Annexure-I

Harcourt Butler Technical University, Kanpur

Department of Computer Science and Engineering

Syllabus

For

M.Tech. (Computer Science & Engineering)

(Effective from the Session: 2022-23)

Course structure and evaluation scheme for M.Tech Computer Science & Engineering
(Effective from the Session: 2022-23)

SEMESTER –I

S.No.	Course Type	Course Code	Course Title	Credits	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	ECS501	Foundation of Computer Science	4(3-0-2)	15	20	15	50	50	100
2.	PCC	ECS503	Advanced Algorithms	4(3-0-2)	15	20	15	50	50	100
3.	PCC	ECS 505	Professional Aspects in Software Engineering	3(3-0-0)	30	20	-	50	50	100
4.	PCC	ECS 507	Research Methodology	3(3-0-0)	30	20	-	50	50	100
5.	PCC	ECS	Departmental Elective I	3(3-0-0)	30	20	-	50	50	100
Total Credits				**17**						

SEMESTER –II

S.No.	Course Type	Course Code	Course Title	Credits	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	ECS 502	Artificial Intelligence	4(3-0-2)	15	20	15	50	50	100
2.	PCC	ECS 504	Computer Networks & Security	4(3-0-2)	15	20	15	50	50	100
3.	PCC	ECS 506	Advanced Databases	3(3-0-0)	30	20	-	50	50	100
4.	PEC	ECS	Departmental Elective II	3(3-0-0)	30	20	-	50	50	100
5.	PEC	ECS	Departmental Elective III	3(3-0-0)	30	20	-	50	50	100
Total Credits				**17**						

SEMESTER –III

S.No.	Course Type	Course Code	Course Title	Credits	Sessional Marks				ESM	Total Mark
					MSE	TA	Lab	Total		
1.	PCC	ECS601	Soft Computing	3(3-0-0)	30	20	-	50	50	100
2.	PCC	ECS	Department Elective IV	3(3-0-0)	30	20	-	50	50	100
3.	PCC	ECS	Department Elective V	3(3-0-0)	30	20	-	50	50	100
4.	PCC	ECS603	Seminar	2(0-0-4)	-	50	-	50	50	100
5.	PCC	ECS605	Minor Dissertation	3(3-0-6)	-	50	-	50	50	100
Total Credits				14						

SEMESTER –IV

S.No.	Course Type	Course Code	Course Title	Credits	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	ECS602	Dissertation	12(0-0-24)	-	50	-	50	50	100
Total Credits				12						

List of Departmental Electives

	BASKET 1	BASKET 2	BASKET 3	BASKET 4	BASKET 5
Departmental Elective I	Data Science ECS-511	Data Warehousing & Data Mining ECS-513	Multimedia Systems ECS-515	Wireless & Mobile Networks ECS-517	Modeling and Simulation ECS-519
Departmental Elective II	Cloud Computing ECS- 512	Software Requirements Engineering and Risk Management ECS- 514	Digital Image Processing ECS- 516	Storage Area Network High ECS- 518	Real Time Systems ECS- 520
Departmental Elective III	Machine Learning ECS-522	Software Project Planning & Management ECS-524	Digital Forensics ECS-526	Performance Networking ECS-528	Embedded Systems ECS-530
Departmental Elective IV	Internet of Things (IoT) ECS-611	Software Testing & Auditing ECS-613	Computer Vision ECS-615	Sensor Network ECS-617	Robotics ECS-619
Departmental Elective V	Big Data Analytics ECS-621	Software Metrics & Quality Assurance ECS-623	Bio informatics ECS-625	Optical Networks ECS-627	Mobile Application Development ECS-629

FOUNDATION OF COMPUTER SCIENCE (ECS 501)

COURSE OBJECTIVES:

- **Review of core concepts of computer science.**
- **To provide theoretical and conceptual knowledge to the student to make their foundation for further learning and research.**

COURSE OUTCOMES:

- To understand the proof of correctness and running time of the algorithms for the classic problems in various domains
- To be able to know the concepts of the algorithms and to know the efficiency of the algorithms.
- to understand the fundamentals of operating systems and advanced topics.
- To understand various catagories of Programming Languages and their design principles.
- To understand the theoretical aspects of computation.
- To learn the design of complex databases through normalization and tackle issues like synchronization.

UNIT-I: DATA STRUCTURE
List, Stack, Queue, Tree, Hash Table, Graph,

UNIT-II: PARADIGMS OF PROGRAMMING LANGUAGES
Imperative Programming Languages: Procedural Vs Object Oriented Paradigm, Declarative Programming : Functional and Logical Programming Languages, Hybrid Paradigm of Programming , Aspect Oriented Programming

UNIT-III: OPERATING SYSTEM
Scheduling Algorithm, Synchronization Technique, Paging and Segmentation, Virtual Memory.

UNIT-IV: AUTOMATA THEORY
Finite Automata, Regular Expression, Context Free Grammar, Push Down Automata.

UNIT-V: DATABASE SYSTEM
Concepts and Architecture; Data Model; Normalization; SQL Advanced Transaction Processing, Deadlock and Concurrency Control.

REFERENCES:

1. Hopcroft & Ullman, "Introduction to Automata Theory, Languages, and Computation", Narosa Publishing House.
2. Aho, Hopcroft and Ullman, "Data Structures and Algorithms", Addison Wesley.

LAB-1: FOUNDATION OF COMPUTER SCIENCE (ECS551)

Laboratory experiments are based on theory contents (total 10 experiments).

ADVANCED ALGORITHM (ECS 503)

Course Outcomes:

- Understand and apply mathematical preliminaries to the analysis and design of various types of algorithms.
- Understand and apply the probabilistic analysis and randomized algorithms.
- Apply various algorithmic strategies and paradigms to model engineering problems.
- Understand NP completeness related issues and approximation to np complete problems.

UNIT 1

Algorithm Fundamentals: Basic Concept, Analysis of Algorithm, Growth of Functions, Master's Theorem. Analysis of algorithms for classic problems in various domains.

UNIT 2

Introduction to Probabilistic Analysis and Randomized Algorithms.

UNIT 3

Advance Design and Analysis Techniques: Dynamic Programming, Greedy Algorithms, Branch and bound, Back Tracking.

UNIT 4

Introduction to Computational Geometry, NP Completeness. Introduction to Approximation Algorithms

UNIT 5

Parallel Algorithm: Performance Measures of Parallel Algorithms, Parallel Merging/Sorting Algorithms on CREW/EREW, Parallel searching algorithms.

REFERENCES:

1. Coreman, Rivest, Lisserson, "Algorithm", PHI.
2. Basse, "Computer Algorithms: Introduction to Design & Analysis",Addision Wesley.
3. Horowitz, Sahani, and Rajasekaran " Fundamental of Computer Algorithms", Universities Press

LAB-II: ADVANCED ALGORITHMS (ECS552)

Laboratory experiments are based on theory contents (total 10 experiments).

Professional Aspects in Software Engineering (ECS 505)

Course Objectives

• The aim of the course is to provide an understanding of the working knowledge of the techniques for estimation, design, testing and quality management of large software development projects.

• Topics include process models, software requirements, software design, software testing, software process/product metrics, risk management, quality management and UML diagrams

Course Outcomes

- The ability to analyze and implement solutions to complex problems involving computer applications and networks
- Ability to translate end-user requirements into system and software requirements, using e.g. UML, and structure the requirements in a Software Requirements Document (SRD).
- Identify and apply appropriate software architectures and patterns to carry out high level design of a system and be able to critically compare alternative choices.
- Will have experience and/or awareness of testing problems and will be able to develop a simple testing report
- A solid understanding to the methods of modern software engineering

UNIT 1

Introduction to Software Engineering: Defining the problem, identifying resources, identifying tools. Process models: The waterfall model, incremental process models, evolutionary process models, the unified process. Agile Methodology- Scrum and XP.

Software Project Management: Software Project Planning and its characteristics, Types of metrics, Effort Estimation- FP, LOC, FP vs. LOC, Helstead's Software Engineering Measures, Cyclomatic Complexity.

Schedule & Cost Estimation Models- Activity Networks-PERT/CPM, COCOMO-I, COCOMO-II, Risk Assessment- Probability Matrix, Risk Management.

UNIT 2

Object Oriented Software Engineering

Object-oriented methodologies. Unified Modeling Language, Use Case Centric Development, Structural and Behavioral Modeling, User Interface design, Component and Deployment Diagrams, Design Principles and Patterns.

UNIT 3

Component-Based Software Engineering: CBSE process, Domain engineering, Component based development, Classifying and retrieving components and economics of CBSE.

Client/Server Software Engineering: Structure of client/server systems, Software engineering for Client/Server systems, Analysis modelling issues, Design for Client/Server systems, Testing issues

UNIT 4

Web Engineering: Attributes Of web-based applications, the WebE process, a framework for WebE. Formulating, Analysing web-based systems, design and testing for web-based applications, Management issues.

UNIT 5

Software Quality: CASE tools, metrics, Standards, Certification and Assessment. TQM, Bootstrap methodology, The SPICE project, ISO-IEC 15504,SEI-CMM, Six Sigma Concept for Software Quality.

Computer-Aided Software Engineering: Building Blocks for CASE, taxonomy Of CASE tools, integrated CASE environments, Integration architecture, and CASE repository.

Recommended Books:

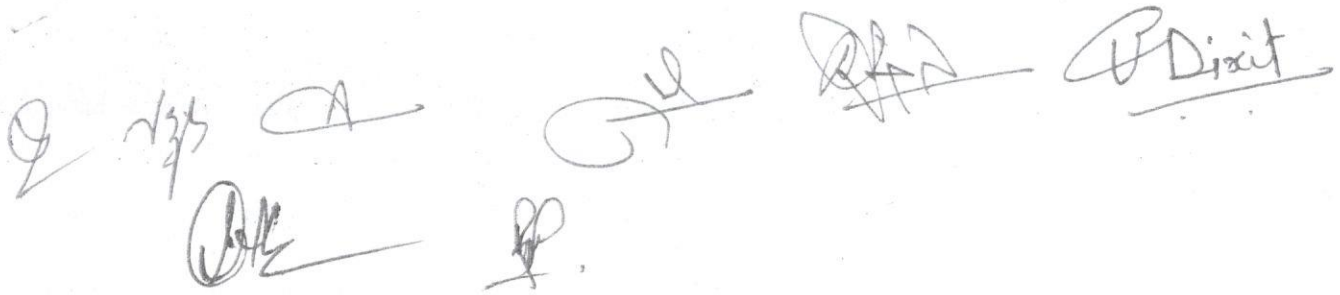
I. Sommerville, "Software Engineering, 9th ed.", Addison Wesley Professional, 2010, ISBN-13: 978-0137035151

II. Roger S. Pressman, Software Engineering a Practitioners Approach, McGraw-Hill.

III. K. K. Agrawal and Yogesh Singh, Software Engineering New Age Publishing

IV. Object-Oriented Software Engineering Practical software development using UML and Java by Timothy C. Lethbridge & Robert Langaniere Mcgraw-Hill Co.

V. Priestley, Object Oriented Design Using UML, Mcgraw Hill Co.



(ECS-507)

RESEARCH METHODOLOGY (~~BMA 701/702~~)

UNIT I

Defining research and research problems, classification of research; Scientific explanation and social science/management research; Review of Literature. Research questions; Research framework; Hypotheses formulation, Research Variable

UNIT II:

Research design formulations; Classification of research design - exploratory research design; descriptive research design.
Causal & experimental research design. Measurement and scaling; Scales of measurements, Comparative and non- comparative scaling techniques; research framework; hypothesis formulation, sample research proposal preparation/ case studies.

UNIT III:

Tools of data collection; Questionnaire design- process and structure; Reliability and validity. Sampling design and procedure; Classification of sampling techniques, Sample size

UNIT IV:

Overview of statistical techniques for data analysis – descriptive, statistics, theoretical distribution, central
limit theorem testing of hypothesis, regression analysis, correlation analysis, inferencing, non-parametric statistics
and test, analysis of variance CANOVA), experimental design, response surface methodology
univariate and multivariate analysis of statistical data

UNIT V:

Ethical issues in Research: Academic Integrity Report, Report writing and use of plagiarism check, citation ethics etc.
Use of Computer softwarere for Data Analysis & Reporting: Report compilation, Overview of Software like MS word,
MS Excel, MS Power point, Latex, SPSS etc.

Reference books:

1. Research Methodology by C.R. Kothari, New age International, New Delhi. (Major contents of unit 1- IV available)
2. Statistical Methods by S. P. Gupta, S. Chand & Sons.
3. Fundamentals of Statistics by D. N. Elhance, KITAB MAHAL ALLAHABAD.
4. Fundamentals of applied statistics b) S.C. Gupta & V.K. Kapoor, S. Chand & Sons.
5. Research Methodology by R. Paneer shelvarn. PHI publications.
6. Research Methodology: A step by step Guide for Beginners by Ranjit Kumar, Sage Publication (I) P. Ltd- New Delhi 4•h edition.
7. Internet sources & Lecture notes.

DATA SCIENCE (ECS 511)

Course Outcomes:

- Understand the core concepts and methods in data science.
- Understand the issues and challenges in data collection , storage and management.
- Understand and Apply various techniques for data analysis.
- Understand various data visualization techniques.
- Understand Learn Python programming tools for data science.

Unit 1

Introduction to core concepts and technologies: Introduction, Terminology, data science process, data science toolkit, Types of data, Example applications, Mathematical Foundations for Data Science: linear algebra; Analytical and numerical solutions of linear equations; Mathematical structures, concepts and notations used in discrete mathematics. Introduction to Statistical Methods: basic and some advanced concepts of probability and statistics; Concepts of statistics in solving problems arising in data science.

Unit 2

Data collection and management: Introduction, Sources of data, Data collection and APIs, Exploring and fixing data, Data storage and management, using multiple data sources.

Unit 3

Data analysis: Introduction, Terminology and concepts, Introduction to statistics, Central tendencies and distributions, Variance, Distribution properties and arithmetic, Samples/CLT, Basic machine learning algorithms, Linear regression, SVM, Naive Bayes.

Unit 4

Data visualization: Introduction, Types of data visualization, Data for visualization: Data types, Data encodings, Retinal variables, mapping variables to encodings, Visual encodings.

Unit 5

Pandas and NumPy: NumPy Basics - Fast Element wise array functions, Multidimensional Array, Data Processing using arrays, file i/o with arrays; Pandas - Data Structures, Essential Functionality, Summarizing and Computing Descriptive Statistics, Handling Missing Data, Hierarchical Indexing.

References:

R. V. Hogg, J. W. McKean and A. Craig, Introduction to Mathematical Statistics, 8th Ed., Pearson Education India, 2019.

Avrim Blum, John Hopcroft, Ravindran Kannan, "Foundations of Data Science", Cambridge University Press, 2020.

Ani Adhikari and John DeNero, 'Computational and Inferential Thinking: The Foundations of Data Science' , GitBook, 2019.

Python For Data Analysis (O Reilly, Wes Mckinney)

DATA WAREHOUSING & DATA MINING (ECS 513)

Course Outcomes:

1. Understand importance of abstraction of Knowledge from unstructured sources. (Understand)
2. Use of data pre-processing, cleaning, transformation and integration for knowledge discovery and data mining principles. (Apply)
3. Understand classification and prediction in the areas of machine learning algorithms which underpin the knowledge discovery. (Understand)
4. Design data mining and data warehousing systems and solutions to meet user requirements and specifications. (Apply, Analyze)
5. Use of multidimensional and web mining as techniques for extracting knowledge from a data warehouse. (Apply, Evaluate)

UNIT-I:

Data Warehousing and Business Analysis: - Data warehousing Components, Building a Data warehouse, Mapping the Data Warehouse to a Multiprocessor Architecture, DBMS Schemas for Decision Support, Data Extraction, Cleanup, and Transformation Tools, Metadata reporting, Query tools and Applications, Online Analytical Processing (OLAP) – OLAP and Multidimensional Data Analysis.

UNIT-II:

Data Mining: - Data Mining Functionalities – Data Preprocessing, Data Cleaning, Data Integration and Transformation, Data Reduction, Data Discretization and Concept Hierarchy Generation.

Association Rule Mining: - Efficient and Scalable Frequent Item set Mining Methods, Mining Various Kinds of Association Rules, Association Mining to Correlation Analysis, Constraint-Based Association Mining.

UNIT-III:

Classification and Prediction: - Issues Regarding Classification and Prediction, Classification by Decision Tree Introduction, Bayesian Classification, Rule Based Classification, Classification by Back propagation, Support Vector Machines, Associative Classification, Lazy Learners, Other Classification Methods, Prediction Accuracy and Error Measures, Evaluating the Accuracy of a Classifier or Predictor , Ensemble Methods, Model Section.

UNIT-IV:

Cluster Analysis: - Types of Data in Cluster Analysis, A Categorization of Major Clustering Methods, Partitioning Methods, Hierarchical methods, Density-Based Methods. Grid-Based Methods, Model-Based Clustering Methods, Clustering High- Dimensional Data, Constraint-Based Cluster Analysis, Outlier Analysis.

UNIT-V:

Mining Object, Spatial, Multimedia, Text and Web Data: Multidimensional Analysis and Descriptive Mining of Complex Data Objects, Spatial Data Mining, Multimedia Data Mining, Text Mining, Mining the World Wide Web.

REFERENCES:

1. Jiawei Han and Micheline Kamber, "Data Mining Concepts and Techniques" Second Edition,
2. Alex Berson and Stephen J. Smith, "Data Warehousing, Data Mining & OLAP", Tata McGraw Hill Edition, Tenth Reprint 2007.

3. G. K. Gupta, "Introduction to Data Mining with Case Studies", Eastern Economy Edition, Prentice Hall of India, 2006.
4. Pang-Ning Tan, Michael Steinbach and Vipin Kumar, "Introduction to Data Mining", Pearson Education, 2007.
5. Soman K.P., Shyam Diwakar and V. Ajay, "*Insight into Data mining Theory and Practice*", Eastern Economy Edition, Prentice Hall of India, 2006.
6. Daniel T.Larose, "*Data Mining Methods and Models*", Wile-Interscience, 2006.

MULTIMEDIA SYSTEMS (ECS 515)

Course Outcome:

- Students will work with all aspects of images, videos and animation.
- Define the basic concepts of image / video coding technology and compression standards
- Describe the fundamentals of multimedia content, description and presentation.
- Design the fundamentals of multimedia communication.
- Explain the concept of wireless multimedia communication.

UNIT-I:
Introduction: Concept of Multimedia, Media & data stream, main properties of multimedia system, Data stream characteristics for continuous media, Multimedia Applications, Hardware Software requirements, Storage Technologies: RAID, Optical Media.

UNIT-II:
Components of multimedia and file formats: Text, Basic sound concepts, MIDI, Speech, Basic concept of Images, Graphics format, Basic concepts of Video & animation, Conventional system, Computer based animation, Authoring Tools, Categories of Authoring Tools. Latest Web technologies, such as XML, X3D and Semantic Web.

UNIT-III:
Compression Techniques: Lossless and Lossy compression, Run length coding, Statistical Coding, Transform Coding, JPEG, MPEG, Text compression using static Huffmann technique, Dynamic Huffmann Technique, Arithmetic Technique.

UNIT-IV:
Multimedia Communication: Stream characteristics for Continuous media – Temporal Relationship – Object Stream Interactions, Media Levity, Media Synchronization – Models for Temporal Specifications – Streaming of Audio and Video – Jitter – Fixed playout and Adaptive playout – Recovering from packet loss – RTSP — Multimedia Communication Standards – RTP/RTCP – SIP and H.263. Multimedia servers, databases and content management; Multimedia information system and applications.

UNIT-V:
Wireless Multimedia Communication: End to End QoS provisioning in Wireless Multimedia Networks – Adaptive Framework – MAC layer QoS enhancements in Wireless Networks – A Hybrid MAC protocol for 10 Multimedia Traffic – Call Admission Control in Wireless Multimedia Networks – A Global QoS Management for Wireless Networks.

REFERENCES:

1. David Hillman, "Multimedia Technology & Applications", Galgotia Publications, 2000
2. Nigel Chapman & Jenny Chapman, "Digital Multimedia", Wiley Publications, 2000 2. D.P. Mukherjee, "Fundamentals of Computer Graphics and Multimedia", PHI, 2001
3. Nalin K Sharda, 'Multimedia Information Networking', Prentice Hall of India, 1999
4. Aura Ganz, Zvi Ganz and Kitti Wongthawaravat, 'Multimedia Wireless Networks: Technologies, Standards and QoS', Prentice Hall, 2003.
5. Ellen Kayata Wesel, 'Wireless Multimedia Communications: Networking Video, Voice and Data', Addision Wesley, 1998

Wireless and Mobile Networks (ECS 517)

Course Outcomes:

- Understand various wireless LAN and Mobile Technologies available in Mobile industry.
- Understand theoretical foundation and core principles of Wireless and Mobile Networks.
- Study the issues and challenges in Mobile routing and various related protocols.
- Study the issues and challenges in mobile transport layer and various related protocols.
- To get aware of state of art and latest industry standards in Wireless Mobile Networks.

Unit-1: Introduction

Wireless and Mobile Networks: History of different types of wireless technologies, Facts, Statistics, and Trends, Wireless Transmission: Signals, Antennas, Coding, Signal Propagation, Multiplexing, Modulation, Spread Spectrum, Introduction to Cellular systems, satellite systems, broadcast systems, Introduction to wireless LANs and technologies like Wi-Fi (IEEE 802.11), WiMAX (IEEE 802.16), Low-rate wireless personal area networks (IEEE 802.15), Bluetooth, Zigbee, LoRA and others.

Unit-2: Cellular Network Foundations

Theoretical foundations in the core principles of modern cellular systems, Network planning techniques, Connectivity requirements analysis, Design of resource allocation mechanisms, Power control for fixed-rate and rate-adaptive systems. Wireless Medium Access Control: Common Problems, SDMA, FDMA, TDMA, CDMA. Wireless Telecommunications Systems: GSM, DECT, TETRA, UMTS, IMT-2000, LTE.

Unit-3: Mobile Network Layer

Issues and Problems of IP in Wireless Networks, Principles behind Mobile IP, Security issues and DHCP, Routing in Ad-hoc Networks and Wireless Sensor Networks: Need for routing and routing classifications, Table Driven Routing Protocols, Source Initiated On-Demand Routing Protocols, Hybrid Protocols – Zone Routing, Basic network performance metrics for evaluating and maintaining Quality of Service (QoS), Concepts and background to distinguish among various performance metrics for different wireless/mobile infrastructures.

Unit-4: Mobile Transport Layer

Effects of mobility and wireless transmissions on reliable transport protocols such as TCP, Support for Mobility: File Systems, databases, WWW and Mobility, WAP, Application layer for mobile networks, Traditional TCP-Congestion Control, Slow start, Fast retransmit/fast recovery, Implications of mobility, Classical TCP, Indirect TCP, Snooping TCP, Mobile TCP, Transmission/time out freezing and advancements.

UNIT-5: Advanced Wireless Networks

Architecture and applications of Cellular, LTE, and 3G/4G/5G Systems, Wireless Broadband Networks-3G, Harmonized 3G, 3G CDMA, Smart Phones and 3G Evolution, 4G Vision, 4G features and challenges, Applications of 4G, 4G Technologies, 5G Wireless technologies, VANET: Connected and autonomous cars, Drone networking.

Reference Books:

1. J. Schiller, Mobile Communications, 2nd edition, Addison Wesley.
2. Wireless Communications and Networks, William Stallings, 2nd edition, Prentice Hall.
3. Erik Dahlman, Stefan Parkvall, Johan Skold and Per Beming, "3G Evolution HSPA and LTE for Mobile Broadbandl, Second Edition, Academic Press, 2008.
4. Anurag Kumar, D. Manjunath, Joy Kuri, Wireless Networking, First Edition, Elsevier 2011.
5. Simon Haykin, Michael Moher, David Koilpillai, Modern Wireless Communications, First Edition, Pearson Education 2013

ECS-519

Modeling and Simulation (~~MTCS-016~~)

Unit-1: Introduction

Systems and system environment, Components of a system, Static and Dynamic systems, Discrete and continuous systems, Model of a system, Types of Models, Art and science of the modeling process, Simulation methods and Principles, Continuous, Discrete-Event and other System Simulation Techniques, Advantages and disadvantages of Simulation, Simulation examples: Simulation of queuing systems.

Unit-2: Physical Modeling

Identify the key parameters of a model, estimate model outcomes, Dimensions analysis, Dimensionless grouping of input and output variables to find empirical relations, similarity criteria and their application to physical models, Modeling of System with Known Structure, Deterministic model, State Space Model, Transfer functions block diagram and sub systems, Modeling for control.

UNIT-3: Random Processes and Queuing Models

Random process, Discrete/continuous time processes, Markovian property, Markov chain, State Transition Diagrams, Birth-death process, Little's theorem, Introduction to Queues and Random Noise, Random Variates Generation, Sensitivity Analysis, Steady state analysis of M/M/1 model; multi-server models, M/G/1 and other queuing models, Burke's theorem, network of queues, Jackson theorem.

UNIT-4: Model Performance

Probability density and distribution functions, Location, scale and shape parameters, discrete and continuous probability distributions; Inverse transform method, composition and acceptance-rejection methods, efficiency and quality measures, Measures of performance and their estimation, Output analysis for terminating and steady-state simulations, Verification, Calibration, Validation and Optimization of models via Simulation.

UNIT-5: Simulation, Analysis and Viewing Tools

General structure and features of a simulation tool, Study of MATLAB as a simulation tool to describe the system syntax, define elementary representations, functions etc., Explain programming and the scripting process, e.g., relational operations, logical representations, condition statements, loops, etc., Create tabular and graphical and multidimensional visualization results. Various important tool boxes of MATLAB.

Reference Books:

1. Law, A.M. and Kelton, W.D., "Simulation, Modeling and Analysis", 3rd Ed., Tata McGraw-Hill.
2. Banks, J., Carson, L.S., Nelson, B.L. and Nicol, D.M., "Discrete Event System Simulation", 4th Ed., Pearson Education
3. Alberto Leon-Garcia, "Probability and Random Processes for Electrical Engineers", 2nd Ed., Pearson Education
4. Network Simulation: SimEvent tool box in MATLAB, general features of network simulation packages, case study of OMNET++/ns2/ns3/NetSim.