Academic Press, 2010.

5	Christof Koch and Idan Segev (Eds), Methods in Neuronal Modeling: From Ions to Networks, second edition, The MIT Press, 1998.

ADDITIONAL REFERENCE BOOKS	
1	P. Wallisch et al., Matlab for neuroscientists: An introduction to scientific computing in Matlab, Academic Press, 2008. *An introduction to algorithms and computational methods that are useful in neuroscience. Useful if you don't have much programming experience.*
2	F. Rieke, D. Warland, R. de Ruyter van Steveninck, and W. Bialek, Spikes: Exploring the Neural Code, MIT Press, 1997. *A useful reference on the neural code and information-theoretic methods.*
3	Gilbert Strang, Introduction to Linear Algebra, 4th Edition, Wellesley-Cambridge Press, 2009.

B.Tech. MaC - IV, Semester – IX EVOLUTIONARY ALGORITHMS MA 455	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	understand the essential principles of evolutionary computation.
CO2	apply genetic algorithms to solve optimization problems.
CO3	utilize various evolutionary computation techniques for complex problems.
CO4	develop constraint handling techniques within evolutionary algorithms.
CO5	implement and analyze multi-objective evolutionary algorithms (MOEAs).

2.	Syllabus	
	INTRODUCTION AND PRINCIPLES OF EVOLUTIONARY COMPUTATION (EC)	**(05 Hours)**
	Introduction to Optimization, Generalized Formulation, Scope of Optimization via Applications, Characteristic of Optimization Functions Principles of EC: Natural Evolutional and Genetics, Generalized Framework, Behaviour and Typical run of EC, Advantages and Limitations.	
	BINARY-CODED GENETIC ALGORITHM (BGA)	**(06 Hours)**
	Introduction, Binary Representation and Decoding, Working Principle of binary coded GA (BGA), BGA on Generalized Framework, Operators, Hand Calculations, Graphical Examples.	
	REAL-CODED GENETIC ALGORITHM (RGA)	**(06 Hours)**
	Concepts and Need of Real-Coded GA (RGA), Algorithm, RGA on Generalized Framework, Operators, Hand Calculations, Graphical Examples, Case studies.	
	OTHER EC TECHNIQUES	**(07 Hours)**
	Differential Evolution (DE): Introduction, Concepts, Operators, Algorithm, DE on Generalized Framework, Graphical Examples, Case studies; Particle Swarm Optimization (PSO): Introduction, Concepts, Operators, PSO on Generalized Framework, Graphical Examples, Case studies.	
	CONSTRAINT HANDLING TECHNIQUES	**(05 Hours)**
	Generalized Constraint Formulation, Karush Kuhn Tucker (KKT) conditions, Penalty Function Method, Parameter-Less Deb's Method, Hand Calculations, Graphical Examples, Case studies.	
	INTRODUCTION TO MULTI-OBJECTIVE OPTIMIZATION	**(06 Hours)**

	Introduction, Generalized Formulation, Concept of Dominance and Pareto-optimality, Graphical Examples, Terminologies, Difference with Single-objective optimization, Approaches to multi-objective optimization.	
	CLASSICAL MULTI-OBJECTIVE OPTIMIZATION METHODS	**(05 Hours)**
	Weighted- Sum Method, ε-Constraint Method, Weighted Metric Methods, Hand Calculations, Difficulties with Classical approaches, Ideal Multi- Objective Optimization Approach.	
	MULTI-OBJECTIVE EVOLUTIONARY ALGORITHMS (MOEAS)	**(05 Hours)**
	Introduction, MOEAs on generalized Framework, Algorithms: NSGA-II, SPEA2, Graphical Examples, Case Studies; Hypervolume Indicator (HV) for Performance Assessment.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial will be based on components of evolutionary algorithms
2	Tutorial will be based on the working principle of binary-coded genetic algorithms
3	Tutorial will be based on problems of binary-coded genetic algorithms
4	Tutorial will be based on operators in real-coded genetic algorithms
5	Tutorial will be based on differential evolutions
6	Tutorial will be based on particle swarm optimization
7	Tutorial will be based on generalized constraint formulation, Karush Kuhn Tucker (KKT) conditions
8	Tutorial will be based on penalty function method, parameter-less Deb's method
9	Tutorial will be based on multi-objective optimization
10	Tutorial will be based on classical methods of multi-objective optimization
11	Tutorial will be based on NSGA II, SPEA2.

4.	**Books Recommended**
1	D. E. Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning," Pearson, New York, 1st Ed., 2022
2	K. Deb, "Multi-Objective Optimization Using Evolutionary Algorithms," Wiley, Chichester, 2nd Ed., 2022.
3	K. A. De Jong, "Evolutionary Computation: A Unified Approach," MIT Press, Cambridge, 2nd Ed., 2023.

4	A. E. Eiben and J. E. Smith, "Introduction to Evolutionary Computing," Springer, Berlin, 2nd Ed., 2015.
5	H.-G. Beyer, "The Theory of Evolution Strategies," Springer, Berlin, 1st Ed., 2001.

B.Tech. MaC - IV, Semester – IX COMPUTATIONAL FLUID DYNAMICS MA 457	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	apply fluid dynamics principles and governing equations.
CO2	discretize and solve PDEs for fluid flow.
CO3	implement discretization methods: finite difference, volume, and element.
CO4	use turbulence models and solution algorithms in CFD.
CO5	conduct and analyse CFD simulations using software tools.

2.	Syllabus	
	INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS	**(05 Hours)**
	Computational Fluid Dynamics: What, When, and Why? CFD Applications, Numerical vs Analytical vs Experimental, Modelling vs Experimentation, Fundamental principles of conservation, Reynold's transport theorem, Conservation of mass, Conservation of linear momentum: Navier-Stokes equation, Conservation of Energy.	
	FUNDAMENTALS OF DISCRETIZATION	**(08 Hours)**
	Discretization principles, Finite Element Method, Finite difference method, well posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Finite volume method (FVM), illustrative examples: 1-D steady state heat conduction without and with constant source term.	
	FINITE VOLUME METHOD	**(08 Hours)**
	Fundamental Concepts and Illustrations Using 1-D Steady-State Diffusion Problems: Physical consistency, Overall balance, FV Discretization of a 1-D steady state diffusion type problem, Composite material with position dependent thermal conductivity, Four basic rules for FV Discretization of 1-D steady state diffusion type problem, Source term linearization, Implementation of boundary conditions.	
	DISCRETIZATION OF CONVECTION-DIFFUSION EQUATIONS: A FINITE VOLUME APPROACH	**(08 Hours)**
	Central difference scheme, Upwind scheme, Exponential scheme and Hybrid scheme, Power law scheme, Generalized convection-diffusion formulation, Finite volume discretization of two-dimensional convection-diffusion problem, The concept of false diffusion, QUICK scheme.	
	MESH GENERATION	**(04 Hours)**
	Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation.	

	DISCRETIZATION OF NAVIER STOKES EQUATIONS	**(07 Hours)**
	Stream Function-Vorticity approach and Primitive variable approach, Staggered grid and Collocated grid, SIMPLE Algorithm, SIMPLER Algorithm, Discretization using unstructured grid.	
	TURBULENCE MODELLING AND ADVANCED TOPICS	**(05 Hours)**
	Important features of turbulent flow, Vorticity transport equation, Statistical representation of turbulent flows: Homogeneous turbulence and isotropic turbulence, General Properties of turbulent quantities, Reynolds average Navier stokes (RANS) equation, k-ε and k-ω models.	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Practical**
1	Practical based on finite difference method
2	Practical based on finite element method
3	Practical based on finite volume method I
4	Practical based on finite volume method II
5	Practical based on discretization of convection-diffusion equations I
6	Practical based on discretization of convection-diffusion equations II
7	Practical based on mesh generation
8	Practical based on SIMPLE algorithm
9	Practical based on SIMPLER algorithm
10	Practical based on discretization of NS equation using unstructured grid
11	Practical based on RANS equation
12	Practical based on k-ε model
13	Practical based on k-ω model

4.	**Books Recommended**
1	J. H. Ferziger, M. Peric, and R. L. Street, "Computational Fluid Dynamics: A Practical Approach," Elsevier, 3rd Ed., 2022.
2	S. V. Patankar, "Numerical Heat Transfer and Fluid Flow," CRC Press, 1st Ed., 2021.

3	H. K. Versteeg and W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The Finite Volume Method," Pearson, 3rd Ed., 2023.
4	M. A. Griebel, T. Dornseifer, and T. Neumayer, "Numerical Simulation in Fluid Dynamics: A Practical Introduction," SIAM, 2nd Ed., 2021.
5	C. A. J. Fletcher, "Computational Techniques for Fluid Dynamics," Springer, 2nd Ed., 2022.

B.Tech. MaC - IV, Semester – IX DATA ANALYTICS MA 453	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	understand and apply key data analysis techniques, including statistical modelling and Bonferroni's Principle.
CO2	utilize MapReduce and Spark for large-scale data processing.
CO3	implement PCA and SVD for dimensionality reduction.
CO4	apply algorithms for similarity search and data stream mining.
CO5	analyse social-network graphs and develop neural network models for machine learning.

2.	Syllabus	
	INTRODUCTION TO DATA ANALYSIS	**(05 Hours)**
	Basic concepts of statistical modelling, Regression analysis (linear and logistic), Model evaluation and selection, Overview of information awareness concepts, Privacy and ethical considerations in data analysis, Bonferroni's Principle: Understanding the principle of multiple comparisons, Application of Bonferroni correction in statistical analysis.	
	DISTRIBUTED FILE SYSTEMS	**(08 Hours)**
	Principles and architecture of MapReduce, Implementation of MapReduce for large-scale data processing, Case studies and practical examples, Introduction to Spark and its components, Spark RDDs (Resilient Distributed Datasets), Data processing with Spark SQL and DataFrames, Performance optimization techniques.	
	DIMENSIONALITY REDUCTION	**(07 Hours)**
	Theory and mathematics of PCA, Applications of PCA in data visualization and noise reduction, Understanding SVD and its relationship with PCA, Applications of SVD in data compression and latent semantic analysis.	
	FINDING SIMILAR ITEMS	**(06 Hours)**
	Common distance measures (Euclidean, Manhattan, cosine similarity), Applications in clustering and classification, Techniques for finding nearest neighbors, KD-trees, Ball-trees, and Approximate Nearest Neighbor (ANN) methods.	
	MINING DATA STREAMS	**(06 Hours)**
	Concepts of Data Stream Mining, Characteristics of data streams, Algorithms for data stream processing (e.g., Count-Min Sketch, Sliding Window), Real-time data analytics, Handling high-velocity data streams.	

	LINK ANALYSIS AND SOCIAL-NETWORK MINING	**(07 Hours)**
	Centrality measures (degree, closeness, betweenness, eigenvector), Applications in network analysis, Graph clustering algorithms, Community detection methods, Techniques for partitioning graphs, Methods for detecting overlapping communities.	
	APPLICATIONS OF LARGE-SCALE MACHINE LEARNING	**(06 Hours)**
	Basics of Multi-Layer Perceptron and neural network architecture, Training and evaluation of MLP models, Recurrent Neural Networks (RNN), Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM).	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Practical**
1	Practical based on basic statistical modelling
2	Practical based on data analysis tools
3	Practical based on MapReduce framework
4	Practical based on large datasets using Apache Spark
5	Practical based on dimensionality reduction techniques to high-dimensional data
6	Practical based on similarity measures and perform near neighbour search
7	Practical based on data streams
8	Practical based on social network graphs and detect communities
9	Practical based on large-scale machine learning models
10	Project on Data Analytics

4.	**Books Recommended**
1	J. Han, M. Kamber, and J. Pei, "Data Mining: Concepts and Techniques," Morgan Kaufmann, 4th Ed., 2023.
2	A. W. Moore and W. S. Cooley, "Data Stream Mining: A Review," Wiley, 2nd Ed., 2022.
3	T. M. Mitchell, "Machine Learning," McGraw-Hill Education, 3rd Ed., 2022.
4	I. Goodfellow, Y. Bengio, and A. Courville, "Deep Learning," MIT Press, 1st Ed., 2021.
5	H. Korth, "Distributed Systems for Data Mining," Springer, 1st Ed., 2022.

B.Tech. MaC - IV, Semester – IX HYBRID ALGOTHIMS MA 476	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	develop and implement hybrid algorithms by integrating multiple algorithmic paradigms
CO2	evaluate and optimize the computational efficiency of hybrid algorithms
CO3	apply hybrid algorithms in the areas like machine learning and optimization
CO4	conduct performance analysis and benchmarking of hybrid algorithms
CO5	develop and apply hybrid algorithms in the context of big data analytics

2.	Syllabus	
	INTRODUCTION TO HYBRID ALGORITHMS	**(09 Hours)**
	Overview of Algorithmic Paradigms: Heuristic, Metaheuristic, and Exact Algorithms; Definition and Motivation for Hybrid Algorithms; Case Studies of Successful Hybrid Algorithms; Review of Exact Algorithms: Backtracking, Branch and Bound, Dynamic Programming; Review of Heuristic and Metaheuristic Algorithms: Greedy Algorithms, Simulated Annealing, Genetic Algorithms, Tabu Search.	
	DESIGN PRINCIPLES OF HYBRID ALGORITHMS	**(06 Hours)**
	Why Hybridize? The Need for Combining Algorithms; Frameworks for Hybrid Algorithms; Design Considerations and Challenges; Hybridization Strategies: Sequential, Parallel, Hierarchical.	
	HYBRID GENETIC ALGORITHMS AND PARTICLE SWARM OPTIMIZATION	**(09 Hours)**
	Memetic Algorithms: Combining Genetic Algorithms with Local Search; Real-world Applications of Hybrid Genetic Algorithms; Integration of Particle Swarm Optimization with Local Search Techniques; Applications in Continuous and Discrete Optimization; Case Studies and Performance Analysis.	
	HYBRID ANT COLONY OPTIMIZATION AND SIMULATED ANNEALING	**(09 Hours)**
	Enhancing Ant Colony Optimization with Heuristics; Real-world Applications: Routing, Scheduling, and Assignment Problems; Combining Simulated Annealing with Other Metaheuristics; Applications in Nonlinear and Combinatorial Optimization; Case Studies and Performance Analysis.	
	HYBRID ALGORITHMS IN MACHINE LEARNING & MULTI-OBJECTIVE OPTIMIZATION	**(06 Hours)**
	Hybrid Approaches in Neural Networks; Combining Support Vector Machines with Hybrid Optimization Techniques; Multi-objective Optimization Concepts; Pareto Optimality and Hybrid Approaches; Case Studies in Real-world Multi-objective Problems.	

	ADVANCED TOPICS IN HYBRID ALGORITHMS AND REAL-WORLD APPLICATIONS	**(06 Hours)**
	Hybrid Algorithms in Real-time and Embedded Systems; Trade-offs between Performance, Accuracy, and Resource Utilization; Hybrid Quantum Algorithms; Hybrid Algorithms in Big Data Analytics; Parallel and Distributed Hybrid Algorithms.	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Practical**
1	Practical based on heuristic and metaheuristic algorithms on an optimization problem
2	Practical based on an exact algorithm (e.g., Branch and Bound)
3	Practical based on designing a hybrid algorithm combining dynamic programming
4	Practical based on implementing a Memetic Algorithm for a complex optimization problem
5	Practical based on developing a Hybrid Particle Swarm Optimization algorithm
6	Practical based on implementing a Hybrid Ant Colony Optimization algorithm
7	Practical based on implementing a Hybrid Simulated Annealing algorithm
8	Practical based on implementing a hybrid algorithm for feature selection in a machine learning model
9	Practical based on developing a Hybrid Algorithm for a multi-objective optimization problem
10	Practical based on implementing a Hybrid Algorithm for task scheduling in a real-time system
11	Practical based on implementing Hybrid Algorithm in a big data context

4.	**Books Recommended**
1	E. Talbi, "Metaheuristics: From Design to Implementation," John Wiley & Sons, 1st Ed., 2009.
2	C. Blum and A. Roli, "Hybrid Metaheuristics: An Emerging Approach to Optimization," Springer, 1st Ed., 2008.
3	J. Kennedy and R. Eberhart, "Swarm Intelligence," Morgan Kaufmann, 1st Ed., 2001.
4	D. Simon, "Evolutionary Optimization Algorithms: Biologically-Inspired and Population-Based Approaches to Computer Intelligence," John Wiley & Sons, 1st Ed., 2013.
5	M. Preuss, "Multimodal Optimization by Means of Evolutionary Algorithms," Springer, 1st Ed., 2015.

B.Tech. MaC - IV, Semester – IX STOCHASTIC FINANCE MA 483	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	implement models using stochastic processes for financial markets.
CO2	utilize stochastic calculus techniques to solve financial problems and price derivatives.
CO3	compute the pricing of various financial derivatives using advanced models.
CO4	develop and apply risk management strategies using stochastic models and tools.
CO5	apply advanced stochastic methods to address complex financial scenarios.

2.	Syllabus	
	INTRODUCTION TO STOCHASTIC PROCESSES	**(08 Hours)**
	Basic Concepts: Random Variables, Expectation, Variance; Introduction to Stochastic Processes: Definitions and Classifications; Markov Chains and Processes; Brownian Motion: Properties and Applications in Finance; Stochastic Differential Equations (SDEs).	
	STOCHASTIC CALCULUS AND ITO'S LEMMA	**(09 Hours)**
	Introduction to Stochastic Calculus; Ito's Integral and its Properties; Ito's Lemma: Derivation and Applications; Applications of Ito's Lemma in Finance: Stock Price Dynamics; Geometric Brownian Motion (GBM) and the Black-Scholes Model.	
	FINANCIAL DERIVATIVES AND PRICING MODELS	**(08 Hours)**
	Introduction to Financial Derivatives: Options, Futures, and Swaps; Risk-neutral Valuation; Pricing European and American Options; Binomial Option Pricing Model; Monte Carlo Simulation for Option Pricing.	
	INTEREST RATE MODELS AND BONDS	**(06 Hours)**
	Introduction to Interest Rate Models; The Vasicek Model and CIR Model; Modeling the Term Structure of Interest Rates; Bond Pricing and Duration; Pricing of Interest Rate Derivatives	
	RISK MANAGEMENT AND HEDGING STRATEGIES	**(07 Hours)**
	Introduction to Financial Risk Management; Hedging Strategies using Derivatives; Value at Risk (VaR) and Expected Shortfall; Portfolio Optimization under Uncertainty; Applications of Stochastic Models in Risk Management.	

	STOCHASTIC MODELS IN FINANCIAL APPLICATIONS	**(07 Hours)**
	Jump Diffusion Models and Applications; Stochastic Control in Finance; Credit Risk Models: Structural and Reduced-form Approaches; Introduction to Stochastic Volatility Models; Emerging Trends and Research Directions in Stochastic Finance	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial will be based on understanding and solving problems related to basic stochastic processes
2	Tutorial will be based on the formulation and solution of simple stochastic differential equations
3	Tutorial will be based on solving problems using Ito's Lemma
4	Tutorial will be based on the derivation and application of the Black-Scholes equation
5	Tutorial will be based on solving problems related to the pricing of European and American options
6	Tutorial will be based on implementing Monte Carlo simulations
7	Tutorial will be based on applying interest rate models
8	Tutorial will be based on solving problems related to the term structure of interest rates
9	Tutorial will be based on solving problems related to the pricing interest rate derivatives
10	Tutorial will be based on designing hedging strategies
11	Tutorial will be based on calculating and interpreting Value at Risk (VaR) and Expected Shortfall
12	Tutorial will be based on jump diffusion models in pricing financial instruments
13	Tutorial will be based on analyzing stochastic volatility models

4.	**Books Recommended**
1	S. E. Shreve, "Stochastic Calculus for Finance I: The Binomial Asset Pricing Model," Springer, 1st Ed., 2004.
2	J. Hull, "Options, Futures, and Other Derivatives," Pearson, 10th Ed., 2017.
3	D. Lamberton and B. Lapeyre, "Introduction to Stochastic Calculus Applied to Finance," Chapman & Hall/CRC, 2nd Ed., 2007.
4	T. Björk, *"Arbitrage Theory in Continuous Time,"* Oxford University Press, 3rd Ed., 2009.
5	M. A. H. Dempster and M. J. K. Thomas, "Stochastic Calculus for Finance II: Continuous-Time Models," Springer, 2nd Ed., 2023.

B.Tech. MaC - IV, Semester – IX FOUNDATIONS OF ROBOTICS MA 466/CS/AI4XX	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	describe various types of robots and their applications.
CO2	solve forward and inverse kinematics problems for robotic arms.
CO3	analyze forces and torques in robotic systems.
CO4	implement PID and adaptive control strategies for robots.
CO5	utilize sensors and actuators in robotic applications.

2.	Syllabus	
	INTRODUCTION	**(08 Hours)**
	Basic concepts, history, and evolution of robotics; Types of robots and their applications; Robot classifications, structure, and components; Robotic systems and their integration.	
	ROBOT KINEMATICS	**(09 Hours)**
	Kinematic modeling of robots; Forward and inverse kinematics; Denavit-Hartenberg (DH) parameters; Kinematic chains.	
	ROBOT DYNAMICS	**(08 Hours)**
	Dynamics of robotic systems; Newton-Euler and Lagrangian methods; Dynamic modeling of manipulators; Motion control.	
	ROBOT CONTROL SYSTEMS	**(08 Hours)**
	Control systems in robotics: feedback and feedforward control; PID control; Trajectory planning; Adaptive control.	
	ROBOTIC SENSORS AND ACTUATORS	**(08 Hours)**
	Types and principles of sensors and actuators; Integration into robotic systems; Sensors for vision, proximity, and force measurement; Actuators and their control.	
	ROBOTICS PROGRAMMING AND SIMULATION	**(04 Hours)**
	Programming and simulation tools for robotics; Using simulation software to model robotic systems; Basic programming concepts for robotic control	

	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial will be based on identifying different types of robots and their components
2	Tutorial will be based on analyzing the structure and classification of robots
3	Tutorial will be based on solving problems related to forward and inverse kinematics
4	Tutorial will be based on practical exercises involving kinematic chains
5	Tutorial will be based on determining the end-effector position for different robotic configurations
6	Tutorial will be based on Newton-Euler and Lagrangian methods
7	Tutorial will be based on solving dynamic modeling problems
8	Tutorial will be based on designing and implementing PID controllers
9	Tutorial will be based on developing and testing trajectory planning algorithms
10	Tutorial will be based on the operation of different sensors and actuators
11	Tutorial will be based on using simulation software to model robotic systems
12	Tutorial will be based on writing simple programs to control robotic systems

4.	**Books Recommended**
1	R. C. Dubois and A. D. H. DeWit, "Introduction to Robotics: Mechanics and Control," Pearson, 3rd Ed., 2021.
2	J. J. Craig, "Introduction to Robotics: Mechanics and Control," Pearson, 4th Ed., 2018.
3	M. Erdmann and M. T. Mason, "Introduction to Robotics: Analysis, Control, Applications," MIT Press, 2018.
4	S. M. LaValle, "Planning Algorithms," Cambridge University Press, 2006.
5	**H. K. Khalil and J. K. Lemmon**, *"Nonlinear Systems,"* Prentice Hall, 3rd Ed., 2014.

B.Tech. MaC - IV, Semester – IX FINANCIAL INSTRUMENTS AND RISK MANAGEMENT MA 477	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	evaluate characteristics and valuation methods of various financial instruments.
CO2	implement strategies for managing market, credit, and operational risks.
CO3	compute Value at Risk (VaR) and other risk measures.
CO4	use derivatives effectively for risk management and hedging strategies.
CO5	evaluate and apply software tools for financial risk management.

2.	Syllabus	
	INTRODUCTION TO FINANCIAL INSTRUMENTS	**(08 Hours)**
	Overview of financial markets and instruments; Types of financial instruments: equities, bonds, derivatives, and alternative investments; Characteristics and valuation of financial instruments; Market dynamics and trading mechanisms.	
	FIXED INCOME SECURITIES	**(08 Hours)**
	Understanding bonds and interest rates; Bond pricing and yield calculations; Duration and convexity: concepts and applications; Risk factors affecting fixed income securities.	
	DERIVATIVES AND THEIR VALUATION	**(08 Hours)**
	Introduction to derivatives: forwards, futures, options, and swaps; Valuation of derivatives: Black-Scholes model, Binomial model; Hedging strategies and their applications; Risk management using derivatives	
	RISK MANAGEMENT PRINCIPLES	**(09 Hours)**
	Fundamentals of risk management; Types of financial risks: market risk, credit risk, operational risk, liquidity risk; Risk assessment and measurement techniques; Risk management frameworks and regulatory considerations.	
	QUANTITATIVE RISK MANAGEMENT TECHNIQUES	**(07 Hours)**
	Value at Risk (VaR): concepts, methods, and applications; Stress testing and scenario analysis; Risk-adjusted performance measures; Introduction to risk management software and tools.	
	ADVANCED TOPICS IN RISK MANAGEMENT	**(05 Hours)**
	Emerging trends in risk management; Advanced risk modelling techniques; Application of machine learning and AI in risk management; Future challenges and opportunities in financial risk management	

	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial will be based on financial instruments and their valuation methods.
2	Tutorial will be based on analyzing market dynamics and trading mechanisms
3	Tutorial will be based on bond prices, yields, duration, and convexity
4	Tutorial will be based on analyzing risk factors
5	Tutorial will be based on valuing derivatives using different models
6	Tutorial will be based on hedging strategies for risk management
7	Tutorial will be based on different types of financial risks
8	Tutorial will be based on risk management frameworks and regulatory considerations to case studies
9	Tutorial will be based on calculating Value at Risk (VaR)
10	Tutorial will be based on risk-adjusted performance measures
11	Tutorial will be based on exploring advanced risk modeling techniques
12	Tutorial will be based on application of machine learning and AI in risk management

4.	**Books Recommended**
1	J. C. Hull, "Risk Management and Financial Institutions," Wiley, 5th Ed., 2018.
2	S. R. Glantz, "The Volatility of Financial Markets: A Handbook of Quantitative Risk Management," Wiley, 2018.
3	M. A. H. Dempster, "Quantitative Risk Management: Theory and Practice," Cambridge University Press, 2017.
4	P. Jorion, "Value at Risk: The New Benchmark for Managing Financial Risk," McGraw-Hill, 3rd Ed., 2007.
5	**S. R. Glantz, "The Volatility of Financial Markets: A Handbook of Quantitative Risk Management," Wiley, 2018.**

B.Tech. MaC - IV, Semester – IX COMPUTATIONAL HEAT AND MASS TRANSFER MA 484	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	understand principles of heat and mass transfer, including phase change.
CO2	apply numerical methods to solve heat and mass transfer problems.
CO3	develop skills for simulating heat and mass transfer systems computationally.
CO4	analyze and solve complex engineering problems using computational techniques.
CO5	implement advanced methods like adaptive mesh refinement and phase change modeling

2.	Syllabus	
	INTRODUCTION TO HEAT AND MASS TRANSFER	**(07 Hours)**
	Basics of heat transfer: Conduction, convection, and radiation, Mass transfer fundamentals: Diffusion and convective mass transfer, Governing equations: Heat diffusion equation, convective-diffusion equation, Introduction to computational methods for solving heat and mass transfer problems, Relevance and applications in industry and engineering	
	NUMERICAL METHODS FOR HEAT TRANSFER	**(08 Hours)**
	Finite difference methods (FDM) for heat conduction, Explicit, implicit, and Crank-Nicolson schemes Stability analysis: CFL conditions, Numerical solutions for transient 1D and 2D heat conduction, Discretization errors and mesh generation	
	COMPUTATIONAL METHODS FOR CONVECTIVE HEAT TRANSFER	**(08 Hours)**
	Introduction to convective heat transfer, Finite volume methods (FVM) for convective heat transfer problems, Boundary layer equations and solution techniques, Numerical solution of forced and natural convection problems, Turbulent flow models and computational considerations	
	COMPUTATIONAL MASS TRANSFER	**(07 Hours)**
	Governing equations for mass transfer: Diffusion and convection, Numerical methods for solving diffusion and convection-diffusion equations, Modeling mass transfer in porous media, Mass transfer in multi-component systems, Applications in chemical and environmental engineering	
	HEAT AND MASS TRANSFER WITH PHASE CHANGE	**(07 Hours)**
	Introduction to phase change processes: Melting, freezing, and evaporation, Governing equations for phase change problems, Numerical techniques for solidification and melting problems, Stefan problem and its computational solution, Applications in materials processing and energy systems	

	ADVANCED TOPICS AND APPLICATIONS	**(08 Hours)**
	Advanced numerical techniques: Adaptive mesh refinement, multigrid methods, Heat and mass transfer in porous media, Applications in energy systems: Heat exchangers, thermal insulation, and renewable energy systems, Introduction to commercial computational tools: ANSYS, Fluent, COMSOL Multiphysics	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Tutorials**
1	Practical based on simulating steady-state 1D heat conduction using finite difference methods
2	Practical based on transient 1D heat conduction using explicit finite difference methods
3	Practical based on implicit and Crank-Nicolson methods for transient 1D heat conduction
4	Practical based on 2D steady-state heat conduction in a rectangular plate using finite difference methods
5	Practical based on solving transient 2D heat conduction using the finite difference method
6	Practical based on convective heat transfer in a 2D duct using finite volume methods
7	Practical based on solving natural convection problems using finite volume methods
8	Practical based on mass diffusion in a 2D domain using finite difference methods
9	Practical based on solving 2D convection-diffusion problems using finite difference methods
10	Practical based on simulating phase change (melting/solidification) using the enthalpy method
11	Practical based on solving heat transfer in porous media using finite volume methods
12	Practical based on adaptive mesh refinement (AMR) techniques for heat conduction problems

4.	**Books Recommended**
1	F. P. Incropera and D. P. DeWitt, "Introduction to Heat Transfer," Wiley, 6th Ed., 2011.
2	C. K. Dixit and U. C. Mohanty, "Computational Fluid Dynamics and Heat Transfer: A Practical Approach," Springer, 1st Ed., 2021.
3	A. J. Ghajar and S. Kakac, "Heat and Mass Transfer: Fundamentals and Applications," CRC Press, 6th Ed., 2020.
4	Y. Jaluria, "Computational Heat Transfer," CRC Press, 2nd Ed., 2017.
5	**F. P. Incropera and D. P. DeWitt, "Introduction to Heat Transfer," Wiley, 6th Ed., 2011.**

B.Tech. MaC - IV, Semester – IX COMPUTATIONAL FLUID DYNAMICS IN POROUS MEDIA MA 479	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	understand porous media properties and their impact on fluid flow.
CO2	apply Darcy's Law to analyze flow in porous materials.
CO3	analyze capillary pressure, wettability, and saturation in porous media.
CO4	evaluate groundwater resources and aquifer properties in various formations.
CO5	apply continuity equations to model confined and unconfined groundwater flow.

2.	Syllabus	
	INTRODUCTION TO POROUS MEDIA	**(04 Hours)**
	Definition and general aspects of porosity, Determination and classification of porosity, Compressibility of porous media, Capillary properties: saturation and wettability	
	MEASUREMENT AND CHARACTERIZATION OF POROUS MEDIA	**(07 Hours)**
	Classification of reservoir rocks based on wettability, Measurement of wettability, Contact angle measurement, Amott method, Capillary pressure, Definition, Measurement of capillary pressure in a porous medium, Method of centrifuge, Mercury injection (Purcell method), The Leverett function, Pore size distribution, Vertical equilibrium	
	PERMEABILITY AND DARCY'S LAW	**(07 Hours)**
	Permeability, Darcy's law, Definition and units of permeability, Measurements of permeability, Klinkenberg effect, Analogies between the laws of Darcy, Ohm and Fourier, Filtration velocity, Quadratic equation of filtration, Relative permeabilities, Definition of relative permeability, Definitions of end-point saturations, Relative permeability measurements, The HASSLER method, PENN-STATE-method, Welge-method, Saturation distribution and relative permeability	
	INTRODUCTION TO GROUND WATER	**(07 Hours)**
	Introduction, Types of springs, Infiltration gallery, Karsez, distribution of water on earth, Groundwater resources of India, Geological formations, Properties of aquifers: void ratio, Specific retention, Specific yield, Methods of determining specific yield, Pumping method, The porosity, Specific yield and specific retention of different formations	
	PERMEABILITY AND HYDRAULIC CONDUCTIVITY IN SOIL FORMATION	**(09 Hours)**

	Permeability and hydraulic conductivity, Hydraulic conductivity or permeability coefficient, The effect of porosity, Pore space geometry, Submergence, Tortuosity of soil pores, Entrapped air, Measurement of hydraulic conductivity, Constant head method, Variable head method, Field methods, Below the water table field methods, Above the water field method, Intrinsic permeability, Apparent specific yield, Coefficient of storage, Specific storage, Hydraulic resistance, Leakage factor, Distribution of subsurface water, Zone of aeration, Soil water zone, Intermediate zone, Capillary fringe, Important features of the capillary fringe zone, Zone of saturation, Soil moisture, Groundwater flow potential, Measurement of groundwater, Conjunctive use of groundwater.	
	CONTINUITY EQUATIONS FOR GROUNDWATER FLOW	**(11 Hours)**
	Introduction, Three-dimensional continuity equation for groundwater flow, Continuity equation for homogeneous and isotropic formation (Medium), Confined and unconfined aquifer, General continuity equation in Cartesian coordinates, General continuity equation in polar coordinates, Continuity equation for confined aquifer with leakage from top and bottom, Dupuit-Forchheimer theory for unconfined aquifer with recharge, Flow through an unconfined aquifer.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorial will be based on defining porosity, calculating it from material samples, and discussing its types.
2	Tutorial will be based on capillary properties.
3	Tutorial will be based on wettability measurement techniques.
4	Tutorial will be based on capillary pressure and measurement
5	Tutorial will be based on darcy's law and permeability
6	Tutorial will be based on relative permeability
7	Tutorial will be based on groundwater resources
8	Tutorial will be based on hydraulic conductivity
9	Tutorial will be based on subsurface water zones
10	Tutorial will be based on the continuity equation for groundwater flow
11	Tutorial will be based on Dupuit-Forchheimer theory
12	Tutorial will be based on exploring various methods for measuring groundwater flow potential

4.	**Books Recommended**
1	L Xue, X Guo, H Chen, “Fluid Flow In Porous Media: Fundamentals And Applications”, World Scientific, 2020.
2	M. K. Ghosh, "Fundamentals of Groundwater," Springer, 2019.
3	R. H. Jackson, "Groundwater: A Comprehensive Guide," Taylor & Francis, 2021.
4	V. C. Agarwal, Groundwater Hydrology, PHI Learning Private Limited, New Delhi, 2012.
5	J. Bear, Hydraulics of Groundwater, Dover Publications, 2007.

B.Tech. MaC - IV Advanced Mathematical Methods-II	Scheme	L	T	P	Credit
		3	1	0	4

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	demonstrate a common framework that distinguishes various multivariate analytic techniques
CO2	develop the solution of ODEs using asymptotic methods
CO3	apply perturbation theory to solve various problems related to engineering and sciences
CO4	solve non-linear ODEs related to engineering and sciences using the homotopy analysis method
CO5	design and implement a technique based on varied factors for ODEs

2.	Syllabus	
	INTRODUCTION	**(06 Hours)**
	Review on Power Series Method, Taylor Series Method.	
	ASYMPTOTIC METHOD	**(09 Hours)**
	Introduction, Asymptotic Solutions at Irregular Singular Points at Infinity, Method of Finding Solutions at Irregular Points, Asymptotic Method for Constructing Solutions along with the validity for large values, Asymptotic Solutions of Perturbed Problems, Solutions to ODEs Containing a Large Parameter, Applications.	
	PERTURBATION TECHNIQUES	**(12 Hours)**
	Basic Idea behind the Perturbation Method, Regular Perturbation Theory, Singular Perturbation Theory, Boundary-Layer Method, Applications.	
	METHOD OF MULTIPLE SCALES	**(08 Hours)**
	Introduction, Method of Multiple Scales, Applications.	
	HOMOTOPY ANALYSIS METHOD	**(10 Hours)**
	Introduction, Background, A brief history of the HAM, Characteristic of homotopy analysis method, Some advances of the HAM, Generalized zeroth-order deformation equation, Basic ideas of the homotopy analysis method, Convergence of homotopy series solution.	
	Tutorials will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

4.	**Books Recommended**
1	C. M. Bender and S. A. Orszag, Advanced Mathematical Methods for Scientists and Engineers: Asymptotic Methods and Perturbation Theory, Springer Science & Business Media, 1999.
2	S. I. Hayek, Advanced Mathematical Methods in Science and Engineering, 2nd Edition, Chapman and Hall/CRC, 2010.
3	J. B. Doshi, Analytical Methods in Engineering, Narosa Publishing House, 1998.
4	A. D. Polyanin and V. F. Zaitsev, Handbook of Ordinary Differential Equations: Exact Solutions, Methods, and Problems, 3rd Edition, Chapman and Hall/CRC, 2017.
5	S. Liao, Homotopy Analysis Method in Nonlinear Differential Equations, Springer-Verlag Berlin Heidelberg, 2012.

B.Tech. MaC - IV Multi-Objective Optimization	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**1**	**0**	**04**

1.	**Course Outcomes (COs):** **At the end of the course, students will be able to**
CO1	classify simple (single) objective and multi-objective optimization problems
CO2	formulate real world problems in multiobjective optimization.
CO3	solve multiobjective optimization problems by classical approaches
CO4	solve multiobjective optimization problems by Evolutionary approaches
CO5	explain the importance of multiobjective optimization in real life

2.	**Syllabus**	
	ELEMENTS OF MULTIOBJECTIVE DECISION MAKING PROBLEM	**(06 Hours)**
	Introduction, Multiobjective decisions making process, Judgment and the value system, Decision making unit and the decision makers, Objectives and attributes, Decision Situation, Symbolic representation of the multiobjective Decisions problem, Scale of measurement, Elementary decision analysis, types of decision problems, Choosing a decision rule, decision tree.	
	MULTIOBJECTIVE OPTIMIZATION	**(07 Hours)**
	Definition of Multiobjective optimization, Difference between Single and Multiobjective optimization, Formation of multiobjective optimization problem, Pareto-optimality, Efficiency and dominance, Compromise Solution.	
	METHODS TO SOLVE MULTIOBJECTIVE OPTIMIZATION PROBLEMS	**(15 Hours)**
	Graphical method, Multiobjective simplex method, Goal programming method, ε constraint method, weighted sum method, Fuzzy programming approach with linear, exponential and hyperbolic membership function.	
	EVOLUTIONARY APPROACHES	**(09 Hours)**
	Introduction to Evolutionary approaches, Difficulties with classical optimization algorithm, Genetic Algorithm for the solution of multiobjective optimization problem.	
	SELECTED MULTIOBJECTIVE OPTIMIZATION PROBLEMS	**(08 Hours)**
	Multiobjective transportation problems, Multiobjective solid transportation problems, Multiobjective assignment problems.	
	Tutorials will be based on the coverage of the above topics separately.	**(30 Hours)**

	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)

4.	**Books Recommended**
1	C. Vira, Y. H. Yacov, Multiobjective Decision Making Theory and Methodology, North Holand, Elsevier Science Publishing Company Newyork, 2008.
2	K. Deb, Multiobjective Optimization using Evolutionary Algorithms, John Willey & Sons, 2003.
3	S. N. Sivanandam, S. N. Deepa, Introduction to Genetic Algorithms, Springer-Verlag Berlin Heidelberg, 2008.
4	D. T. Luc, Multiobjective Linear Programming an Introduction, Springer International Publishing Switzerland, 2016
5	J. Lu, G. Zhang, D. Ruan and F. Wu, Multiobjective Group Decision Making Methods, Software and Applications With Fuzzy Set Techniques, Imperial College Press London, 2007.

B.Tech. MaC - IV Fuzzy Logic and Computation	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	demonstrate the concepts of crisp sets and fuzzy sets
CO2	apply various operations on fuzzy sets
CO3	demonstrate the fuzzy arithmetic
CO4	solve the fuzzy equations
CO5	solve the Engineering problems using the theory of fuzzy sets and fuzzy mathematics

2.	Syllabus	
	INTRODUCTION	**(9 Hours)**
	Uncertainty, Imprecision and Vagueness, Brief history of Fuzzy logic, Foundation of Fuzzy Theory, Definition of Fuzzy sets, Fuzzy sets verse crisp sets, Alpha-cuts, Theorems on Cuts, Normality Extension Principle.	
	OPERATIONS ON FUZZY SETS	**(8 Hours)**
	Types of operations, Completion, Union and intersection, Difference, t-norm, t-conorms.	
	FUZZY ARITHMETIC	**(8 Hours)**
	Fuzzy numbers. Addition, Subtraction, Multiplication and Division, Triangular and trapezoid fuzzy numbers.	
	FUZZY RELATIONS AND FUZZY EQUATIONS	**(12 Hours)**
	Crisp verses fuzzy relations, Binary fuzzy relations, Fuzzy equivalence relations, Fuzzy ordering relations. Fuzzy relation equations, Sup-i composition, Inf-w composition, Solution methods.	
	ENGINEERING APPLICATIONS	**(8 Hours)**
	Fuzzy controlar, Applications in Civil engineering, Mechanical engineering and Computer engineering.	
	Tutorials will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

4.	**Books Recommended**
1	H. J. Zimmerman, Fuzzy Set Theory and its Applications, 3rd Edition, Kluwer Academic Publishers, Boston, MA, 1996
2	D. Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications, Academic Press, Cambridge, MA, 1980
3	T. J. Ross, Fuzzy Logic with Engineering Applications, 3rd Edition, Wiley Publication, 2011
4	G. J. Klir, U. St. Clair and B. Yuan, Fuzzy Set Theory Foundations and Applications, PHI Inc. USA, 1997
5	C. Mohan, An Introduction to Fuzzy Set Theory and Fuzzy Logic, Viva Books Private Limited, 2017

B.Tech. MaC - IV Computational Finance and Financial Econometrics	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	model financial derivatives
CO2	implement computational algorithms
CO3	analyze financial risks
CO4	optimize investment portfolios
CO5	apply stochastic processes

2.	Syllabus	
	INTRODUCTION	**(10 Hours)**
	Computing asset returns, Univariate random variables and distributions, Characteristics of distributions, the normal distribution, linear function of random variables, quantiles of a distribution, Value-at-Risk	
	BIVARIATE DISTRIBUTIONS AND TIME SERIES CONCEPTS	**(08 Hours)**
	Covariance, correlation, autocorrelation, linear combinations of random variables, Covariance stationarity, autocorrelations, MA(1) and AR(1) models	
	DESCRIPTIVE STATISTICS	**(06 Hours)**
	Histograms, sample means, variances, covariances and autocorrelations	
	CONSTANT EXPECTED RETURN MODEL	**(08 Hours)**
	Monte Carlo simulation, standard errors of estimates, confidence intervals, bootstrapping standard errors and confidence intervals, hypothesis testing, Maximum likelihood estimation, review of unconstrained optimization methods	
	INTRODUCTION TO PORTFOLIO THEORY	**08 hours)**
	Portfolio theory with matrix algebra, Review of constrained optimization methods, Markowitz algorithm, Markowitz Algorithm using the solver and matrix algebra	
	STASTICAL ANALYSIS OF EFFICIENT PORTFOLIOS	**(5hours)**
	Risk budgeting, Euler's theorem, asset contributions to volatility, beta as a measure of portfolio risk, The Single Index Model, Estimation using simple linear regression	
	Tutorials will be based on the coverage of the above topics separately.	**(30 Hours)**

	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)

4.	**Books Recommended**
1	Brooks, Chris, Introductory Econometrics for Finance, Cambridge, 2019.
2	E.J. Elton et al., Modern Portfolio Theory and Investment Analysis, Wiley, New York.
3	Remillard, Statistical Methods for Financial Engineering, Chapman and Hall/CRC, 2013.

B.Tech. MaC - IV ADVANCED MATHEMATICAL AND SIMULATION MODELING	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	explain the concept of mathematical modelling & simulation
CO2	formulate the real-world problem into Mathematical form
CO3	analyze the mathematical model
CO4	apply simulation in the analysis of real-world problems
CO5	develop a computer code for the simulation of a system

2.	Syllabus	
	INTRODUCTION TO MATHEMATICAL MODELLING	**(12 Hours)**
	Introduction to mathematical modelling, Real-world problems, Identification of parameters, Significant parameters, Importance of parameters, Reduction of an open problem to a closed form, Conversion of a real problem into a mathematical problem, Quest for a mathematical technique for solution, Importance of numerical techniques, Physical interpretation of solution, Types of mathematical models, Characteristics of mathematical models, Framework of mathematical models, Validation of mathematical model, Advantage and disadvantage of mathematical model.	
	MATHEMATICAL MODELS	**(12 Hours)**
	Models based on system of algebraic equations, ODE based simple modelling, Population dynamics modelling, Multi-compartmental modelling, Detection of diabetic model, Technological innovation model, Heat and mass transport Models, Heat conduction and diffusion Problems.	
	INTRODUCTION TO SIMULATION	**(10 Hours)**
	Introduction to simulation, Types of simulation, Simulation methodology, Random number generation, Monte-Carlo simulation, Simulation of continuous system, Discrete event simulation, Design of experiments, Validation.	
	SOME CASE STUDIES	**(11 Hours)**
	Simulation of queuing system, Simulation of inventory control, Simulation of forecasting, Simulation of maintenance problem, Simulation of network problems, Simulation of regression analysis, Simulation of linear programming problems.	

	Practicals : 1. Radioactive decay and Newton's law of Colling Model with their simulation 2. Population dynamics model and their simulation 3. Single Compartment modelling and their simulation 4. Multi compartment modelling and their simulation 5. Technological innovation model and their simulation 6. Detection of Diabetic model and their simulation 7. Analytical solution of PDE with MATLAB and their simulation (Heat Equation) 8. Analytical solution of PDE with MATLAB and their simulation (Wave Equation) 9. Simulation for Forecasting and PERT Network 10. Operation research based Simple simulation problems	
	(Total Contact Time: Hours)	

4.	**Books Recommended**
1	J. N. Kapoor, Mathematical Modeling, New Age International(p) Limited, 2018.
2	B. Barnes and G. R. Fulford, Mathematical Modelling with Case Studies, Using Maple and MATLAB, 3rd Edition, CRC press, 2015.
3	J. Caldwell, K. S. Ng Douglas and J. Caldwell, Mathematical Modeling: Case Studies and Projects (Texts in the Mathematical Sciences), Springer Netherlands, 2004.
4	N. Deo, System Simulation with Digital Computer, PHI New Delhi, 2006.
5	F. L. Severvance, System Modeling and Simulation: An Introduction, John Wiley, 2001.

B.Tech. MaC - IV UNCERTAINTY THEORY AND COMPUTATION	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**0**	**2**	**04**

1.	**Course Outcomes (COs):** **At the end of the course, students will be able to**
CO1	understand the various mathematical models and theories used to handle uncertainty.
CO2	apply fuzzy logic, possibility theory, and evidence theory in real-world problems.
CO3	gain practical experience in dealing with uncertainty in AI, machine learning, and decision-making.
CO4	aware of advanced topics and current research trends in uncertainty theory.
CO5	explore various theories and methods used to handle uncertainty in mathematical and computational contexts

2.	**Syllabus**	
	Introduction to Uncertainty Theory	**(12 Hours)**
	Basic Concepts of Uncertainty: Definition, types of uncertainty (epistemic vs. aleatory), and sources of uncertainty in mathematical models. Probabilistic Uncertainty: Review of probability theory, probability distributions, expectation, and variance. Non-Probabilistic Models: Introduction to fuzzy sets, possibility theory, and evidence theory (Dempster-Shafer Theory). Applications of Uncertainty: Case studies in finance, engineering, artificial intelligence, and decision-making.	
	Fuzzy Set Theory and Fuzzy Logic	**(12 Hours)**
	Fuzzy Sets and Membership Functions: Definition, properties, and operations on fuzzy sets. Fuzzy Logic: Linguistic variables, fuzzy rules, and fuzzy inference systems. Fuzzy Decision-Making: Fuzzy multi-criteria decision-making (FMCDM), applications in control systems, and expert systems. Fuzzy Numbers and Arithmetic: Operations on fuzzy numbers, fuzzy arithmetic, and its applications.	
	Possibility Theory and Evidence Theory	**(11 Hours)**
	Possibility Theory: Possibility distributions, possibility and necessity measures, comparison with probability theory. Applications of Possibility Theory: Decision-making under uncertainty, reliability analysis, and risk assessment.	

	Dempster-Shafer Theory (Evidence Theory): Basic belief assignments, Dempster's rule of combination, and applications in data fusion and sensor networks. Comparison of Theories: Advantages and limitations of possibility theory and evidence theory.	
	Uncertainty in Artificial Intelligence and Machine Learning	**(10 Hours)**
	Handling Uncertainty in AI: Bayesian networks, probabilistic graphical models, and belief networks. Uncertainty in Machine Learning: Uncertainty quantification in regression and classification models, predictive distributions, and confidence intervals. Deep Learning and Uncertainty: Bayesian deep learning, dropout as a Bayesian approximation, and applications in AI. Applications in Robotics and Autonomous Systems: Decision-making under uncertainty, SLAM (Simultaneous Localization and Mapping), and reinforcement learning with uncertainty.	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

4.	**Books Recommended**
1	Hillier & Lieberman, Introduction to Operations Research, 11th Edition, McGraw Hill India.
2	Uncertainty Theory: A Branch of Mathematics for Modeling Human Uncertainty" by Baoding Liu, 1st ed., Springer Berlin Heidelberg 2010
3	Fuzzy Sets and Fuzzy Logic: Theory and Applications" by George J. Klir and Bo Yuan, Pearson, 2010.
4	Uncertainty Modelling in Knowledge Engineering and Decision Making by Baoding Liu, 2016
5	Bayesian Networks and Decision Graphs by Finn V. Jensen and Thomas Nielsen, 2nd ed. 2007.

B.Tech. MaC - IV REINFORCEMENT LEARNING	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**0**	**2**	**04**

1.	**Course Outcomes (COs):** **At the end of the course, students will be able to**
CO1	Understand the theoretical underpinnings and mathematical foundations of Reinforcement Learning.
CO2	design, implement, and evaluate RL algorithms.
CO3	Gain practical experience in applying RL to problems in Mathematics and Computing.
CO4	aware of the latest advancements and ethical considerations in the field of RL.
CO5	design, implement, and evaluate RL algorithms.

2.	**Syllabus**	
	Foundations of Reinforcement Learning	**(09 Hours)**
	Introduction to Machine Learning Paradigms: Overview of Supervised, Unsupervised, and Reinforcement Learning. Key Concepts in RL: Agents, Environments, States, Actions, Rewards, and Policies. Mathematical Framework: Markov Decision Processes (MDPs) - States, Actions, Transition Probabilities, Rewards, and Discount Factors. Exploration vs. Exploitation: Strategies for balancing exploration and exploitation in RL. Applications of RL: Case studies in Gaming, Robotics, Finance, etc.	
	Dynamic Programming and Basic RL Algorithms	**(09 Hours)**
	Dynamic Programming (DP) Basics: Bellman Equations, Policy Evaluation, and Policy Iteration. Value Iteration and Policy Iteration: Mathematical derivations and algorithmic implementation. Monte Carlo Methods: Overview, Monte Carlo Prediction, and Control.Temporal Difference (TD) Learning: TD(0), SARSA, Q-Learning. Comparing DP, Monte Carlo, and TD Methods: Strengths, limitations, and applications.	
	Function Approximation and Advanced RL Algorithms	**(09 Hours)**
	Function Approximation: Linear and Non-Linear Function Approximation, Deep Q-Networks (DQN). Policy Gradient Methods: REINFORCE Algorithm, Actor-Critic Models, and their mathematical foundations. Advanced Exploration Strategies: Epsilon-Greedy, Softmax, Upper Confidence Bound (UCB). Inverse Reinforcement Learning (IRL): Basics and applications in complex environments. Partially Observable MDPs (POMDPs): Challenges and solutions.	
	Practical Implementation and Computational Aspects	**(09 Hours)**

	Programming Tools for RL: Introduction to Python, TensorFlow, PyTorch, and OpenAI Gym. Hands-On Projects: - Implementing Q-Learning and SARSA in Python. - Designing and training an agent in OpenAI Gym environments. - Exploring Deep Reinforcement Learning with DQNs. - Implementing Policy Gradient Methods. Optimization and Debugging: Techniques for improving the performance of RL algorithms.	
	Applications of RL in Mathematics and Computing	**(09 Hours)**
	Case Studies: - RL in Game Theory and Economic Models. - RL for Portfolio Optimization in Finance. - Applications in Computational Biology and Health Informatics. - RL in Natural Language Processing (NLP) and AI-based tutoring systems. Ethical Considerations and Challenges in RL: Safety concerns, fairness, and responsible AI practices. Future Directions in RL: Emerging trends, open problems, and potential areas for research.	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

4.	**Books Recommended**
1	R. S. Sutton and A. G. Barto. Reinforcement Learning - An Introduction. MIT Press. 1998.
2	Richard S. Sutton and Andrew G. Barto, "Reinforcement learning: An introduction", Second Edition, MIT Press, 2019
3	Li, Yuxi. "Deep reinforcement learning." arXiv preprint arXiv:1810.06339 (2018).
4	Wiering, Marco, and Martijn Van Otterlo. "Reinforcement learning." Adaptation, learning, and optimization 12 (2012)
5	Russell, Stuart J., and Peter Norvig. "Artificial intelligence: a modern approach."Pearson Education Limited, 2016

B.Tech. MaC - IV ADVANCED OPERATIONS RESEARCH	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	explain the importance of operations research in real life problems.
CO2	apply basic concepts of Mathematics to formulate and solve OR problems
CO3	incorporate chance factor and calculate project completion time in PERT & CPM
CO4	interpret multi-stage decision process through dynamic programming
CO5	solve NLPP using different methods.

2.	Syllabus	
	INTRODUCTION	**(08 Hours)**
	Nature and scope of Operations Research, Convex sets and convex functions and their properties, Inventory control -Deterministic including price breaks and Multi-item with constraints, Probabilistic (with and without lead time).	
	QUEUING THEORY	**(08 Hours)**
	Basic Structures of queuing models, Poisson queues –M/M/1, M/M/C for finite and infinite queue length, Non-Poisson queue -M/G/1, Machine Maintenance (steady state).	
	PERT AND CPM	**(10 Hours)**
	Introduction, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis, Probability in PERT analysis, Project Time-Cost, Trade-off, Updating of the project, Resource allocation-resource smoothing and resource levelling	
	DYNAMIC AND GEOMETRIC PROGRAMMING	**(10 Hours)**
	Introduction, Nature of dynamic programming, Deterministic processes, Non-Sequential discrete optimization, Allocation problems, Assortment problems, Sequential discrete optimization, Long-term planning problem, Multi-stage decision process, Application of Dynamic Programming in production scheduling and routing problems.	
	NONLINEAR PROGRAMMING	**(9 Hours)**
	Quadratic Programming, Duality theory, Search techniques - one variable (Fibonacci, Golden Section method) and several variables (Conjugate Gradient, Newton's method) , Introduction	

	to geometric programming, Posynomial, Arithmatic-Geometric inequality, Geometric programming (both unconstrained and constrained).	
	Tutorial will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

4.	**Books Recommended**
1	F. S. Hiller and G. J. Lieberman, Introduction to Operations Research, 8th Edition, Tata McGraw-Hill, New Delhi, 2009.
2	K. Swarup, P. K. Gupta and M. Mohan, Operations Research, 19th Edition, S. Chand & Sons, New Delhi, 2017.
3	H. A. Taha, Operations Research: An Introduction, 9th Edition, Pearson, New Delhi, 2014.
4	J. K. Sharma, Operations Research: Theory and Applications, 6th Edition, Trinity Press, New Delhi, 2017.
5	M. S. Bazarra, H. D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, 3rd Edition, John Wiley & Sons, New Jersy, 2016.