Sardar Vallabhbhai National Institute of Technology (SVNIT) Surat
Department of Mathematics

B.Tech. Mathematics and Computing (MaC) 4th Year

Sr. No.	Subject	Code	Scheme L-T-P	Credits (Min.)	Hours of Learning (Approx.)
	Seventh Semester				
1	Topology and Functional Analysis	MA407	3-1-0	4	70
2	Elective-VII	MA4AA	3-1-0 3-0-2	4	70/85
3	Elective-VIII	MA4BB	3-1-0 3-0-2	4	70/85
4	Elective-IX (Specialization#3)	MA4CC	3-X-X	4	70/85
5	Elective-X (Specialization#4)	MA/CS/AI4DD	3-X-X	4	70/85
			Total	**20**	**350-410**
6	Mini Project-III/ Vocational Training / Professional Experience (Optional) (**mandatory for exit**)	MAV07 / MAP07	0-0-10	5	200 (20 X 10)
	Eighth Semester				
1	Industrial Internship / Professional Experience (Mandatory)	MA404	0-0-40	20	800 (40 X 20)
			Total	**20**	**800**

Sr. No.	Elective	Code	Scheme L-T-P
	Elective-VII to Elective-X		
1	Big Data Analytics	MA452/CS452	3-0-2
2	Multi Objective Optimization	MA453	3-1-0
3	Evolutionary Algorithms	MA454	3-1-0
4	Computational Fluid Dynamics	MA455	3-0-2
5	Natural Language Processing	MA456/CS459	3-0-2
6	Image Processing and Mining	MA457	3-0-2
7	Computational Finance and Portfolio Optimization	MA458	3-1-0
8	Foundations of Robotics	MA459	3-1-0
9	Neural Network	MA460	3-0-2
10	Quantum Computing	MA461	3-0-2
11	Error Correcting Codes	MA462	3-0-2
12	Cloud Computing	MA463	3-0-2
13	Hybrid Algorithms	MA464	3-0-2
14	Financial Instruments and Risk Management	MA465	3-1-0
15	Advanced Operations Research	MA466	3-1-0
16	Theoretical and Computational Neuroscience	MA467	3-1-0
17	Stochastic Finance	MA468	3-1-0

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	understand the concept of topology and the intrinsic properties of topological spaces.
CO2	Apply the knowledge of compactness, countability, and separation axioms to 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 related problems.
CO4	apply 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	Tutorials will be based on Topology: Introduction.
2	Tutorials will be based on Topology: compactness, countability and separation axioms.
3	Tutorials will be based on fundamentals of normed linear space.
4	Tutorials will be based on bounded linear maps on normed linear spaces.
5	Tutorials will be based on Hilbert spaces.
6	Tutorials will be based on bounded operators in Hilbert space.

4.	**Books Recommended**
1	J. R. Munkres, Topology, Pearson Education (India), 2nd Edition, 2015.
2	G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Education, New York, 1st Edition, 2017.
3	S. Ponnusamy, Foundations of Functional Analysis, Narosa Publishing House, New Delhi, 2018.
4	E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 2015.
5	B. V. Limaye, Functional Analysis, New Age International Private Limited, 3rd Revised Edition, 2014.

ADDITIONAL REFERENCE BOOKS	
1	K. D. Joshi, Introduction to General Topology, New Age International, New Delhi, 3rd Edition, 2022.
2	M. A. Armstrong, Basic Topology, Springer (India), 2004.
3	C. W. Patty, Foundations of Topology, Second Edition, Jones & Barlett Student Edition, 2nd Edition, 2010.
4	B. V. Limaye, Functional Analysis, New Age International Private Limited, 3rd Revised Edition, 2014.
5	J. B. Conway, A Course in Functional Analysis, Springer-Verlag, New York, 2nd Edition, 1990.

B.Tech. MaC - IV, Semester – VII BIG DATA ANALYTICS MA 452	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 key data analysis techniques, including statistical modelling and Bonferroni's Principle.
CO2	utilize MapReduce and Spark for large-scale data processing.
CO3	implement principal component analysis (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	**(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 principal component analysis (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 TO 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, San Francisco, 4th Edition, 2022.
2	A. W. Moore and W. S. Cooley, Data Stream Mining: A Review, Wiley, Hoboken, 2nd Edition, 2022.
3	T. M. Mitchell, Machine Learning, McGraw-Hill Education, New York, 3rd Edition, 2022.
4	I. Goodfellow, Y. Bengio, and A. Courville, Deep Learning, MIT Press, Cambridge, 1st Edition, 2021.
5	H. Korth, Distributed Systems for Data Mining, Springer, Berlin, 1st Edition, 2022.

B.Tech. IV (Mathematics and Computing), Semester – VII BIG DATA ANALYTICS CS452	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 key requirements and issues in big data management and its associated applications in intelligent business and scientific computing.
CO2	Use state of the art big data analytics techniques and algorithms.
CO3	Analyze large sets of data to discover patterns and other useful information.
CO4	Compare and evaluate the impact of big data analytics tools and techniques.
CO5	Develop big data solutions using state of the art analytics tools/techniques.

2.	**Syllabus**	
	INTRODUCTION – DATA WAREHOUSING, DATA MINING	**(09 Hours)**
	Define Data Warehousing and Data Mining - The Building Blocks, Defining Features – Data Warehouses and Data Marts, Overview of the Components, Metadata in the Data Warehouse, Need for Data Warehousing, Basic Elements of Data Warehousing, Trends in Data Warehousing.	
	CONCEPTS AND TECHNIQUES IN DATA WAREHOUSING	**(8 Hours)**
	OLAP (Online analytical processing) Definitions, Difference Between OLAP and OLTP, Dimensional Analysis, Define Cubes, Drill-down and Roll-up - Slice and Dice or Rotation, OLAP Models, ROLAP versus MOLAP, Defining Schemas: Stars, Snowflakes and Fact Constellations.	
	CONCEPT DESCRIPTION AND ASSOCIATION RULE MINING	**(08 Hours)**
	Introduction to Concept Description, Data Generalization and Summarization-based Characterization, Analytical Characterization, Class Comparisons, Descriptive Statistical Measures, Market Basket Analysis- Basic Concepts, Association Rule Mining, The Apriori Algorithm, Mining Multilevel Association Rule Mining, Mining Multidimensional Association Rule Mining.	
	INTRODUCTION TO CLASSIFICATION AND PREDICTION	**(10 Hours)**
	Introduction to Classification and Prediction, Issues Regarding Classification, Classification using Decision Trees, Bayesian Classification, Classification by Back Propagation, Prediction Classification Accuracy.	
	ADVANCED TOPICS	**(10 Hours)**
	Clustering, Spatial Mining, Web Mining, Text Mining, Map-Reduce and Hadoop Ecosystem.	
	Practicals will be based on the coverage of the above topics.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

4.	**Books Recommended**
1	Jiawei Han, Micheline Kamber, Jian Pei, Morgan Kaufmann, “Data Mining Concepts and Techniques”, 3rd Edition, Morgan Kaufmann, 2012.
2	Paulraj Ponnian, “Data Warehousing Fundamentals”, 1st Edition, John Willey, May 24, 2010.
3	Robert D. Schneider, Hadoop for Dummies, 1st Edition, Wiley India, Apr 14, 2014.
4	M. Kantardzic, “Data mining: Concepts, models, methods and algorithms”, 3rd Edition, John Wiley & Sons Inc., Nov 12, 2019.
5	M. Dunham, “Data Mining: Introductory and Advanced Topics”, 1st Edition, Pearson, Sep 1, 2002.

B.Tech. IV (Mathematics and Computing), Semester – VII Multi-Objective Optimization MA-453	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 multi-objective optimization.
CO3	solve multi-objective optimization problems by classical approaches
CO4	solve multi-objective optimization problems by Evolutionary approaches
CO5	explain the importance of multi-objective optimization in real-life

2.	**Syllabus**	
	ELEMENTS OF MULTIOBJECTIVE DECISION MAKING PROBLEM	**(06 Hours)**
	Introduction, Multiobjective decisions making process, Judgement 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 + 15 Hours = 60 Hours)	

3.	**Tutorial**
1	Tutorial will be based on multiobjective decisions making process
2	Tutorial will be based on types and rules of multiobjective decision problems

3	Tutorial will be based on single and multiobjective optimization
4	Tutorial will be based on the multiobjective optimization problem
5	Tutorial will be based on methods to solve multiobjective optimization problems
6	Tutorial will be based on fuzzy programming approach with linear, exponential and hyperbolic membership function
7	Tutorial will be based on evolutionary approaches and difficulties with classical optimization algorithm
8	Tutorial will be based on Genetic Algorithm
9	Tutorial will be based on multiobjective transportation problems and solid transportation problems
10	Tutorial will be based on multiobjective assignment problems.

4.	**Books Recommended**
1.	Luc D. T. Multiobjective linear programming: an introduction, Springer, Switzerland, 2016
2.	Simon, D. Evolutionary optimization algorithms, John Wiley & Sons, Hoboken, 2013.
3.	Rao, S. S. Engineering optimization: theory and practice, John Wiley & Sons, Hoboken, 5^{th} edition, 2020.
4.	Lobato, F. S. and Steffen Jr, V. Multi-objective optimization problems: concepts and self-adaptive parameters with mathematical and engineering applications, Springer, Switzerland, 2017.
5.	Tzeng, G. H. and Huang, J. J. Fuzzy multiple objective decision making, CRC Press, Boca Raton, 2013.

B.Tech. MaC - IV, Semester – VII EVOLUTIONARY ALGORITHMS MA 454	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 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 Edition, 2022.
2	K. Deb, Multi-Objective Optimization Using Evolutionary Algorithms, Wiley, Chichester, 2nd Edition, 2022.
3	K. A. De Jong, Evolutionary Computation: A Unified Approach, MIT Press, Cambridge, 2nd Edition, 2023.
4	A. E. Eiben and J. E. Smith, Introduction to Evolutionary Computing, Springer, Berlin, 2nd Edition, 2015.
5	Thomas Weise, Ke Tang, and Xin Yao, Introduction to Evolutionary Computation in Practice, Springer, Cham, 1st Edition, 2022.

B.Tech. MaC - IV, Semester – VII COMPUTATIONAL FLUID DYNAMICS MA 455	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	formulate fluid flow problems.
CO2	simulate the results using software.
CO3	implement discretization methods: finite difference, volume, and element.
CO4	use turbulence models and solution algorithms in CFD.
CO5	analyse CFD simulations using software tools.

2.	**Syllabus**	
	GENERAL INTRODUCTION	**(07 Hours)**
	Computational Fluid Dynamics, 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	**(12 Hours)**
	Discretization principles, Finite difference method, Finite Element Method, well-pose 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. Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation.	
	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.	
	FVM FOR CONVECTION-DIFFUSION EQUATIONS	**(09 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.	
	FVM FOR NAVIER STOKES EQUATIONS	**(09 Hours)**
	Stream Function-Vorticity approach and Primitive variable approach, Staggered grid and Collocated grid, SIMPLE Algorithm, SIMPLER Algorithm, Discretization using unstructured grid.	
	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

4.	**Books Recommended**
1	J. H. Ferziger, M. Peric, and R. L. Street, Computational Fluid Dynamics: A Practical Approach, Elsevier, Amsterdam, 3rd Edition, 2022.
2	S. V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press, Boca Raton, 1st Edition, 2021.
3	H. K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson, London, 3rd Edition, 2023.
4	M. A. Griebel, T. Dornseifer, and T. Neumayer, Numerical Simulation in Fluid Dynamics: A Practical Introduction, SIAM, Philadelphia, 2nd Edition, 2021.
5	C. A. J. Fletcher, Computational Techniques for Fluid Dynamics, Springer, Berlin, 2nd Edition, 2022.

B.Tech. (Mathematics and Computing), Semester – VII NATURAL LANGUAGE PROCESSING MA456	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	comprehend the core concepts and principles of natural language processing (NLP).
CO2	apply machine learning techniques to address various NLP tasks.
CO3	perform statistical analysis, classification, and recognition using acquired NLP knowledge.
CO4	assess the performance of machine translation systems using statistical criteria.
CO5	design efficient solutions for parsers, translators, and various applications based on NLP for everyday use.

2.	**Syllabus**	
	INTRODUCTION	**(06 Hours)**
	Human Languages, Language Models, Computational Linguistics, Ambiguity and Uncertainty in Language, Processing Paradigms, Phases in Natural Language Processing, Basic Terminology, Overview of Different Applications, Regular Expressions and Automata, Finite State Transducers and Morphology, Automata, Word Recognition, Lexicon, Morphology, Acquisition Models, Linguistics Resources, Introduction to Corpus, Elements in Balanced Corpus.	
	SYNTAX AND SEMANTICS	**(08 Hours)**
	Natural Language Grammars: Lexeme, Phonemes, Phrases and Idioms, Word Order, Tense, Probabilistic Models of Spelling, N-grams, Word Classes and Part of Speech Tagging using Maximum Entropy Models, Transformation-Based Tagging (TBL), Context-Free Grammars for English, Features and Unification, Lexicalized and Parsing, Treebanks, Language and Complexity, Representing Meaning, Semantic Analysis, Lexical Semantics, Word Sense Disambiguation.	
	PROBABILISTIC LANGUAGE MODELING	**(08 Hours)**
	Statistical Inference, Hidden Markov Models, Probabilistic (Weighted) Finite State Automata, Estimating the Probability of a Word, and Smoothing, Probabilistic Parsing, Generative Models of Language, Probabilistic Context-Free Grammars, Statistical Alignment and Machine Translation, Clustering, Text Categorization, Viterbi Algorithm for Finding Most Likely HMM Path.	
	PRAGMATICS	**(07 Hours)**
	Discourse, Dialogue and Conversational Agents, Natural Language Generation, Machine Translation, Dictionary-Based Approaches, Reference Resolution, Algorithm for Pronoun Resolution, Text Coherence, Discourse Structure, Applications of NLP: Spell-Checking.	
	MACHINE TRANSLATION	**(08 Hours)**

	Probabilistic Models for Translating Between Languages, Alignment, Translation, Language Generation, Expectation Maximization, Automatically Discovering Verb Subcategorization, Language Modelling Integrated into Social Network Analysis, Automatic Summarization, Question-Answering, Interactive Dialogue Systems.	
	ADVANCED TOPICS	**(08 Hours)**
	Summarization, Information Retrieval, Vector Space Model, Term Weighting, Homonymy, Polysemy, Synonymy, Improving User Queries, Document Classification, Sentence Segmentation, and Other Language Tasks, Automatically-Trained Email Spam Filter, Automatically Determining the Language, Speech Recognition.	
	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 will be based on the topics.**
1	Regular Expressions and Automata, Finite State Transducers and Morphology Word Recognition, Lexicon, Morphology, Basic Terminology.
2	Word Classes and Part-of-Speech Tagging, Maximum Entropy Models, N-grams, Context-Free Grammars.
3	Context-Free Grammars for English, Features and Unification, Lexicalized Parsing, Treebanks.
4	Representing Meaning, Semantic Analysis, Lexical Semantics, Word Sense, Disambiguation (WSD).
5	Hidden Markov Models (HMM), Probabilistic Language Modelling, Viterbi Algorithm, Statistical Inference.
6	Statistical Alignment, Machine Translation, Probabilistic Models, Expectation Maximization.
7	Natural Language Generation (NLG), Dialogue and Conversational Agents, Reference Resolution, Text Coherence.
8	Information Retrieval, Vector Space Model, Term Weighting, Document Classification
9	Automatic Summarization, Text Coherence, Sentence Segmentation, Clustering
10	Speech Recognition, Automatically Determining the Language, Homonymy, Polysemy, Synonymy, and Speech-to-Text Integration.

4.	**Recommended Books**
1	J. Eisenstein, *Introduction to Natural Language Processing*, The MIT Press, Cambridge, 2019.
2	Y. Goldberg, *Neural Network Methods for Natural Language Processing*, Morgan & Claypool Publishers, San Rafael, 2017.
3	M. Honnibal and I. Montani, *Practical Natural Language Processing for Developers*, Explosion AI, Berlin, 2020.
4	H. Lane, C. Howard, and H. Hapke, *Natural Language Processing in Action*, Manning Publications, Shelter Island, 2nd Edition, 2022.

5	T. Wolf, J. Chaumond, L. Debut, and V. Sanh, *Transformers for Natural Language Processing: Build, Train, and Fine-Tune Deep Neural Networks for NLP*, Packt Publishing, Birmingham, 2020.

5.	**Additional Referral Books**
1	D. Jurafsky and J. H. Martin, *Speech and Language Processing*, Pearson, Boston, 2nd Edition, 2008.
2	J. Allen, *Natural Language Understanding*, Pearson, Boston, 2nd Edition, 1994.
3	C. Manning and H. Schutze, *Foundations of Statistical Natural Language Processing*, The MIT Press, Cambridge, 1999.
4	S. Bird, E. Klein, and E. Loper, *Natural Language Processing with Python: Analyzing Text with the Natural Language Toolkit*, O'Reilly Media, Sebastopol, 2009.
5	J. Perkins, *Python Text Processing with NLTK 2.0 Cookbook*, Packt Publishing, Birmingham, 2nd Edition, 2010.

B.Tech. (Mathematics and Computing), Semester – VII NATURAL LANGUAGE PROCESSING CS459	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	comprehend the core concepts and principles of natural language processing (NLP).
CO2	apply machine learning techniques to address various NLP tasks.
CO3	perform statistical analysis, classification, and recognition using acquired NLP knowledge.
CO4	assess the performance of machine translation systems using statistical criteria.
CO5	design efficient solutions for parsers, translators, and various applications based on NLP for everyday use.

2.	**Syllabus**	
	INTRODUCTION	**(06 Hours)**
	Human Languages, Language Models, Computational Linguistics, Ambiguity and Uncertainty in Language, Processing Paradigms, Phases in Natural Language Processing, Basic Terminology, Overview of Different Applications, Regular Expressions and Automata, Finite State Transducers and Morphology, Automata, Word Recognition, Lexicon, Morphology, Acquisition Models, Linguistics Resources, Introduction to Corpus, Elements in Balanced Corpus.	
	SYNTAX AND SEMANTICS	**(08 Hours)**
	Natural Language Grammars: Lexeme, Phonemes, Phrases and Idioms, Word Order, Tense, Probabilistic Models of Spelling, N-grams, Word Classes and Part of Speech Tagging using Maximum Entropy Models, Transformation-Based Tagging (TBL), Context-Free Grammars for English, Features and Unification, Lexicalized and Parsing, Treebanks, Language and Complexity, Representing Meaning, Semantic Analysis, Lexical Semantics, Word Sense Disambiguation.	
	PROBABILISTIC LANGUAGE MODELING	**(08 Hours)**
	Statistical Inference, Hidden Markov Models, Probabilistic (Weighted) Finite State Automata, Estimating the Probability of a Word, and Smoothing, Probabilistic Parsing, Generative Models of Language, Probabilistic Context-Free Grammars, Statistical Alignment and Machine Translation, Clustering, Text Categorization, Viterbi Algorithm for Finding Most Likely HMM Path.	
	PRAGMATICS	**(07 Hours)**
	Discourse, Dialogue and Conversational Agents, Natural Language Generation, Machine Translation, Dictionary-Based Approaches, Reference Resolution, Algorithm for Pronoun Resolution, Text Coherence, Discourse Structure, Applications of NLP: Spell-Checking.	
	MACHINE TRANSLATION	**(08 Hours)**

	Probabilistic Models for Translating Between Languages, Alignment, Translation, Language Generation, Expectation Maximization, Automatically Discovering Verb Subcategorization, Language Modelling Integrated into Social Network Analysis, Automatic Summarization, Question-Answering, Interactive Dialogue Systems.	
	ADVANCED TOPICS	**(08 Hours)**
	Summarization, Information Retrieval, Vector Space Model, Term Weighting, Homonymy, Polysemy, Synonymy, Improving User Queries, Document Classification, Sentence Segmentation, and Other Language Tasks, Automatically-Trained Email Spam Filter, Automatically Determining the Language, Speech Recognition.	
	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 will be based on the topics.**
1	Regular Expressions and Automata, Finite State Transducers and Morphology Word Recognition, Lexicon, Morphology, Basic Terminology.
2	Word Classes and Part-of-Speech Tagging, Maximum Entropy Models, N-grams, Context-Free Grammars.
3	Context-Free Grammars for English, Features and Unification, Lexicalized Parsing, Treebanks.
4	Representing Meaning, Semantic Analysis, Lexical Semantics, Word Sense, Disambiguation (WSD).
5	Hidden Markov Models (HMM), Probabilistic Language Modelling, Viterbi Algorithm, Statistical Inference.
6	Statistical Alignment, Machine Translation, Probabilistic Models, Expectation Maximization.
7	Natural Language Generation (NLG), Dialogue and Conversational Agents, Reference Resolution, Text Coherence.
8	Information Retrieval, Vector Space Model, Term Weighting, Document Classification
9	Automatic Summarization, Text Coherence, Sentence Segmentation, Clustering
10	Speech Recognition, Automatically Determining the Language, Homonymy, Polysemy, Synonymy, and Speech-to-Text Integration.

4.	**Recommended Books**
1	J. Eisenstein, *Introduction to Natural Language Processing*, The MIT Press, Cambridge, 2019.
2	Y. Goldberg, *Neural Network Methods for Natural Language Processing*, Morgan & Claypool Publishers, San Rafael, 2017.
3	M. Honnibal and I. Montani, *Practical Natural Language Processing for Developers*, Explosion AI, Berlin, 2020.
4	H. Lane, C. Howard, and H. Hapke, *Natural Language Processing in Action*, Manning Publications, Shelter Island, 2nd Edition, 2022.

5	T. Wolf, J. Chaumond, L. Debut, and V. Sanh, *Transformers for Natural Language Processing: Build, Train, and Fine-Tune Deep Neural Networks for NLP*, Packt Publishing, Birmingham, 2020.

5.	**Additional Referral Books**
1	D. Jurafsky and J. H. Martin, *Speech and Language Processing*, Pearson, Boston, 2nd Edition, 2008.
2	J. Allen, *Natural Language Understanding*, Pearson, Boston, 2nd Edition, 1994.
3	C. Manning and H. Schutze, *Foundations of Statistical Natural Language Processing*, The MIT Press, Cambridge, 1999.
4	S. Bird, E. Klein, and E. Loper, *Natural Language Processing with Python: Analyzing Text with the Natural Language Toolkit*, O'Reilly Media, Sebastopol, 2009.
5	J. Perkins, *Python Text Processing with NLTK 2.0 Cookbook*, Packt Publishing, Birmingham, 2nd Edition, 2010.

B.Tech. IV (Mathematics and Computing), Semester – VII IMAGE PROCESSING AND MINING MA457/CS/AI4XX	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	use image processing techniques to work with p4els, alignment, and improvement.
CO2	implement and evaluate techniques for image enhancement and restoration, including histogram equalization and Wiener filtering.
CO3	apply image compression methods, such as DCT and encoding techniques, for effective image data compression.
CO4	analyze and implement colour image processing techniques using various colour models for colour correction and enhancement.
CO5	utilize image mining methods, including classification and object detection, with advanced techniques like CNNs and RNNs for extracting information from image datasets.

2.	**Syllabus**	
	IMAGE ALIGNMENT AND ENHANCEMENT	**(10 Hours)**
	Origin, Examples, Fundamental Steps and Components of image processing, Pixel Concepts: Domain, Size, Resolution, and Alignment, Motion Models and Transformations: Rotation, Translation, Affine, Scaling, Shearing, Image Alignment: Control-Point Based, MSSD/MSE, and Field of View, Image Warping and Bilinear Interpolation, Histograms and Entropy: Concepts and Alignment Applications, Intensity Transformations: Logarithmic, Power-Law, Linear Contrast Stretching, Histogram Equalization and Specification; Local/Adaptive Equalization, Spatial Filtering: Convolution, Correlation, Mean/Median Filtering.	
	IMAGE RESTORATION	**(9 Hours)**
	Introduction to Image Restoration and Blur Models, Defocus and Motion Blur; Fourier Interpretation, Inverse Filter: Definition and Limitations, Blur Camera and Flutter Shutter Camera: Code and Concepts, Wiener Filter: Concept, Formula, and Derivation, Regularized Restoration with Gradient Penalty, PCA for Image Denoising: Algorithm and Wiener Filter.	
	IMAGE COMPRESSION	**(8 hours)**

	Lossless and Lossy Compression Techniques, Discrete Cosine Transform (DCT): Definition and Basic Properties, 1D and 2D DCT; Kronecker Product of 1D DCT Bases, Comparison of DCT and DFT; DCT Computation using FFT, DCT Energy Compaction, DCT Quantization in JPEG: Quantization Matrix and Step, Huffman Encoding and Run-Length Encoding in JPEG, Structure and Properties of Huffman Encoder and Decoder, JPEG for Color Image Compression: YCbCr Color Scheme and Artifacts, Video Compression with MPEG: Residuals, Motion Compensation, and I, P, B Frames.	
	COLOR IMAGE PROCESSING	**(8 hours)**
	Introduction to Color Models: RGB, CMY(K), HSI, YCbCr, Merits and Demerits of Hue in Image Processing, Human Visual System: Structure and Function of Rods and Cones, Perception of Color and Its Implications in Image Processing, Illumination Models: Specular, Ambient, and Diffuse Light, Discussion on the Impact of Hue and Illumination Models in Color Correction and Enhancement.	
	IMAGE MINING	**(10 hours)**
	Definition, Scope, and Applications, Classifications: Supervised and Unsupervised Methods, Object Detection, Image Segmentation Content-Based Image Retrieval: Methods and Algorithms, Multimodal Data Mining Techniques, Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Scalability Issues, Tools, and Frameworks, Data Security, Bias, and Fairness in Mining.	
	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 will be based on the topics.**
1	On Aligning images using control-point-based methods and adjusting the field of view with MSSD/MSE.
2	On applying rotation, translation, affine transformations, scaling, and shearing to images, and performing matrix representation and composition.
3	On Warping images with forward and reverse transformations, and implementing bilinear interpolation for resizing.
4	On Calculating and visualizing image histograms, and performing histogram equalisation and specification, including local/adaptive histogram equalisation.
5	On Applying logarithmic, power-law (gamma), and linear contrast stretching transformations to adjust image intensity.
6	On Using convolution and correlation operations for filtering, and implementing mean and median filtering for noise reduction, including derivative filters for edge detection.
7	On Addressing image blur with inverse filters, implement Wiener filter restoration, and use PCA for image denoising with Wiener filtering.

8	On Performing image compression with lossless and lossy techniques, implement Discrete Cosine Transform (DCT), and apply Huffman and run-length encoding in JPEG.
9	On Implementing colour models such as RGB, CMY(K), HSI, and YCbCr, and analyze the impact of hue and illumination models on colour correction and enhancement.
10	On Classify and cluster images using supervised and unsupervised methods, perform object detection and image segmentation, and apply content-based image retrieval techniques with CNNs and RNNs.

4.	**Books Recommended**
1.	R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, Pearson, Prentice Hall, 4th Edition, 2018.
2.	R. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, London, 2011.
3.	S. E. Umbaugh, *Digital Image Processing and Analysis: Human and Computer Vision Applications with CVIPtools*, CRC Press, Boca Raton, 3rd Edition, 2010.
4.	J. Han, M. Kamber, and J. Pei, *Data Mining: Concepts and Techniques*, Morgan Kaufmann, San Francisco, 3rd Edition, 2011.
5.	A. C. Bovik, *Handbook of Image and Video Processing*, Academic Press, Cambridge, 2nd Edition, 2010.

5.	**Additional Referral Books**
1	W. K. Pratt, *Digital Image Processing: PIKS Scientific Inside*, Wiley, Hoboken, 4th Edition, 2007.
2	J. A. K. Jain, *Fundamentals of Digital Image Processing*, Prentice Hall, New Jersey, 1989.
3	T. M. Mitchell, *Machine Learning*, McGraw-Hill, New York, 1997
4	I. H. Witten and E. Frank, *Data Mining: Practical Machine Learning Tools and Techniques*, Morgan Kaufmann, San Francisco, 2nd Edition, 2005.

B.Tech. IV (Mathematics and Computing), Semester – VII **Computational Finance and Portfolio Optimization** **MA-458**	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 financial derivatives
CO2	implement computational algorithms
CO3	deal financial risks
CO4	demonstrate the optimize investment portfolios
CO5	design the stochastic processes

2.	**Syllabus**	
	INTRODUCTION	**(10 Hours)**
	Basic concept of finance, 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	
	Econometric	**(06 Hours)**
	Econometrics, Scope and applications in engineering, economics, and business, deterministic vs. stochastic models, Types of data: time-series, cross-sectional, panel data, Real-life examples of econometric applications in technology and engineering, Basic concepts of regression analysis, Simple Linear Regression, Multiple Linear Regression, Violations of OLS Assumptions, Time-Series Econometrics, Econometric models for decision-making in engineering and management	
	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	**(05 hours)**
	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 + 15 Hours = 60 Hours)	

3.	**Tutorials**
1	Tutorials will be based on Computing asset returns, Univariate random variables and distributions, etc.
2	Tutorials will be based on characteristics of distributions, the normal distribution, linear function of random variables, etc.
3	Tutorials will be based on covariance, correlation, autocorrelation, etc.
4	Tutorials will be based on linear combinations of random variables, covariance stationarity, autocorrelations, etc.
5	Tutorials will be based on econometrics, applications, business, deterministic, stochastic models, time series, etc.
6	Tutorials will be based on multiple linear regression, violations of OLS assumptions, time-series econometrics, etc.
7	Tutorials will be based on Monte Carlo simulation, standard errors of estimates, etc.
8	Tutorials will be based on Maximum likelihood estimation, review of unconstrained optimization methods, etc.
9	Tutorials will be based on portfolio theory, Markowitz algorithm, etc.
10	Tutorials will be based on risk budgeting, Euler's theorem, beta as a measure of portfolio risk, etc.

4.	**Books Recommended**
1	Chris B. Introductory Econometrics for Finance, Cambridge University Press, South Africa, 4th Edition, 2019.
2	Elton E. J., Modern Portfolio Theory and Investment Analysis, Wiley, New York. 9th Edition, 2014.
3	Remillard B., Statistical Methods for Financial Engineering, Chapman and Hall/CRC, UK, 1st Edition, 2013.
4	Zivot E., Introduction to Computational Finance and Financial Econometrics, Chapman and Hall/CRC, UK, 1st Edition, 2024.
5	Pfaff B, Financial Risk Modelling and Portfolio Optimization with R, Wiley–Blackwell, USA, 1st Edition, 2012.

B.Tech. MaC - IV FOUNDATIONS OF ROBOTICS MA 459	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, New York, 3rd Edition, 2021.
2	J. J. Craig, Introduction to Robotics: Mechanics and Control, Pearson, New York, 4th Edition, 2018.
3	M. Erdmann and M. T. Mason, Introduction to Robotics: Analysis, Control, Applications, MIT Press, Cambridge, 2018.
4	S. B. Niku, Introduction to Robotics: Analysis, Control, Applications, Wiley, Hoboken, 3rd Edition, 2020.
5	H. K. Khalil and J. K. Lemmon, Nonlinear Systems, Prentice Hall, Upper Saddle River, 3rd Edition, 2014.

B.Tech. IV (Mathematics and Computing), Semester – VII NEURAL NETWORKS MA-460	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	demonstrate different types of neural networks and different types of learning models.
CO2	determine the mathematical foundations of neural network models.
CO3	Implement464 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	R. Rojas, Neural Networks - A Systematic Introduction, Springer-Verlag, Berlin, New - York, 1st Ed., 2013.
2	C. Koch, Biophysics of Computation: Information Processing in Single Neurons, Oxford University Press, 2nd Ed., 2024.
3	L. D. Knowings, Building Neural Networks from Scratch with Python, L. D. Knowings, 2024.
4	S. Kumar, Neural Networks, A classroom approach, Mc Graw Hill, 2nd Ed., 2018.
5	S. Haykin, Neural Networks & Learning Machines, Pearson Education India, 3rd Ed., 2016.

B.Tech. IV (Mathematics and Computing), Semester -VII QUANTUM COMPUTING MA461	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	relate the key differences between classical and quantum computing.
CO2	represent quantum states, perform measurements, and build quantum circuits using quantum gate operations.
CO3	describe and implement algorithms like Deutsch-Jozsa, Grover's, and Shor's, including the Quantum Fourier Transform.
CO4	design, simulate, and execute quantum circuits and algorithms using Qiskit.
CO5	discuss the limitations and applications of NISQ technology and explore advanced topics like quantum machine learning and cryptography.

2.	**Syllabus**	
1	**INTRODUCTION TO QUANTUM COMPUTING**	**(10 Hours)**
	Classical vs. Quantum Computing, Basic Concepts: Qubits, Superposition, and Entanglement, Introduction to Quantum Gates, Postulates of Quantum Mechanics, Quantum States and State Vectors, Measurement in Quantum Mechanics, Bloch Sphere Representation, Building Quantum Circuits, Quantum Gate Operations, Quantum Circuit Examples.	
2	**QUANTUM ALGORITHMS**	**(10 Hours)**
	Introduction to Quantum Algorithms, Deutsch-Jozsa Algorithm, Grover's Algorithm, Shor's Algorithm for Factoring, Quantum Fourier Transform, Applications of Shor's Algorithm, The Need for Error Correction in Quantum Computing, Quantum Error Correction Codes, The Surface Code.	
3	**PRACTICAL QUANTUM COMPUTING WITH QISKIT**	**(09 Hours)**
	Introduction to Qiskit, Quantum Circuits in Qiskit, Simulating Quantum Circuits, Quantum Algorithms in Qiskit, Grover's Algorithm Implementation, Shor's Algorithm Implementation.	
4	**QUANTUM COMPUTING IN THE NISQ ERA**	**(09 Hours)**
	Overview of NISQ Technology, Limitations of Current Quantum Computers, Examples of NISQ Applications	
5	**SOME ADVANCED TOPICS AND APPLICATIONS**	**(04 Hours)**
	Quantum Machine Learning, Quantum Cryptography, Quantum Communication, Quantum Computing in Industry, Case Studies: IBM Quantum, Google's Quantum Supremacy.	
	Practical will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Practical will be based on the following topics.**
1	Visualizing qubits on the Bloch Sphere and understanding superposition.
2	Constructing basic quantum circuits using quantum gates (X, H, CNOT).
3	Simulating and analyzing quantum state measurements and their outcomes.
4	Step-by-step implementation and analysis of the Deutsch-Jozsa Algorithm
5	Designing and executing Grover's Algorithm using Qiskit for search problems.
6	Simulating Shor's Algorithm and exploring its impact on cryptography.
7	Understanding and applying basic quantum error correction codes.
8	Creating and running quantum circuit simulations using Qiskit's tools.
9	Exploring practical applications of quantum computing in the NISQ era.
10	Introduction to quantum machine learning concepts and implementation using Qiskit.

4.	**Books Recommended**
1	M. A. M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information: 10th Anniversary Edition*, Cambridge University Press, Cambridge, 2010
2	S. Kaiser and C. Granade, *Learn Quantum Computing with Python and Q#*, Manning Publications, New York, 2021.
3	E. G. Rieffel and W. H. Polak, *Quantum Computing: A Gentle Introduction*, The MIT Press, Cambridge, 2011.
4	B. Schumacher and M. Westmoreland, *Quantum Processes, Systems, and Information*, Cambridge University Press, Cambridge, 2010.
5	J. Preskill, *Lecture Notes on Quantum Computation*, Caltech, 2015.

5.	**Additional Referral Books**
1	P. Kaye, R. Laflamme, and M. Mosca, *An Introduction to Quantum Computing*, Oxford University Press, Oxford, 2007.
2	C. P. Williams and S. H. Clearwater, *Explorations in Quantum Computing*, Springer, New York, 1998.
3	D. McMahon, *Quantum Computing Explained*, Wiley, Hoboken, 2008.
4	A. Barenco, *Quantum Mechanics and Quantum Computation*, Oxford Science Publications, Oxford, 1995.

B.Tech. IV (Mathematics and Computing), Semester – VII ERROR CORRECTING CODES MA462	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 the fundamental concepts and significance of error-correcting codes in communication systems.
CO2	demonstrate proficiency in using vector spaces, matrices, and finite fields in the context of coding theory.
CO3	analyse block codes, including Hamming and cyclic codes, and understand their error detection and correction capabilities.
CO4	evaluate and construct advanced error-correcting codes, such as LDPC and Turbo codes, compared to traditional methods.
CO5	utilize software tools for the construction of error-correcting codes.

2.	**Syllabus**	
	INTRODUCTION TO ERROR-CORRECTING CODES	**(8 Hours)**
	Overview of error-correcting codes; Applications and significance in communication systems, Basic concepts: Error detection vs. error correction, Vector spaces and matrices, Finite fields and Galois fields. Type of codes, Types of errors, Error Control Strategies.	
	LINEAR CODES AND CYCLIC CODES	**(12 Hours)**
	Introduction to linear codes, Generator and parity-check matrices, Repetition codes, Cyclic codes and their Properties, Generator and Parity-check Matrices, Shortened cyclic codes, Hamming codes: Construction, Error detection and correction capabilities. Some Decoding algorithms: Syndrome, Maximum likelihood, Error-trapping etc., BCH codes and their implementations, Reed-Solomon Codes, Definition and importance of weight enumerators.	
	BOUNDS IN CODING THEORY	**(7 Hours)**
	Lower Bounds: Sphere-covering bound, Gilbert-Varshamov bound, Hamming bound, Perfect Codes, Golay Codes, Singleton bound, MDS Code, Plotkin bound, Preparata Codes, Kerdock Codes.	
	ADVANCED ERROR-CORRECTING CODES	**(10 Hours)**
	LDPC (Low-Density Parity-Check) codes, Turbo codes, Comparison of advanced codes with traditional methods.	
	SOFTWARE LEARNING	**(8 Hours)**
	Computations with some software tools such as MAGMA (Computational Algebra System), SageMath.	
	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 will be based on the topics as follows.**
1	On basic concepts of error correction in communication systems, examining the role of vector spaces and matrices for the same.
2	Definition, types, and properties of block codes, including Hamming codes and their error detection and correction capabilities.
3	On linear codes, including generator and parity-check matrices, and Hamming and repetition codes.
4	Introduction to finite fields and their application in coding theory, focusing on Galois fields.
5	On the construction of cyclic codes and their properties
6	Some encoding and decoding algorithms of cyclic codes.
7	BCH codes and Reed-Solomon codes.
8	Exploring various bounds in coding theory such as the Sphere-covering bound, Gilbert-Varshamov bound, Hamming bound, and others.
9	Introduction to advanced codes like LDPC and Turbo codes, and their comparison with traditional methods.
10	Utilizing software tools for the construction of optimal error-correcting codes.

4.	**Books Recommended**
1	M. Siegel and M. J. E. Golay, *Error Correction Codes: Theory and Practice*, Wiley, Hoboken, 2013.
2	S. Lin, Y. S. Han, and L. Wei, *Modern Coding Theory*, Cambridge University Press, Cambridge, 2017.
3	J. F. K. Coetzee and J. H. Conway, *Error Correcting Codes and Finite Fields*, CRC Press, Boca Raton, 2015.
4	T. K. Moon, *Error Correction Coding: Mathematical Methods and Algorithms*, Wiley, Hoboken, 2011.
5	S. Lin and D. J. Costello, *Error Control Coding: Fundamentals and Applications*, Pearson India, New Delhi, 2nd Edition, 2010.

5.	**Additional References/ Referral Books**
1	F. J. MacWilliams and N. J. A. Sloane, *The Theory of Error-Correcting Codes*, North-Holland, Amsterdam, 1983.
2	R. Hill, *A First Course in Coding Theory*, Oxford University Press, Oxford, 1997.

3	W. C. Huffman and V. Pless, *Fundamentals of Error-Correcting Codes*, Cambridge University Press, Cambridge, 2003.
4	S. Ling and C. Xing, *Coding Theory: A First Course*, Cambridge University Press, Cambridge, 2004.
5	Bosma, W., Cannon, J., Playoust, C. “The Magma Algebra System, I. The User Language”, Journal of Symbolic Computation, Vol 24 (3-4), 235-265, 1997. Calculator Available at: http://magma.maths.usyd.edu.au/calc/ (limited free version)
6	SageMath, version 9.7, The Sage Developers, 2021. Available at: https://www.sagemath.org

B.Tech. IV (Mathematics and Computing), Semester – VII CLOUD COMPUTING MA463/CS/AI4XXX	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 core concepts, history, and evolution of cloud computing, including the various service and deployment models.
CO2	analyze cloud architecture and design principles, focusing on infrastructure components like virtualization, storage, and networking.
CO3	evaluate cloud storage solutions and data management techniques, including security and compliance considerations.
CO4	apply cloud security best practices, including identity and access management, encryption, and regulatory compliance.
CO5	develop and deploy cloud-based applications using DevOps practices, with an emphasis on automation and continuous integration

2.	**Syllabus**	
	INTRODUCTION TO CLOUD COMPUTING	**(10 Hours)**
	Overview of Cloud Computing: Concepts, History, and Evolution, Cloud Service Models: IaaS, PaaS, SaaS, Cloud Deployment Models: Public, Private, Hybrid, Community, Key Cloud Providers: AWS, Azure, Google Cloud.	
	CLOUD ARCHITECTURE AND DESIGN	**(9 Hours)**
	Cloud Infrastructure: Virtualization, Storage, and Networking, Cloud Service Components: Compute, Storage, Networking, Security, Scalability and Elasticity: Auto-scaling and Load Balancing, Cloud Architecture Patterns and Best Practices.	
	CLOUD STORAGE AND DATA MANAGEMENT	**(10 Hours)**
	Cloud Storage Solutions: Object Storage, Block Storage, File Storage, Data Management in the Cloud: Backup, Recovery, and Disaster Recovery, Data Security and Compliance: Encryption, Access Control, and Auditing, Big Data Integration and Management in the Cloud.	
	CLOUD COMPUTING SECURITY	**(8 Hours)**
	Cloud Security Fundamentals: Threats, Risks, and Vulnerabilities, Identity and Access Management (IAM), Security Best Practices: Encryption, Firewalls, and Network Security, Compliance Standards and Regulations: GDPR, HIPAA, and PCI-DSS	

	CLOUD APPLICATIONS AND DEVOPS	**(8 Hours)**
	Cloud Application Development: Designing and Deploying Applications in the Cloud, Continuous Integration and Continuous Deployment (CI/CD), DevOps Practices in the Cloud: Automation, Monitoring, and Management, Case Studies: Real-world Cloud Implementations and Use Cases.	
	Practical’s will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact Time: 45 Hours + 30 Hours = 75 Hours)	

3.	**Practicals will be based on the topics as follows.**
1	Create and manage virtual machines on AWS, Azure, or Google Cloud.
2	Deploy and manage a simple web application using a PaaS platform.
3	Implement auto-scaling and load balancing in a cloud environment.
4	Work with object storage, block storage, and file storage on a cloud platform.
5	Configure IAM roles, users, and policies for secure access control.
6	Set up and automate backup plans and test disaster recovery strategies.
7	Monitor and manage cloud resources using tools like AWS CloudWatch or Azure Monitor.
8	Configure firewalls, encryption, and network security in a cloud environment.
9	Set up a CI/CD pipeline using tools like Jenkins or GitLab CI on a cloud platform.
10	Migrate an on-premise application to the cloud, addressing challenges and best practices.

4.	**Books Recommended**
1	T. Erl, Z. Mahmood, and R. Puttini, *Cloud Computing: Concepts, Technology & Architecture*, Prentice Hall, Upper Saddle River, 2023.
2	L. A. Barroso, J. Clidaras, and U. Hölzle, *The Datacenter as a Computer: An Introduction to the Design of Warehouse-Scale Machines*, Morgan & Claypool Publishers, San Rafael, 2nd Edition, 2013.
3	R. Buyya, J. Broberg, and A. Goscinski, *Cloud Computing: Principles and Paradigms*, Wiley, Hoboken, 2011.
4	A. Bahga and V. Madisetti, *Cloud Computing: A Hands-On Approach*, Wiley, Hoboken, 2014.
5	A. Bahga and V. Madisetti, *Cloud Computing: A Hands-On Approach*, Wiley, Hoboken, 2014.

B.Tech. MaC - IV HYBRID ALGORITHMS MA 464	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	apply hybrid algorithms in the context of big data analytics

2.	**Syllabus**	
	INTRODUCTION	**(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	M. S. S. D. Kumar and L. P. S. S. R. Kumar, Optimization Using Evolutionary Algorithms and Metaheuristics: Applications in Engineering, CRC Press, Boca Raton, 1st Edition, 2022.
2	S. Mirjalili, Comprehensive Metaheuristics: Algorithms and Applications, Elsevier, Amsterdam, 1st Edition, 2022.
3	S. B. Niku, Optimization Using Evolutionary Algorithms and Metaheuristics: Applications in Engineering, CRC Press, Boca Raton, 1st Edition, 2022.
4	D. Simon, Evolutionary Optimization Algorithms: Biologically-Inspired and Population-Based Approaches to Computer Intelligence, John Wiley & Sons, Hoboken, 1st Edition, 2013.
5	M. Preuss, Multimodal Optimization by Means of Evolutionary Algorithms, Springer, Berlin, 1st Edition, 2015.

B.Tech. MaC - IV **FINANCIAL INSTRUMENTS AND RISK MANAGEMENT** **MA 465**	**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, Hoboken, 5th Edition, 2018.
2	S. R. Glantz, The Volatility of Financial Markets: A Handbook of Quantitative Risk Management, Wiley, Hoboken, 2018.
3	M. A. H. Dempster, Quantitative Risk Management: Theory and Practice, Cambridge University Press, Cambridge, 2017.
4	P. Jorion, Value at Risk: The New Benchmark for Managing Financial Risk, McGraw-Hill, New York, 4th Edition, 2022.
5	S. R. Glantz, The Volatility of Financial Markets: A Handbook of Quantitative Risk Management, Wiley, Hoboken, 2018.

B.Tech. IV (Mathematics and Computing), Semester – VII ADVANCED OPERATIONS RESEARCH MA-466	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 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 AND GEOMETRIC 8 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, Tata McGraw-Hill, New Delhi, 11th Edition, 2015.
2	K. Swarup, P. K. Gupta and M. Mohan, Operations Research, S. Chand & Sons, New Delhi, 19th Edition, 2017.
3	H. A. Taha, Operations Research: An Introduction, Pearson, New Delhi, 10th Edition, 2019.
4	J. K. Sharma, Operations Research: Theory and Applications, Trinity Press, New Delhi, 6th Edition 2017.
5	M. S. Bazarra, H. D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, New Jersy, 3rd Edition, 2016.

B.Tech. IV (Mathematics and Computing), Semester – VII THEORETICAL AND COMPUTATIONAL NEUROSCIENCE MA-467	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	illustrate 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	Tutorials will be based on Introduction to Neurons.
2	Tutorials will be based on Point models: Hodgkin Huxley Equations (HHE), Analysis of Neural Models.
3	Tutorials will be based on Spike Trains: Encoding and Decoding.
4	Tutorials will be based on Plasticity.
5	Tutorials will be based on Modeling Phenomena with Plasticity.
6	Tutorials will be based on Theoretical Approaches and Current Research.

4.	**Books Recommended**
1	L. Johnston, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, American Medical Pub, 2023.
2	E. Kandel and J. Schwartz, Principles of Neural Science, McGraw-Hill, 5th Edition, 2012.
3	G. B. Ermentrout and D. H. Terman, Mathematical Foundations of Neuroscience, Springer, 10th Edition, 2010.
4	F. Gabbiani and S. J. Cox, Mathematics for Neuroscientists, Academic Press, 2nd Edition, 2017.
5	S. Carter, Computational Neuroscience: Modeling and Applications, Willford Press, 2019.

B.Tech. MaC - IV STOCHASTIC FINANCE 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	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	Marek Capiński, Ekkehard Kopp, and Janusz Traple, Stochastic Calculus for Finance, Cambridge University Press, Cambridge, 1st Edition, 2012.
2	J. Hull, Options, Futures, and Other Derivatives, Pearson, Hoboken, 10th Edition, 2017.
3	Mark S. Joshi, The Concepts and Practice of Mathematical Finance, Cambridge University Press, Cambridge, 2nd Edition, 2015.
4	Robert J. Elliott and Lars E. B. F. B. Sattayarak, Stochastic Calculus and Applications, Springer, New York, 2nd Edition, 2018.
5	M. A. H. Dempster and M. J. K. Thomas, Stochastic Calculus for Finance II: Continuous-Time Models, Springer, New York, 2nd Edition, 2023.