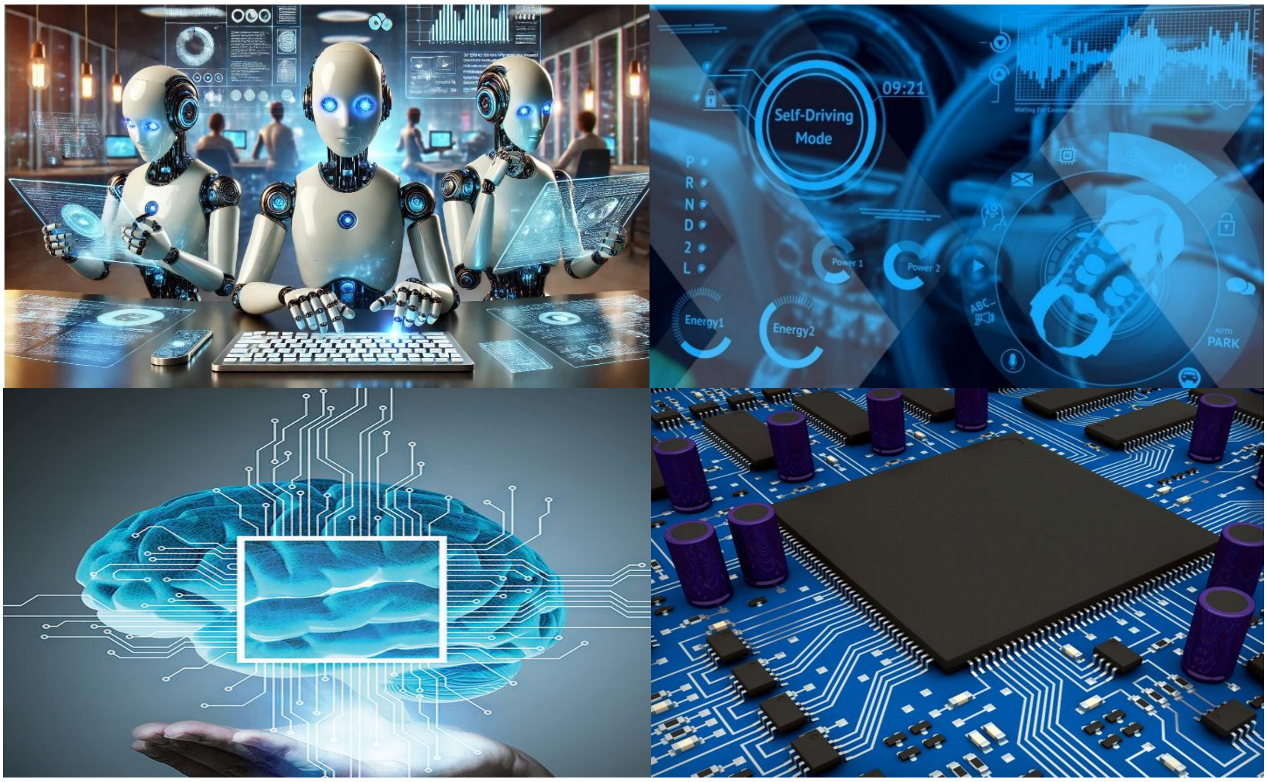
Curriculum & Contents

M. Tech.

Autonomous Systems and Machine Intelligence (ASMI)



Offered by: Electrical and Electronics Engineering Department (EEE)

विश्वजीवनामृतं ज्ञानम्

ABV-Indian Institute of Information Technology & Management, Gwalior

Name of the program: M. Tech. (Autonomous Systems and Machine Intelligence)
(Credits: 72)

Name of the Department: Electrical and Electronics Engineering

SEMESTER-I				
S. No.	**Subject Code**	**Title of the course**	**L-T-P**	**Credits**
1.	EE-603	Machine Learning Techniques	3-0-2	4
2.	EE-612	Sensors and Actuators	3-0-2	4
3.	EE-613	Next-Generation Communication Systems	3-0-2	4
4.	EE-614	Human-Machine Interaction	3-0-0	3
5.	EE-XXX	Elective-1	3-0-0	3
6.	EE-XXX	Elective-2	3-0-0	3
			Total credits	**21**

SEMESTER-II				
S. No.	**Subject code**	**Title of the course**	**L-T-P**	**Credits**
1.	EE-615	Autonomous Systems	3-0-2	4
2.	EE-616	Artificial Intelligence	3-0-2	4
3.	EE-617	Advanced Embedded Systems	3-0-2	4
4.	EE-609	Engineering Research Methodology	2-1-0	3
5.	EE-XXX	Elective-3	3-0-0	3
6.	EE-XXX	Elective-4	3-0-0	3
			Total credits	**21**

EXIT AFTER YEAR-1: Post Graduate Diploma in Autonomous Systems and Machine Intelligence

SEMESTER-III				
S. No.	**Subject code**	**Title of the course**	**L-T-P**	**Credits**
1	EE-XXX	MOOC-1/ Elective-5	3-0-0	3
2	EE-698	M. Tech Dissertation-I / Internship	NA	12
			Total credits	**15**

SEMESTER-IV				
S. No.	**Subject Code**	**Title of the course**	**L-T-P**	**Credits**
1	EE-699	M. Tech Dissertation-II / Internship	NA	15
			Total credits	**15**

SEMESTER-I	SEMESTER-II	SEMESTER-III	SEMESTER-IV	TOTAL CREDITS
21	21	15	15	**72**

S.N.	Code	Electives I,II,III, IV, and V Category: Autonomous & Intelligent Transportation, Communication & Signal Processing, VLSI & Embedded Systems
1	EE-065	High-Performance Computing Systems
2	EE-067	Sensors for Autonomous System
3	EE-073	Data Analytics
4	EE-075	Reinforcement Learning
5	EE-078	Quantum Computing
6	EE-080	Deep Learning for Autonomous Systems
7	EE-082	Advanced Control System
8	EE-069	Digital Image Computation
9	EE-070	Audio Signal Processing
10	EE-071	Advanced Digital Signal Processing
11	EE-072	Biomedical Signal Processing
12	EE-074	Computer Vision
13	EE-076	Internet of Bio-Nano Things
14	EE-079	Cyber Security
15	EE-081	Optimization Techniques
16	EE-083	Internet of Things
17	EE-085	Software Defined Radio
18	EE-086	Quantum Communication
19	EE-087	5G and 6G standards
20	EE-088	Smart Antennas
21	EE-089	Advanced Optical Communication
22	EE-092	Data Communication Protocol
23	EE-051	Device and Interconnect Modelling
24	EE-052	VLSI Signal Processing

25	EE-053	Low Power VLSI
26	EE-054	Microcontroller and Embedded Systems
27	EE-055	Memory Devices and Circuits
28	EE-056	VLSI Architecture
29	EE-057	Hardware Security
30	EE-058	FPGA-Based System Design
31	EE-059	Quantum Electronics
32	EE-060	RF Circuit Design
33	EE-061	Mixed Signal SoC Design
34	EE-062	AI-Accelerator Design
35	EE-063	System-on-Chip Design
36	EE-064	Embedded Software
37	EE-066	Special Topics in IC Design and Technology
38	EE-068	Network on Chip
39	EE-602	System Design using HDL
40	EE-608	Design Verification and Testing
41	EE-610	CAD for VLSI

Course Contents

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-603
4	**Title of the subject**	Machine Learning Techniques
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand key machine learning concepts and algorithms, including supervised and unsupervised learning. • Gain practical experience in implementing machine learning models. • Learn data preprocessing techniques and model evaluation methods for accurate performance assessment. • Explore neural networks and deep learning basics, focusing on real-world applications.
8	**Brief Contents**	Supervised, unsupervised, and reinforcement learning, along with their real-world applications. It explores key algorithms like linear regression for model fitting and evaluation, and classification techniques such as Logistic Regression, K-Nearest Neighbors, and Support Vector Machines. The course also delves into decision trees and random forests, examining their use in both classification and regression tasks. Unsupervised learning methods like K-means clustering, Hierarchical Clustering, and DBSCAN are discussed. Basics of neural networks, including their architecture, backpropagation, and activation functions. Students will learn how to evaluate models using techniques like cross-validation, confusion matrices, precision, recall, and F1 scores. Dimensionality reduction techniques, including PCA etc.
9	**Lab Content**	Implementation of various machine learning algorithms, starting with supervised learning techniques like linear regression, logistic regression, K-Nearest Neighbors, and Support Vector Machines for both classification and regression tasks. They will explore unsupervised learning methods such as K-means clustering, Hierarchical Clustering, and DBSCAN to uncover patterns in data. The lab will also cover decision trees and random forests, and introduce students to the basics of neural networks, including their architecture, backpropagation, and activation functions. Additionally, students will practice model evaluation using techniques like cross-validation, confusion matrices, precision, recall, and F1 scores. The lab will conclude with experiments on dimensionality reduction using methods like PCA to simplify complex datasets.
10	**Text/ Reference Books**	1. "Pattern Recognition and Machine Learning" by Christopher M. Bishop 2. "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow" by Aurélien Géron 3. "Machine Learning: A Probabilistic Perspective" by Kevin P. Murphy 4. "Introduction to Machine Learning with Python" by Andreas C. Müller and Sarah Guido 5. "MATLAB for Machine Learning" by Giuseppe Ciaburro

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-612
4	**Title of the subject**	Sensors and Actuators
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand the principles and working mechanisms of various types of sensors and actuators. • Explore calibration techniques and the characteristics of different sensors in real-world environments. • Gain hands-on experience in controlling actuators such as motors and solenoids for the development of autonomous systems.
8	**Brief Contents**	This course covers the principles, design, and applications of sensors and actuators in modern systems. Topics include the working principles of various types of sensors such as temperature, pressure, humidity, proximity, and motion sensors. Students will explore the characteristics and calibration. The course also focuses on actuators, including motors, solenoids, and piezoelectric devices, discussing their control use for the development for autonomous systems. Practical sessions will involve designing and implementing systems that use sensors and actuators for real-time monitoring and actuation applications.
9	**Lab Content**	The lab covers experiments on different types of sensors, including temperature sensors (thermocouples, RTDs, thermistors), light and proximity sensors (LDR, IR, ultrasonic), pressure and force sensors (strain gauges, load cells), motion and acceleration sensors (accelerometers, gyroscopes), gas and humidity sensors (MQ-series, DHT11/DHT22), and magnetic sensors (Hall-effect). Additionally, students work with actuators such as DC motors, stepper motors, servo motors, and pneumatic/hydraulic actuators. The lab also focuses on interfacing sensors with microcontrollers like Arduino or Raspberry Pi, enabling real-time data acquisition and control. Advanced topics include smart sensors, IoT applications, and wireless sensor networks.
10	**Text/ Reference Books**	1. Introduction to Sensors and Actuators by John R. Gardner 2. Sensors and Actuators: Engineering System Instrumentation by D. Patranabis 3. Sensors and Transducers by D. Patranabis 4. The Art of Electronics by Paul Horowitz and Winfield Hill

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-613
4	**Title of the subject**	Next-Generation Communication Systems
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand the communication requirements and challenges in autonomous systems. • Explore various wireless communication technologies and network protocols. • Learn sensor network integration and data fusion techniques for autonomous system functionality.
8	**Brief Contents**	This course focuses on communication technologies for autonomous system. It covers communication requirements and challenges in autonomous environments. Topics include signal representation, transmission, and reception. The course also explores multipath fading, path-loss, and noise in communication systems, and how they affect signal quality. Additionally, it covers various next generation wireless communication technologies, network protocols (TCP/IP, UDP, real-time protocols), and machine-to-machine (M2M) communication. The course also explores sensor networks, data fusion techniques etc.
9	**Lab Content**	Network simulation tools such as NS-3 or MATLAB Simulink help in modeling wireless communication environments, analyzing multipath fading, path loss, and network performance. Microcontrollers and embedded systems, including Raspberry Pi and Arduino, are employed for sensor network implementation and machine-to-machine (M2M) communication. Various network analysis tools like Wireshark are used to inspect and evaluate TCP/IP, UDP, and real-time communication protocols. Additionally, data fusion techniques are implemented using Python and MATLAB to process and integrate sensor data from multiple sources. Security and encryption mechanisms are explored using cryptographic libraries and network security tools.
10	**Text/ Reference Books**	1. “Communication Systems" by Simon Haykin 2. “Wireless Communications: Principles and Practice" by Theodore S. Rappaport 3. “Autonomous Vehicles: Opportunities, Strategies, and Disruptions" by Daniel P. K. Riewoldt 4. “Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms" by Nikolaus Correll et al. 5. “Principles of Modern Wireless Communication Systems, Theory and Practice,” A. Jagannatham, McGraw Hill Education (India) Private Limited, 2016.

1	**Semester**	I
2	**Type of course**	Core
3	**Code of the subject**	EE-614
4	**Title of the subject**	Human-Machine Interaction
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamental principles and technologies of human-machine interaction. • Develop skills in designing and evaluating user interfaces with a focus on usability. • Gain proficiency in audio-based interaction techniques, including speech recognition and synthesis. • Learn to implement signal and image-based interaction methods, such as gesture recognition and computer vision.
8	**Brief Contents**	Explores technologies and principles for human-machine interaction (HMI), with a focus on audio, signal, and image-based communication. Fundamental UI design concepts and usability principles to enhance user experience. Speech recognition and synthesis techniques for audio-based communication with machines. Methods to interpret human inputs such as gestures and physiological signals. Computer vision techniques used for face and emotion recognition, gesture detection, and object detection. Relevant tools and frameworks for developing HMI systems based on audio, signal, and image data.
9	**Text/ Reference Books**	1. "Human-Machine Interaction: Control, Communication, and Cognition" by Ian R. McAndrew and Alan M. Wing 2. "Introduction to Mechatronics and Measurement Systems" by David G. Alciatore and Michael B. Histand 3. "Designing the User Interface: Strategies for Effective Human-Computer Interaction" by Ben Shneiderman, Catherine Plaisant, Maxine Cohen, and Steven Jacobs 4. "Human-Computer Interaction" by Alan Dix, Janet Finlay, Gregory D. Abowd, and Russell Beale 5. "Speech and Language Processing" by Daniel Jurafsky and James H. Martin 6. "Computer Vision: Algorithms and Applications" by Richard Szeliski 7. "Designing the User Interface: Strategies for Effective Human-Computer Interaction" by Ben Shneiderman et al.

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-615
4	**Title of the subject**	Autonomous Systems
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand the principles and applications of autonomous systems in robotics, drones, and self-driving vehicles. • Learn the integration and role of sensors like LIDAR, radar, cameras, and IMUs in perception and data collection. • Implement computer vision and deep learning techniques for object detection, tracking, and decision-making in autonomous systems. • Apply path planning, SLAM-based localization, reinforcement learning, and control algorithms for autonomous navigation and decision-making.
8	**Brief Contents**	Introduction to autonomous systems and their applications in robotics, drones, and self-driving vehicles, followed by an exploration of key sensors like LIDAR, radar, cameras, and IMUs (Inertial Measurement Units) and their role in perception and data collection. The course covers computer vision techniques for image processing, feature extraction, object detection, and tracking, along with deep learning architectures such as CNNs and RNNs for decision-making and navigation. Students will also study sensor fusion methods, including Kalman filtering and deep sensor fusion, to combine data from multiple sensors for enhanced accuracy. The syllabus includes path planning, real-time navigation, localization using SLAM, and reinforcement learning for decision-making in dynamic environments. Control systems for vehicle dynamics and the ethical, safety, and security aspects of autonomous systems are also discussed. Finally, the course delves into real-world applications through case studies and hands-on projects.
9	**Lab Content**	In the lab sessions, students will implement and test various autonomous system algorithms using sensors like LIDAR, cameras, and IMUs for perception and navigation. They will work on computer vision tasks, including image processing, object detection, and tracking, using deep learning models such as CNNs. Sensor fusion techniques, including Kalman filtering, will be applied to combine data from multiple sensors for enhanced accuracy. Students will also develop and evaluate path planning and localization algorithms like SLAM for real-time navigation. The lab will include hands-on projects focused on autonomous decision-making and control in dynamic environments.
10	**Text/ Reference Books**	1. "Autonomous Systems: A Comprehensive Approach" by Michael A. Hsieh 2. "Autonomous Robots: From Biological Inspiration to Implementation and Control" by George A. Bekey 3. "Computer Vision: Algorithms and Applications" by Richard Szeliski 4. "Autonomous Vehicles: Opportunities, Strategies, and Disruptions" by Chris Gerdes, Wade H. H. 5. "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville 6. "Robotics: Modelling, Planning and Control" by Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-616
4	**Title of the subject**	Artificial Intelligence
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand the fundamental concepts and techniques in artificial intelligence, including search algorithms and knowledge representation. • Learn probabilistic reasoning and Bayesian networks for handling uncertainty in AI systems. • Gain expertise in reinforcement learning and its applications in decision-making and autonomous systems. • Explore deep learning models and their use in solving complex problems like image recognition.
8	**Brief Content s**	Artificial Intelligence explores core concepts of AI, adversarial each, Bayesian rule, probabilistic learning, reinforcement learning, and deep learning techniques. The course begins with an introduction to the history and applications of AI, followed by a deep dive into search algorithms, including adversarial search used in game-playing AI. Students will learn about the Bayesian rule for probabilistic reasoning and its applications in AI. The course covers probabilistic learning methods, emphasizing the understanding and implementation of models that handle uncertainty. Reinforcement learning is explored in detail, focusing on algorithms that enable agents to learn optimal behaviors through interaction with their environment. Deep learning techniques are introduced, highlighting neural networks, convolutional neural networks (CNNs), and recurrent neural networks (RNNs) for tasks such as image recognition. Practical sessions involve hands-on experience with AI tools like Python, TensorFlow, and PyTorch. By the end of the course, students will be proficient in applying AI methods to solve complex problems.
9	**Lab Content**	Python basics (NumPy, Pandas, Matplotlib, Sklearn), search algorithms (BFS, DFS, A*), constraint satisfaction problems (Sudoku, N-Queens), supervised learning (linear & logistic regression, decision trees, random forest), unsupervised learning (K-means clustering, PCA), neural networks (MLP, CNN using TensorFlow/Keras), NLP (sentiment analysis, named entity recognition), reinforcement learning (Q-learning, OpenAI Gym), computer vision (face detection, object recognition with YOLO), AI ethics (bias analysis, explainability techniques).
9	**Text/ Reference Books**	1. "Artificial Intelligence: A Modern Approach" by Stuart Russell and Peter Norvig 2. "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville 3. "Reinforcement Learning: An Introduction" by Richard S. Sutton and Andrew G. Barto 4. "Pattern Recognition and Machine Learning" by Christopher M. Bishop

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-617
4	**Title of the subject**	Advanced Embedded Systems
5	**Any prerequisite**	None
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Understand the architecture and design principles of embedded systems and microcontrollers. • Develop proficiency in programming microcontrollers and implementing real-time applications using C/C++. • Gain hands-on experience in interfacing peripherals, integrating sensors, and using communication protocols in embedded systems.
8	**Brief Contents**	This course introduces the fundamentals of embedded systems, focusing on microcontroller architecture, real-time operating systems (RTOS), and interfacing techniques. Topics include embedded system design, hardware and software integration, and the use of development tools. Students will explore programming microcontrollers, using languages such as C/C++, and implementing real-time applications. The course covers peripheral interfacing, sensor integration, and communication protocols (I2C, SPI, UART). Practical lab sessions provide hands-on experience in designing, coding, and debugging embedded systems. Applications in various fields, such as automotive, healthcare, and consumer electronics, will be examined, highlighting the role of embedded systems in modern technology.
9	**Lab Content**	The lab component of this course provides hands-on experience in designing, programming, and debugging embedded systems, focusing on microcontroller architecture, real-time operating systems (RTOS), and hardware-software integration. Students will work with microcontrollers such as Arduino, ESP32, and STM32 to develop real-time applications using C and C++. Experiments include peripheral interfacing, where students integrate sensors, actuators, and communication modules using I2C, SPI, and UART protocols. The lab also covers RTOS implementation, allowing students to manage real-time tasks and scheduling efficiently. Development tools such as Keil, MPLAB, and Platform IO are used for coding, compiling, and debugging embedded applications.
10	**Text/ Reference Books**	1. "Embedded Systems: Design and Applications" by Jean-Claude Baron, Didier El Baz, and Michael A. Pecht 2. "The Art of Designing Embedded Systems" by Jack Ganssle 3. "Embedded Systems: Real-Time Interfacing to ARM Cortex-M Microcontrollers" by Jonathan W. Valvano 4. "Programming Embedded Systems: With C and GNU Development Tools" by Michael Barr and Anthony Massa

1	**Semester**	II
2	**Type of course**	Core
3	**Code of the subject**	EE-609
4	**Title of the subject**	Engineering Research Methodology
5	**Any prerequisite**	None
6	**L-T-P**	2-1-0
7	**Learning Objectives of the subject**	• Equip students with the ability to formulate research problems, design experiments, and employ appropriate research methodologies in engineering. • Teach students to collect, analyse, and interpret data using various statistical and computational tools. • Instil a strong understanding of ethical considerations in research, including data integrity, plagiarism, and responsible reporting. • Develop students' skills in technical writing and presentation, enabling them to effectively communicate research findings. • Foster critical thinking and problem-solving abilities, preparing students to tackle complex engineering challenges through rigorous research.
8	**Brief Contents**	This course provides an in-depth understanding of research techniques and methodologies essential for engineering research. Topics include the formulation of research problems, literature review, research design, and experimental methods. Students will learn quantitative and qualitative research methods, data collection and analysis techniques, and the use of statistical tools. The course covers ethical considerations, technical writing, and presentation skills, emphasizing the importance of reproducibility and peer review. Practical sessions will involve developing research proposals, designing experiments, and analysing real-world data, equipping students with the skills to conduct rigorous and impactful engineering research.
9	**Text/ Reference Books**	1. "Research Methodology: A Step-by-Step Guide for Beginners" by Ranjit Kumar 2. "Research Methods for Engineers" by David V. Thiel 3. "Engineering Research: Design, Methods, and Analysis" by Herman Tang 4. "The Craft of Research" by Wayne C. Booth, Gregory G. Colomb, and Joseph M. Williams

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-065
4	**Title of the subject**	High Performance Computing Systems
5	**Any prerequisite**	VLSI Architecture
6	**L-T-P**	3-0-0
7	**Learning Objectives ofthe subject**	• To get in-depth analysis of issues in High Performance Computing systems including Parallel Computing, New Processor Architectures, Power-Aware Computing and Communication, Advanced Topics on Peta scale Computing and Optical Systems. • To understand parallel models of computation such as dataflow, and demand-driven computation.
8	**Brief Contents**	Parallel Processing Concepts; Levels and model of parallelism: Instruction, Transaction, Task, Thread, Memory, Function, Data Flow models, Demand-driven computation; Parallel architectures: Superscalar architectures, Multi-core, Multi- threaded, Server and cloud; Fundamental design issues in HPC: Load balancing, scheduling, Synchronization and resource management; Operating systems for scalable HPC; Parallel languages and programming environments; Fundamental limitations in HPC, Benchmarking HPC, Scalable storage systems, Accelerated HPC, Power-aware HPC Design.
9	**Text/ Reference Books**	1. “High Performance Computing: Modern Systems and Practices" by Thomas Sterling, Matthew Anderson, Maciej Brodowicz, Morgan Kaufmann, 2017. 2. “Introduction to High Performance Computing for Scientists and Engineers" by Georg Hager and Gerhard Wellein, CRC Press, 2010. 3. “Parallel Computer Architecture: A Hardware/Software Approach" by David Culler and Jaswinder Pal Singh, Morgan Kaufmann 1998. 4. “Dataflow Supercomputing" by Patrick K. O'Neil, Springer International Publishing AG, 2017. 5. “Power-Aware Computing" by Andrea Biedenkapp, Rainer Hartenstein, et al. 6. “Introduction to High Performance Computing for Scientists and Engineers" by Georg Hager and Gerhard Wellein

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-067
4	**Title of the subject**	Sensors for Autonomous System
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understanding the fundamentals and functionality of micro sensors. • Exploring sensor usage in autonomous systems. • Examining sensor integration for real-time applications. • Learning mathematical modeling and estimation techniques for real-world systems. • Studying various approaches, including optimization techniques, to achieve desired system outcomes.
8	**Brief Contents**	Introduction and Historical Background, Microsensors, Sensor Principles/Classification-Physical Sensors, Methods for Data Acquisition, Modelling Dynamic Systems using Transfer Functions, Multiple-input-Multiple-output Systems, Feedback control methods, Rule based and Optimization Approaches, Hardware Development, System Dependability, Fault Detection, Diagnosis and Prognosis.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Introduction to Sensors and Actuators" by John R. Gardner. 2. "Sensor Fusion Approaches for Positioning, Navigation, and Mapping: How Autonomous Vehicles and Robots Navigate in the Real World: With MATLAB Examples" by Mohamed M. Atia 3. "Robotics and Smart Autonomous Systems" by Rashmi Priyadarshini, Ram Mohan Mehra, Amit Sehgal, and Prabhu Jyot Singh

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-073
4	**Title of the subject**	Data Analytics
5	**Any prerequisite**	Should have knowledge of one Programming Language (Java preferably), Practice of SQL (queries and sub queries), exposure to Linux Environment.
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the Big Data Platform and its Use cases • Provide an overview of Apache Hadoop • Understand Map Reduce Jobs • Provide hands on Hadoop Eco System • Apply analytics on Structured, Unstructured Data • Exposure to Data Analytics with R
8	**Brief Contents**	Types of Digital Data, Introduction to Big Data, Big Data Analytics, History of Hadoop, Apache Hadoop, Analyzing Data with Unix and Hadoop, Hadoop Streaming, Hadoop Echo System, IBM Big Data Strategy, HDFS Concepts, Command Line Interface, Hadoop file system interfaces, Data flow, Data Ingest with Flume and Scoop and Hadoop archives, Map Reduce Anatomy of a Map Reduce Job Run, Failures, Job Scheduling, Shuffle and Sort, Task Execution, Map Reduce Types and Formats, Map Reduce Features, Introduction to PIG, Execution Modes of Pig, User Defined Functions, Data Processing operators, Data Analytics with R Machine Learning, Big Data Analytics with BigR.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Data Analytics Made Accessible" by Anil Maheshwari (2023 Edition) 2. "Advancing Into Analytics: From Excel to Python and R" by George Mount (2021) 3. "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython" by Wes McKinney (2017) 4. "The Data Warehouse Toolkit: The Definitive Guide to Dimensional Modeling" by Ralph Kimball and Margy Ross (2013) 5. "Data Mining: Concepts and Techniques" by Jiawei Han, Micheline Kamber, and Jian Pei (2011)

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-075
4	**Title of the subject**	Reinforcement Learning
5	**Any prerequisite**	Understanding of Signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamentals of reinforcement learning and Markov decision processes (MDPs). • Learn key algorithms such as Q-learning, Monte Carlo methods, and temporal-difference learning. • Explore advanced techniques in deep reinforcement learning using neural networks. • Implement reinforcement learning algorithms and apply them to real-world problems using Python.
8	**Brief Contents**	The "Reinforcement Learning" course delves into the core concepts and methodologies of reinforcement learning (RL), where agents learn to make decisions by interacting with their environment. Topics include Markov decision processes (MDPs), dynamic programming, Monte Carlo methods, and temporal-difference learning. Students will explore advanced RL techniques such as Q-learning, policy gradients, and deep reinforcement learning using neural networks. The course also covers applications in robotics, game playing, and autonomous systems. Practical sessions involve implementing RL algorithms using Python and frameworks like TensorFlow or PyTorch. By the end of the course, students will be capable of designing and deploying RL solutions for complex problems.
9	**Text/ Reference Books**	1. "Reinforcement Learning: An Introduction" by Richard S. Sutton and Andrew G. Barto 2. "Deep Reinforcement Learning Hands-On" by Maxim Lapan 3. "Reinforcement Learning: State-of-the-Art" edited by Marco Wiering and Martijn van Otterlo 4. "Python Reinforcement Learning" by Sudharsan Ravichandran

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-078
4	**Title of the subject**	Quantum Computing
5	**Any prerequisite**	NA
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course serves as an introduction to the quantum computational model, focusing on understanding and analysing fundamental quantum algorithms. It also explores the limitations of quantum algorithms and provides the essential tools and techniques to demonstrate these constraints.
8	**Brief Content s**	Introduction: Elementary quantum mechanics: linear algebra for quantum mechanics, Quantum states in Hilbert space, The Bloch sphere, Density operators, generalized measurements, no-cloning theorem. Quantum correlations: Bell inequalities and entanglement, Schmidt decomposition, superdense coding, teleportation. Quantum cryptography: quantum key distribution. Quantum gates and algorithms: Universal set of gates, quantum circuits, Solovay-Kitaev theorem, Deutsch-Jozsa algorithm, factoring. Programming a quantum computer: The IBMQ, coding a quantum computer using a simulator to carry out basic quantum measurement and state analysis.
9	**Text/ Reference Books**	1. Phillip Kaye, Raymond Laflamme et. al., An introduction to Quantum Computing, Oxford University press, 2007. 2. Chris Bernhardt, Quantum Computing for Everyone, The MIT Press, Cambridge, 2020 3. David McMahon-Quantum Computing Explained-Wiley-Interscience, IEEE Computer Society (2008). 4. Quantum Computation and Quantum Information, M. A. Nielsen &I. Chuang, Cambridge University Press (2013). 5. (5) Quantum Computing, A Gentle Introduction, Eleanor G. Rieffel and Wolfgang H. Polak MIT press (2014)

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-080
4	**Title of the subject**	Deep Learning for Autonomous Systems
5	**Any prerequisite**	Machine Learning
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Provide an in-depth understanding of deep learning techniques and their applications in autonomous systems. • Enable students to design and implement neural networks for perception, decision-making, and control in autonomous systems. • Introduce state-of-the-art deep learning frameworks and tools for real-world deployment. • Foster the ability to address challenges like dynamic environments, uncertainty, and real-time processing in autonomous systems.
8	**Brief Contents**	Introduction: Defining Autonomous Systems, Artificial Intelligence, Machine Learning, and Deep learning. Overview of the 3 pillars of Autonomous Vehicles: Perception, Prediction, Planning and Quick overview of sensing modalities. Deep learning for Perception, Introduction to deep learning, Neural Network, CNN, regularization techniques. State-of-the-art techniques: Self supervised learning, Vision Transformer, and Deep learning for Prediction. Introduction to Recurrent Neural Networks, Graph Neural Network, Transformer, Diffusion. Generative Models: Variational Autoencoders (VAEs) and Generative Adversarial Networks (GANs) for simulation and environment modeling. Case Studies and Applications: Real-world examples in autonomous vehicles, drones, and robotic systems, addressing challenges in dynamic and uncertain environments.
9	**Text/ Reference Books**	1. Deep Learning From Scratch: Building with Python from First Principles by Seth Weidman. 2. Deep Learning for Computer Vision with Python

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-082
4	**Title of the subject**	Advanced Control System
5	**Any prerequisite**	Understanding of Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand state-space representation and concepts of controllability and observability. • Learn advanced control methods such as optimal, robust, and adaptive control. • Apply modern control design techniques like pole placement and LQR. • Develop and simulate advanced control systems using MATLAB/Simulink for real-world applications.
8	**Brief Contents**	Control theory for designing and analysing complex control systems. State-space representation, controllability, observability, and state feedback control. Students will explore advanced methods like optimal control, robust control, and adaptive control systems. Modern control design techniques such as pole placement, linear quadratic regulator (LQR), and H-infinity control. Students will study the application of these techniques in systems with uncertainty and nonlinearity. Practical sessions involve MATLAB/Simulink to model and simulate advanced control systems, preparing students to tackle real-world control engineering challenges.
9	**Text/ Reference Books**	1. "Modern Control Engineering" by Ogata Katsuhiko 2. "Feedback Control of Dynamic Systems" by Gene F. Franklin, J. Da Powell, and Abbas Emami-Naeini 3. "Advanced Control Engineering" by Roland S. Burns 4. "Robust Control: The Parameter Space Approach" by Kemin Zhou and John C. Doyle

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-069
4	**Title of the subject**	Digital Image Computation
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamentals of digital image representation, storage, and color models in image processing. • Learn techniques for image transformation, enhancement, filtering, and noise reduction. • Gain skills in image segmentation, feature extraction, and morphological processing for object analysis. • Apply image compression and machine learning techniques for recognition, classification, and practical applications.
8	**Brief Contents**	This course covers essential techniques and methods in digital image processing, beginning with an introduction to digital images, their representation, and storage, including color models and resolution. It explores image transformations such as Fourier Transform and Discrete Fourier Transform (DFT) for image analysis and filtering, followed by image enhancement techniques like histogram equalization and noise reduction. Students will learn about linear and nonlinear image filtering, segmentation, and feature extraction methods such as SIFT and SURF for object detection and recognition. The course also covers morphological image processing, including dilation, erosion, and shape analysis, as well as image compression methods like JPEG and PNG. Finally, the course applies machine learning techniques for image recognition and classification, with real-world applications in medical imaging, remote sensing, computer vision, and digital photography.
9	**Lab Content**	Not Applicable
10	**Text/ Reference Books**	1. "Digital Image Processing" by Rafael C. Gonzalez and Richard E. Woods 2. "Computer Vision: Algorithms and Applications" by Richard Szeliski 3. ""Pattern Recognition and Machine Learning" by Christopher M. Bishop 4. "Digital Image Processing Using MATLAB" by Rafael C. Gonzalez, Richard E. Woods, and Steven L. Eddins 5. "Practical Python and OpenCV + Case Studies" by Adrian Rosebrock

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-070
4	**Title of the subject**	Audio Signal Processing
5	**Any prerequisite**	Signals and Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Focuses on algorithms for acoustic and audio signal processing, including applications in audio algorithm design and signal analysis. • Emphasizes critical areas such as monophonic and stereophonic echo cancellation, active noise control, and feedback reduction in communication systems. • Addresses real-world challenges in both wired and wireless communication, with an emphasis on audio signal processing technologies used globally in various industries.
8	**Brief Contents**	Audio signal recording, analysis and representation techniques, audio measurement, sound intensity, noise signal analysis and characterization, stationary and nonstationary signals, probabilistic signal processing techniques with applications for acoustic & audio signal analysis, digital filters for audio enhancement. Characteristics of widely interfaced acoustic signals, multiple sub-filters different error, common error and combined error algorithms, monophonic and stereophonic acoustic echo-cancellation, active noise suppression, feedback cancellation.
9	**Text/ Reference Books**	1. D. Manolakis, M. Ingle, S. Kogon, Statistical and Adaptive Signal Processing, McGraw-Hill, Revised Edition 2014. 2. Jacob Benesty, Israel Cohen, Jingdong Chen, Fundamentals of Signal Enhancement and Array Signal Processing, Wiley & Sons, 2018. 3. Udo Zolzer, Digital Audio Signal Processing, Wiley & Sons, 2008. 4. Steven L. Gay, Jacob Benesty, Acoustic Signal Processing for Telecommunication, Springer, 2001.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-071
4	**Title of the subject**	Advance Digital Signal Processing
5	**Any prerequisite**	Signals and Systems, Digital Signal Processing
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the advanced principles of digital signal processing (DSP) and its applications in real-time systems. • Develop proficiency in advanced DSP techniques such as adaptive filtering, multirate signal processing, and spectral analysis. • Gain expertise in the design and implementation of efficient DSP algorithms for applications like speech, audio, and image processing.
8	**Brief Contents**	Overview of advanced topics in DSP including sampling, quantization, and the z-transform. Emphasis on discrete-time signals and systems, and their mathematical representations.Study of adaptive filter algorithms such as LMS (Least Mean Squares), RLS (Recursive Least Squares), and their applications in noise cancellation, echo cancellation, and channel equalization. Techniques for downsampling and upsampling, interpolation, decimation, and polyphase filters. Applications in data compression and speech signal processing. Advanced methods for spectral estimation, including the periodogram, Bartlett's method, and the Welch method. Wavelet bases. Balian-Low theorem. Multiresolution analysis. (MRA). Focus on real-time and non-stationary signal analysis. Implementation of DSP techniques in communication systems, including OFDM (Orthogonal Frequency Division Multiplexing), channel coding, and modulation schemes.
9	**Text/ Reference Books**	1. “Understanding Digital Signal Processing" by Richard G. Lyons,: Pearson Education. 2. "Digital Signal Processing: Principles, Algorithms, and Applications" by John G. Proakis and Dimitris G. Manolakis 3. "Advanced Digital Signal Processing: Theory and Applications" by Saeed V. Vaseghi Publisher: Wiley-Interscience 4. "Discrete-Time Signal Processing" by Alan V. Oppenheim and Ronald W. Schafer, Publisher: Pearson Education

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-072
4	**Title of the subject**	Biomedical Signal Processing
5	**Any prerequisite**	Understanding of Digital and Analog Signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the principles of acquiring and preprocessing physiological signals. • Learn techniques for noise reduction, filtering, and signal enhancement. • Apply time-domain and frequency-domain analysis methods to biomedical signals. • Develop and implement algorithms for feature extraction and pattern recognition in diagnostics.
8	**Brief Contents**	The "Biomedical Signal Processing" course covers the fundamentals and advanced techniques for analysing physiological signals. Topics include signal acquisition and preprocessing, noise reduction, and filtering. Students will explore time-domain and frequency-domain analysis, feature extraction, and pattern recognition methods. The course also delves into advanced topics such as wavelet transforms, machine learning for biomedical signal analysis, and applications in diagnostics and monitoring. Practical sessions involve MATLAB/Python programming for real-world signal processing tasks. By the end of the course, students will be equipped with the skills to develop and implement algorithms for interpreting complex biomedical signals.
9	**Text/ Reference Books**	1. "Biomedical Signal Processing and Signal Modelling" by Eugene N. Bruce 2. "Biomedical Signal Processing: Principles and Techniques" by D. C. Reddy 3. "Advanced Methods of Biomedical Signal Processing" edited by Sergio Cerutti and Carlo Marchesi 4. "Biomedical Signal Analysis: A Case-Study Approach" by Rangaraj M. Rangayyan

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-074
4	**Title of the subject**	Computer Vision
5	**Any prerequisite**	Understanding of Signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the principles of image formation and feature detection in computer vision. • Learn techniques for object recognition, classification, and scene reconstruction. • Apply motion analysis and 3D vision methods to interpret visual information. • Develop and implement deep learning algorithms for computer vision using Python and OpenCV.
8	**Brief Contents**	The "Computer Vision" course explores the fundamentals and advanced techniques for enabling machines to interpret and understand visual information from the world. Topics include image formation, feature detection, and matching, as well as object recognition and classification. Students will study motion analysis, 3D vision, and scene reconstruction. Advanced topics such as deep learning for computer vision, including convolutional neural networks (CNNs), are also covered. Practical sessions involve implementing algorithms and applications using Python and OpenCV. By the end of the course, students will be proficient in developing computer vision systems for real-world applications.
9	**Text/ Reference Books**	1. "Computer Vision: Algorithms and Applications" by Richard Szeliski 2. "Multiple View Geometry in Computer Vision" by Richard Hartley and Andrew Zisserman 3. "Deep Learning for Computer Vision" by Rajalingappaa Shanmugamani 4. "Learning OpenCV 4: Computer Vision with Python" by Adrian Kaehler and Gary Bradski

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of Subject**	EE-076
4	**Title of the Subject**	Internet of Bio-Nano Things
5	**Prerequisite**	Linear Algebra, Signals and Systems, Digital Communication, Probability and Statistics, Computational Theory
6	**L-T-P**	3-0-0
7	**Learning Objectives**	This course will cover communication techniques and technologies to conceive networks on the nanoscale. Instead of the standard use of electromagnetic waves, we will perform the emission and detection of molecules according to the paradigm of Molecular Communications. We will follow a network architecture approach from a computer network perspective, see the picture on the right. In the physical layer, we will introduce models for the communication channels through molecular means, as well as for emitters and receivers. In the link layer, we will address mechanisms for the information flow and error control mechanisms. In this course, we will not only study theoretical concepts but will conduct many hands-on activities in the MATLAB simulator to model the physical and link layers.
8	**Brief Contents**	Introduction to Molecular communication: Why, what, and how? Applications areas: Biological engineering, Medical and healthcare applications, Industrial applications, Environmental applications, Information and communication technology applications, Nature-made biological nanomachines, Basic physical concepts, Chemical reactions and the master equation, Chemical reactions and the master equation (part 2), Basics of biochemistry, Brownian motion, First arrival time distribution, Concentration and counting, Modulation techniques, Transportation Mechanisms, Timing channels, Concentration channels, Noise and intersymbol interference, Molecular MIMO, Signal transduction, Information theory of molecular communication, Experimental approaches, Jamming bacterial communications: new strategies to combat bacterial infections and the development of biofilms, Quorum sensing and cell-to-cell communication in the dental biofilm.
9	**Text and Reference Books**	1. R. G. Gallager, "Stochastic Processes: Theory for Applications," 1st edition, Cambridge University Press, 2013. 2. T. Nakano, A. Eckford, "Molecular Communication", 1st edition, Cambridge University Press, 2013. 3. P. Peebles, "Probability, Random Variables, and Random Signals", 4th edition, New York, NY: McGraw-Hill, 2017. 4. D. R. Demuth, R. J. Lamont, "Bacterial Cell-to-Cell Communication", 1st Edition, Cambridge University Press, 2006. 5. S.M. Ross, "Stochastic Processes", 2nd Edition, Wiley, 1996. 6. S. Karlin, and H. M. Taylor, "A First Course in Stochastic Processes", 2nd edition, Academic Press, 1975. 7. Research Papers

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-079
4	**Title of the subject**	Cybersecurity
5	**Any prerequisite**	NA
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Develop a understanding of cybersecurity principles and techniques • Explore foundational concepts, and emerging technologies • Gain skills in cryptography, threat detection, network security • Understand policies, compliance, and cyber risk management
8	**Brief Contents**	Introduction to Cybersecurity: Importance, Threat Landscape, Security Goals, Symmetric and Asymmetric Cryptography, Hash Functions, Digital Signatures, Network Security Essentials: Firewalls, Intrusion Detection Systems. Viruses, Worms, Ransomware, SQL Injection, Cloud and IoT Security Challenges, IoT Threats, and Countermeasures, Artificial Intelligence in Security, AI-based Threat Detection, Machine Learning Models for Security, Zero Trust Architecture: Concepts, Zero Trust Network Access, Implementation Strategies, Security Policies and Compliance, Cyber Risk Management and Governance: Risk Assessment, Business Continuity, Disaster Recovery, Future of Cybersecurity
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. Introduction to Modern Cryptography by Jonathan Katz, Yehuda Lindell, 2025, Chapman & Hall/CRC 2. Cryptography and Network Security: Principles and Practice by William Stallings, 2021, Pearson 3. Zero Trust Networks: Building Secure Systems in Untrusted Networks by Evan Gilman, Doug Barth, 2017, O'Reilly Media 4. Computer Security: Principles and Practice by William Stallings, Lawrie Brown, 2017, Pearson 5. The Web Application Hacker's Handbook: Finding and Exploiting Security Flaws by Dafydd Stuttard, Marcus Pinto, 2011, Wiley

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-081
4	**Title of the subject**	Optimization Techniques
5	**Any prerequisite**	NA
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course introduces optimization techniques, covering both linear and non-linear programming. While the primary focus is on convex optimization, the course also explores techniques for optimizing non-convex functions. Following a foundational overview of linear algebra and probability theory, students will learn to formulate engineering problems involving minima and maxima within the framework of optimization.
8	**Brief Contents**	The content covers various optimization and computational techniques, including network flow models and algorithms such as shortest path methods (Dijkstra, label-correcting, and auction algorithms), max-flow and min-cost flow problems (Ford-Fulkerson, simplex methods), and transformations in optimization. It delves into solving linear and nonlinear programming problems using iterative methods, line search techniques, Hessian-based approaches (Newton, conjugate directions, quasi-Newton), and constrained optimization (Lagrange variables, KKT conditions, quadratic programming, convex problems, mixed integer models, and interior point methods). Additionally, it introduces OR models, linear programming techniques (simplex, artificial variables, two-phase, big-M), transportation and assignment problems, sequencing, replacement, game theory, inventory management, and dynamic programming with engineering applications. The final module explores quantum information theory, including density operators, entanglement, teleportation, Shannon entropy, quantum channels, cryptography, and quantum key distribution.
9	**Text/ Reference Books**	1. Boyd, Stephen, Stephen P. Boyd, and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004. 2. D. Bertsekas Nonlinear programming, 2nd Edition, Athena Scientific, 1999, Nashua. 3. V. Chvatal Linear programming, W. H. Freeman, 1983, New York. 4. E. K. P. Chong and S. Zak, An introduction to optimization, 2nd Edition, 2004, John Wiley and Sons (Asia) Pvt. Ltd., Singapore 5. R. Fletcher, Practical methods of optimization, 2nd Edition, Wiley, 2000, New York 6. D. Luenberger, Linear and nonlinear programming, 2nd Edition, 1984, Kluwer Academic Publisher, New York 7. O. L. Mangasarian, Nonlinear programming, SIAM, 1987, Philadelphia

1	**Semester**	I

2	**Type of course**	Elective
3	**Code of the subject**	EE-083
4	**Title of the subject**	Internet of Things
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• To introduce the concept of Internet of Things (IoT), reference layer and various protocols and software. • To make the students capable of building IoT systems using sensors, single board computers and open source IoT platforms.
8	**Brief Contents**	Evolution of IoT, IoT architecture reference layer, IoT protocols, software and gateway protocols, IoT point to point communication technologies IoT Communication Pattern, Introduction to Cloud computation and Big data analytics, IoT security, Sensors: Working Principles: Different types Interface Electronic Circuit for Smart Sensors and Challenges for Interfacing the Smart Sensor, Usefulness of Silicon Technology in Smart Sensor And Future scope of research in smart sensor
9	**Lab Content**	None
10	**Text/ Reference Books**	**Text Books:** 1. IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things, David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Rob Barton and Jerome Henry, Cisco Press, 2017 2. Internet of Things – A hands-on approach, Arshdeep Bahga, Vijay Madisetti, Universities Press, 2015 3. Internet of Things: Architecture, Design Principles and Applications, Rajkamal, McGraw Hill Higher Education **Reference Books:** 1. The Internet of Things – Key applications and Protocols, Olivier Hersent, David Boswarthick, Omar Elloumi and Wiley, 2012 2. "From Machine-to-Machine to the Internet of Things – Introduction to a New Age of Intelligence", Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis, Karnouskos, Stefan Avesand. David Boyle and Elsevier, 2014. 4. Architecting the Internet of Things, Dieter Uckelmann, Mark Harrison, Michahelles and Florian (Eds), Springer,2011. 5. Jacob Fraden, "Handbook of Modern Sensors: physics, Designs and Applications", 2015, 3rd edition, Springer, New York. 6. Jon. S. Wilson, "Sensor Technology Handbook", 2011, 1st edition, Elsevier, Netherland.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-085
4	**Title of the subject**	Software Defined Radio
5	**Any prerequisite**	Understanding of basic concepts of communication systems and signals
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	Understand different models for Software Defined Radio in detail, like Software Defined Radio Architecture for performance optimization. Program and test software-defined radio transceivers; Implement different physical layer communication protocol/algorithm using Software Defined Radio.
8	**Brief Contents**	Introduction: The requirement for software defined radio, Software defined radio architectures; Ideal Software defined radio architectures, required hardware specifications, Digital aspects of a Software Defined radio, Current technology limitations Introduction to USRP radios and GNU Radio software platform and Coding; implementation on SDR: Digital modulation and demodulation; AM transceiver, Time and frame synchronization, channel estimation and equalization; Machine learning with SDR
9	**Lab Content**	NA.
10	**Text/ Reference Books**	1. Travis F. Collins, Robin Getz, Di Pu, and Alexander M. Wyglinski, “Software-Defined Radio for Engineers,” Artech House, 2018 2. F. Xiong,. Digital Modulation Techniques, Artech House, 2006. ProQuest eBook Central. ISBN: 9781580538640 3. J. G. Proakis and M. Salehi, Digital Communications, McGraw-Hill, 5th ed., 2008. (ISBN 978-0-07-295716-7) 4. J. Vanakka, “Digital Synthesizers and Transmitter for Software Radio”, Springer, 2005

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-086
4	**Title of the subject**	Quantum Communication
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Introduce key concepts and theories of Quantum Communication. • Explain the working principles of quantum communication systems. • Explore fundamental limits of quantum communication over classical and quantum channels. • Discuss practical implementation and challenges in quantum communication systems.
8	**Brief Contents**	Vector Spaces, Inner-Product Spaces, Linear Independence and Basis, Finite-Dimensional Hilbert Spaces, Linear Operators and Projectors, Eigenvalue Decomposition, Tensor Products, Analysis and Probability, Limits, Infimum, Supremum, and Continuity, Compact Sets and Convexity, Qubits and Axioms of Quantum Systems, Positive Operator-Valued Measure (POVM), Helstrom Decision Theory and Quantum Communication Systems, Quantum Modulation Schemes, Density Operators and Quantum Entanglement, Quantum Teleportation and Cryptography, Shannon Entropy and Classical Information Theory, Quantum Channels and Noisy Transmission, Quantum Key Distribution
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Quantum Communications", Gianfranco Cariolaro, Springer, 2015. 2. "Quantum Communication, Quantum Networks, and Quantum Sensing", Ivan B. Djordjevic, Academic Press, 2022. 3. Principles of Quantum Communication Theory: A Modern Approach", Sumeet Khatri, and Mark M. Wilde, 2021 4. Quantum Computation and Quantum Information", Michael Nielsen and Isaac Chuang, Cambridge University Press, 2010.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-087
4	**Title of the subject**	5G and 6G Standards
5	**Any prerequisite**	Advanced Communication Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Trace the evolution from 1G to 6G, highlighting key concepts, performance metrics, and advancements. • Study 5G standards, architecture, technologies, use cases, and the role of 3GPP and ITU. • Discover 6G vision, emerging standards, features, enabling technologies, and use cases. • Analyze regulatory, security, spectrum management, and deployment challenges for 5G and 6G.
8	**Brief Contents**	Evolution of Mobile Networks, 1G to 6G Advancements, Performance Metrics and Spectrum Utilization, Energy Efficiency and Sustainability in Wireless Networks, 5G Architecture and Core Technologies, Network Slicing and Virtualization, mmWave Communications and Massive MIMO, 5G NR Interface and Channel Modulation, 5G Use Cases and Applications, Standardization Bodies: 3GPP, ITU, GSMA, 6G Vision and Roadmap, Key Enabling Technologies for 6G, Security and Privacy in 5G/6G Networks, Spectrum Allocation and Regulatory Challenges, Future Trends and Research in 5G/6G Deployment.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. Wireless Communications: Principles and Practice by Theodore S. Rappaport, 2nd Edition, Pearson Education. 2. Xingqin Lin and Namyoon Lee, 5G and Beyond: Fundamentals and Standards, Springer, Edition Number1 3. Abdulrahman Yarali, From 5G to 6G: Technologies, Architecture, AI, and Security, Wiley-IEEE Press

1	**Semester**	I
2	**Type of course**	Elective
3	**Code of the subject**	EE-088
4	**Title of the subject**	Smart Antenna
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamental parameters of antenna and use of cellular concepts and basic architecture, features and benefits of smart antennas. • Able to integrate smart antenna technology with overall communication system design, principle and its performance. • Understand the beamforming techniques and adaptive array techniques. • Understand the implementation of smart antennas for Direct sequence CDMA systems and examine some of the challenges involved in applying smart antennas to CDMA. .
8	**Brief Contents**	Fundamental Parameters of Antenna and cellular concepts, Mobile antennas and mobile Radio Propagation and Modelling. Antennas for Mobile Communication. Different Types of Antennas, Introduction to Smart Antenna systems, need of smart antenna, Fixed Beam forming networks, Switched Beam Systems, Adaptive Antenna Systems, Smart Antennas Techniques for CDMA, Analysis Using Smart Antennas – A Vector Based Approach
9	**Lab Content**	None
10	**Text/ Reference Books**	**1.** Antennas for all applications, 3rd edition, by J.D. Krauss, TMH. **2.** Antenna & Wave Propagation, K.D. Prasad, Satyaprakash publications. 4. Wireless Communications: Principles and practice, 2nd edition, Theodore S. Rappaport, PHI. 5. Joseph C. Liberti and Theodore S. Rappaport, Smart Antennas for Wireless Communications IS 95 and Third Generation CDMA Applications, Prentice Hall PTR 6. Balanis C A, Antenna Theory: design and applications, Wiley 7. Frank Gross, Smart Antennas for Wireless Communications-McGraw Hill 8. Ahmed El-Zooghby, Smart Antenna Engineering, Artech House Publishers 9. Constantine Balanis, Introduction to Smart Antennas, Morgan and Claypool Publisher. 10. F.B. Gross - Smart Antennas for Wireless Communications, McGraw-Hill., 2005.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-089
4	**Title of the subject**	Advanced Optical Communication
5	**Any prerequisite**	Advanced Communication Systems
6	**L-T-P**	3-0-2
7	**Learning Objectives of the subject**	• Learn the fundamentals of optical communication, including fiber properties, light propagation, dispersion, and nonlinearity. • Explore optical sources, detectors, modulation techniques, and design aspects for transmitters and receivers with a focus on SNR and BER. • Understand WDM principles, components, optical amplifiers, and noise management in system performance. • Analyze high-speed modulation techniques, optical networks, emerging technologies, and scalability challenges.
8	**Brief Contents**	Overview of Optical Communication Systems, Optical Fiber Types and Light Propagation, Dispersion and Nonlinear Effects in Fibers, Optical Fiber Waveguides and Specialty Fibers, Optical Sources: LEDs and Laser Diodes, Photodetectors and Receiver Sensitivity, Optical Receivers and Coherent Detection, Point-to-Point Optical Links and Power Budget, Wavelength Division Multiplexing (WDM) Principles and System Design Considerations, Optical Amplifiers: EDFAs and Raman Amplifiers, Optical Network Architectures and Topologies, Optical Cross-Connects and ROADMs, Elastic Optical Networks and Space-Division Multiplexing, Quantum Optical Communication and Future Trends.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. Fiber Optic Communications by Gerd Keiser, 5th Edition, McGraw Hill Education. 2. Optical Fiber Communications: Principles and Practice by John Senior, 3rd Edition, Pearson Education. 3. Optical Networks: Design and Implementation by Rajiv Ramaswami and Kumar Sivarajan, Third Edition.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-092
4	**Title of the subject**	Data Communication Protocol
5	**Any prerequisite**	Knowledge of fundamentals of data structures and associated algorithms
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Define and understand the meaning and role of protocol, the concept of layering, appreciate the role of TCP/IP layer model • Demonstrate the basic concepts of error detection, checking and correction at data link layer and application to flow control protocols. • Apply formulae to practical communication systems and analyse their performances in transmitting data signals.
8	**Brief Contents**	The course will focus on the design and implementation techniques essential for engineering robust networks. Topics include networking principles, Transmission Control, Protocol/Internet Protocol, naming and addressing (Domain Name System), data encoding/decoding techniques, link layer protocols, routing protocols, transport layer services, congestion control, quality of service, network services, Software Defined Networks (SDNs), programmable routers and overlay networks, wireless and mobile networking, security in computer networks, multimedia networking, and network management.
9	**Lab Content**	NA.
10	**Text/ Reference Books**	1. Data and Computer Communications by William Stallings 2. Data communication & Networking by Bahrouz Forouzan. 3. Computer Networks by Andrew S. Tanenbaum

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-051
4	**Title of the subject**	Device and Interconnect Modelling
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	By studying this course, students will gain a comprehensive understanding of technology trends and scaling in the semiconductor industry. They will learn about Moore's Law, technology nodes, and the physical and technological limitations that impact semiconductor miniaturization. The course will provide in-depth knowledge of interconnect modeling and analysis, covering RC, RLC, and transmission line models while exploring the effects of capacitive and inductive coupling on signal integrity. Students will also understand key factors such as power dissipation, reliability concerns, and performance trade-offs in interconnects.
8	**Brief Contents**	Technology trends, Device and interconnect scaling, Interconnect Models: RC model and RLC model, Effect of capacitive coupling, Effect of inductive coupling, Transmission line model, Power dissipation, Interconnect reliability, Driver and Load Device Models, Interconnect Analysis, Time domain analysis, RLC network analysis, RC network analysis and responses in time domain, S domain analysis, Circuit reduction via matrix approximation, Analysis using moment matching, Crosstalk Analysis, Advanced Interconnect Materials. Moore law, Technology nodes and ITRS, Physical & Technological Challenges to scaling, Two terminal MOS Device threshold voltage modelling, C-V Characteristics, Four terminal MOSFET threshold voltage I-V modelling, short channel effect (SCE), High-K gate dielectric, Nonconventional MOSFET – (FDSOI, SOI, Multi-gate MOSFETs). Nonconventional MOSFET – (FDSOI, SOI, Multi-gate MOSFETs) and advanced VLSI devices and interconnects
9	**Lab Content**	NA
10	**Text/ Reference Books**	**1.** Nano Interconnects: Device Physics, Modeling and Simulation by Afreen Khursheed and, Kavita Khare (CRC Press, 2024) **2.** Fundamentals of Device and Systems Packaging: Technologies and Applications, Second Edition by Rao Tummala

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-052
4	**Title of the subject**	VLSI Signal Processing
5	**Any prerequisite**	Digital Circuit, and Signals & Systems
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Provides comprehensive coverage of techniques for designing efficient VLSI architectures specifically for Digital Signal Processing (DSP) systems. • Addresses real-world challenges in implementing DSP systems, such as high throughput data processing, real-time operation, and resource constraints. • Focuses on optimizing power consumption and minimizing chip area while maintaining performance in DSP applications. • Equips students with the skills to design VLSI architectures that meet the demands of modern DSP systems in terms of efficiency and scalability.
8	**Brief Contents**	Discusses Signal Flow Graph (SFG), Data Flow Graph (DFG), and Dependence Graph (DG) for DSP algorithms. Critical path minimization, retiming of DFG, loop retiming, and iteration bounds. Pipelined DSP architectures and parallel realization of DSP algorithms for optimization. Explores parallel realizations of FIR filters, including 2-parallel and 3-parallel architectures, and hardware minimization. Introduces unfolding theorem and polyphase decomposition for efficient DSP realization.
9	**Reference Book**	1. VLSI Digital Signal Processing Systems: Design and Implementation, Keshab K. Parhi,: Wiley-Interscience. 2. VLSI for Signal Processing, Umesh H. Patil, Prentice Hall 3. Digital Signal Processing: A VLSI Implementation Perspective, Keshab K. Parhi, Wiley-Interscience.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-053
4	**Title of the subject**	Low Power VLSI
5	**Any prerequisite**	Digital Electronics
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the Need for Low Power VLSI Design. • Analyze Power Dissipation Mechanisms in CMOS Circuits. • Apply Low Power Design Techniques at device, circuit, and architecture level. • Perform Power Estimation and Analysis. • Understand clock gating and low-power clocking strategies. • Reduce power consumption in clock distribution networks.
8	**Brief Contents**	Need for low-power VLSI chips, Sources of Power Dissipation on Digital Integrated Circuits, Dynamic Dissipation, Static Dissipation, Technology & Device Innovation, Emerging Low power Approaches, Low Power Design Techniques at Architecture and System Levels, Power Consumption of Dedicated Hardware vs. Software Implementations of Systems, Low Power Architecture, RTL design Techniques for Low Power, Low Power Random Access Memory Circuits, Power Analysis and Design at System level and state-of-the-art Low Power Applications.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Low-Power CMOS VLSI Circuit Design" by Kaushik Roy and Sharat C. Prasad 2. "Low-Power Digital VLSI Design: Circuits and Systems" by Abdellatif Bellaouar and Mohamed I. Elmasry 2. "Low Power Digital CMOS Design" by Anantha P. Chandrakasan and Robert W. Brodersen

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-054
4	**Title of the subject**	Microcontroller and Embedded System
5	**Any prerequisite**	Nil
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course aims to convey knowledge of basic concepts of embedded system design required for every state-of-the-art electrical/electronic system in the form of autonomous and real–time computing machine embodied within them. Emphasis is on the features and characteristics of embedded system, design metrics, embedded system design flow, processor, memory and input output interfacing and input output devices, assembly language, hardware description language, I/O interface design and programming, real-time operating system, hardware-software co- design and co-simulation. Special attention will be devoted to the most important challenges facing embedded system designers today and in the coming decade.
8	**Brief Contents**	Introduction to Embedded System, Major components, Design issues, Microprocessor, DSP, Microcontroller architecture, Memory, FPGA, ASIC, ARM architecture fundamentals, Interfacing and Communication Protocols
9	**Text/ Reference Books**	1. "The Art of Designing Embedded Systems" by Jack Ganssle 2. "Embedded Systems: Real-Time Interfacing to ARM Cortex-M Microcontrollers" by Jonathan W. Valvano **3.** “Architecting High-Performance Embedded Systems”, Jim Ledin

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-055
4	**Title of the subject**	Memory Devices and Circuits
5	**Any prerequisite**	Microelectronic Devices/Digital Electronics
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the Fundamentals of Memory Systems. • Analyze SRAM and DRAM Architectures. • Evaluate Non-Volatile Memory Technologies. • Design and Optimize Memory Peripheral Circuits. • Explore Advanced and Emerging Memory Technologies.
8	**Brief Contents**	Introduction to Memory Systems, Memory Arrays, Memory Market, 6T/8T SRAM Design, 3T/1T-1C DRAM Design, Charge Pump Circuits, Open and Folded Bit Line Architecture, Arrays organizations, Sense Amplifiers & Peripheral Circuits, Introduction to Flash memory, NAND/NOR Flash memory, Organization of NAND Flash Memory, Advance 3D NAND Flash Configuration, Next Generation Memory (PCM, MRAM, RRAM), Emerging Memory Devices for Neuromorphic Applications.
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Digital Integrated Circuits: A Design Perspective" by Jan M. Rabaey, Anantha Chandrakasan, and Borivoje Nikolić. 2. "CMOS Digital Integrated Circuits: Analysis and Design" by Sung-Mo Kang and Yusuf Leblebici. 3. "Advanced Memory Technology" by Ye Zhou and Guoxing Wang.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-056
4	**Title of the subject**	VLSI Architecture
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• The course objective is to cover the architecture design of VLSI systems and subsystems with the notion of optimization for area, speed, dissipation, cost and reliability. • Different aspects of VLSI system design and its applications in various fields. • The course also discusses traditional, and state of the art analog and digital VLSI architectures optimized techniques.
8	**Brief Contents**	**Module 1:** ISA, Datapath and Control Path Design, Single Cycle MIPS, 5-Stage Pipeline MIPS, CISC Architecture. **Module 2:** RISC Architecture, Arithmetic Unit Design, Fixed Point and Floating Point, Memory Units, Optimization. **Module 3:** Instruction Level Parallelism, Superscalar Processor, Multi-Core and Multi-Thread Architecture. **Module 4:** Network on Chip, Dynamically Reconfigurable Gate Array, Static vs. Dynamic Reconfiguration. **Module 5:** Single Context vs. Multi-Context Dynamic Reconfiguration, Full Spatial Run-Time Reconfiguration.
9	**Text/ Reference Books**	1. “VLSI Architecture” Prentice Hall publisher by B. Randell and P.C. Treleaven 2. “Physical Architecture of VLSI Systems” Wiley publisher by Robert J. Hannemann, Allan D. Kraus, and Michael Pecht 3. “Advanced VLSI Architectures: From Concept to Silicon” I I P Iterative International Publishers by Mr. Somnath Maity and Mr. Rakesh Kumar

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-057
4	**Title of the subject**	Hardware Security
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Learning the state-of-the-art security methods and devices. • Better understanding of attacks and providing counter measures against them • CMOS implementation of hardware security primitives, Attacks oncyber-physical systems
8	**Brief Contents**	**Module 1:** Fundamentals of Hardware Security and Trust for Integrated Circuits, Physical and Invasive Attacks, Side-Channel Attacks and Countermeasures. **Module 2:** Physically Unclonable Functions (PUFs), Hardware-Based True Random Number Generators, CMOS PUF Implementations. **Module 3:** Hardware Trojan, Hardware Security Primitives, Hardware Trojan Detection and Isolation in IP Cores. **Module 4:** Watermarking of Intellectual Property (IP) Blocks, FPGA Security, Passive and Active Metering for Prevention of Piracy. **Module 5:** Access Control, Counterfeit IC Detection, Security Measures for Integrated Circuits.
9	**Text/ Reference Books**	1. "Introduction to Hardware Security and Trust" Springer publisher by Mohammad Tehranipoor and Cliff Wang 2. "Hardware Security: Design, Threats, and Safeguards" CRC Press publisher by Debdeep Mukhopadhyay and Rajat Subhra Chakraborty 3. "Hardware Security: A Hands-on Learning Approach" Morgan Kaufmann publisher by Swarup Bhunia and Mark Tehranipoor

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-058
4	**Title of the subject**	FPGA-Based System Design
5	**Any prerequisite**	Nil
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	The goal of the course is to study the basic principles and methods of FPGA prototyping. Understanding of principles of IC prototyping; hardware and software; design strategies and methods
8	**Brief Contents**	ROM, SPLD, CPLD Architecture and Features of FPGA and designing techniques. Architecture of ROM – ROM Programming – Architecture of SPLDs – SPLDs programming – Architecture of CPLDs, Basics of FPGAs– Structure of FPGAs Implementation of Digital circuits in FPGA processor, Education FPGA kit – FPGA pin assignment – Interfacing Input/Output devices with FPGA, SPI, I2C, I3C, UART protocol RTL design System Design Examples using Xilinx FPGAs – Traffic light Controller, Real Time Clock, VGA, Keyboard, LCD, Embedded Processor Hardware Design.
9	**Text/ Reference Books**	1. M.J.S. Smith, "Application Specific Integrated Circuits", Pearson, 2000. 2. Peter Ashenden, "Digital Design using Verilog", Elsevier, 2007. 3. W. Wolf, "FPGA based system design", Pearson, 2004. 4. Clive Maxfield, "The Design Warriors's Guide to FPGAs", Elsevier, 2004 5. S. Ramachandran, "Digital VLSI System Design: A Design Manual for implementation of Projects on FPGAs and ASICs Using Verilog" Springer Publication, 2007. 6. Wayne Wolf, "FPGA Based System Design", Prentices Hall Modern Semiconductor Design Series.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-059
4	**Title of the subject**	Quantum Electronics
5	**Any prerequisite**	Microelectronic Devices and Circuits
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Gain insight into the fundamental structure of solids and how their atomic arrangement influences electronic properties. • Grasp the basic principles of quantum mechanics, including wave-particle duality, uncertainty principle, and quantization. • Learn how to solve Schrödinger's wave equation for different potential systems and understand its significance in electronic properties. • Understand the concept of DOS and its importance in determining the electronic properties of materials. • Carrier Transport Phenomenon in Semiconductors.
8	**Brief Contents**	The Crystal Structure of Solids, Introduction to Quantum Mechanics: Principles of Quantum mechanics, Application of Schrodinger's Wave Equations, Introduction to Quantum Theory of Solids: The kronig-Penney Model, Electrical conduction in Solids, DOS, Statistical Mechanics, The semiconductor in Equilibrium Carrier transport Phenomenon, Non-equilibrium Excess Carriers in Semiconductor, PN-Junction, MOSCAP, Thin film Transistors, Quantum Cellular Automata
9	**Lab Content**	NA
10	**Text/ Reference Books**	1. "Quantum Mechanics: Concepts and Applications" by Nouredine Zettili 2. "Semiconductor Physics and Devices" by Donald A. Neamen 3. "Quantum Theory of Solids" by Charles Kittel 4. "Quantum Cellular Automata and Quantum Computing" by S. I. Zernov

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-060
4	**Title of the subject**	RF Circuit Design
5	**Any prerequisite**	Analog IC Design
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Get the idea of various parameters of interest in RF systems. • To understand issues involved in design for GHz frequencies. • To understand theoretical background relevant for design ofactive and passive circuits for RF front end in wireless digital communication systems.
8	**Brief Contents**	Characteristics of passive components for RF circuits. Passive RLC networks. Transmission lines. Two-port network modeling. S-parameter model. The Smith Chart and its applications, Active devices for RF circuits: SiGe MOSFET, GaAs pHEMT, HBT and MESFET. RF Amplifier design: single and multi-stage amplifiers. Review of analog filter design. Voltage references and biasing. Low Noise Amplifier design: noise types and their characterization, LNA topologies, Power match vs Noise match. Linearity and large- signal performance, RF Power amplifiers: General properties.Class A, AB and C Power amplifiers. Class D, E and F amplifiers. Modulation of power amplifiers, Analog communication circuits, Phase-locked loops, Oscillators and synthesizers.
9	**Lab Content**	None
10	**Text/ Reference Books**	1. D. M. Pozar, "*Microwave Engineering*," 4th Edition, Wiley, 2012. 2. C. Bowick, "*RF circuit design*," 2nd Edition, Newnes, 2007. 3. R. C. Li, "*RF Circuit Design*," 2nd Edition, John Wiley & Sons, 2012. 4. G. Gonzalez, "*Microwave Transistor Amplifiers: Analysis and Design*," 2nd Edition, Prentice Hall, 1996. 5. T. H. Lee, "*Planar Microwave Engineering: A Practical Guide to Theory, Measurement, and Circuits*," Cambridge University Press, 2004. 6. D. M. Pozar, "*Microwave and RF Design of Wireless Systems*," John Wiley & Sons, 2001.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-061
4	**Title of the subject**	Mixed Signal SoC Design
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the significance of different biasing styles and apply it for different circuits. • Design basic building blocks like sources, sinks, mirrors, up to layout level. • Comprehend the stability issues of the systems and design Op-amp fully compensated against process, supply and temperature variations. • Identify suitable topologies of the constituent subsystems and corresponding circuits as per the specifications of the system Design. • Analog integrated system including parasitic effects up to tape-out.
8	**Brief Contents**	**Module 1:** Process and Temperature Independent Compensation, Resistor Equivalence of a Switched Capacitor, Parasitic-Sensitive and Parasitic-Insensitive Integrators. **Module 2:** Signal-Flow-Graph Analysis, Noise in Switched-Capacitor Circuits, Performance of Sample-and-Hold Circuits. **Module 3:** Ideal D/A Converter, Ideal A/D Converter, Quantization Noise, Charge-Redistribution A/D, Resistor-Capacitor Hybrid. **Module 4:** Basic Phase-Locked Loop (PLL) Architecture, Voltage-Controlled Oscillator (VCO), Divider, Phase Detector, Loop Filter, PLL in Lock. **Module 5:** Linearized Small-Signal Analysis, Second-Order PLL Model, Jitter and Phase Noise, Period Jitter, Probability Density Function of Jitter, Ring and LC Oscillators.
9	**Text/ Reference Books**	1. "Design of Analog CMOS Integrated Circuits" Mc Graw Hill publisher by Behzad Razavi 2. "Analog Integrated Circuit Design" Wiley publisher by Tony Chan Carusone, David Johns, and Kenneth Martin 3. "Analog Design for CMOS VLSI Systems" Kluwer Academic publishers by Franco Maloberti

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-062
4	**Title of the subject**	AI-Accelerator Design
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• This course provides in-depth coverage of the architectural techniques used to design accelerators for training and inference in machine learning. • Get exposure of implementation of CNN network in FPGA board. • Get an idea about the data system bus used in communication between different system blocks. • To design energy-efficient accelerators, develop the intuition to make trade-offs between ML model parameters and hardware implementation techniques.
8	**Brief Contents**	**Module 1:** Deep Understanding of Neural Networks, Linear Algebra Fundamentals, Accelerating Linear Algebra. **Module 2:** Implementation of Deep Learning Kernels, Zynq Series FPGA Architecture, Interface Knowledge. **Module 3:** High-Speed Protocols (Ethernet 100/10 Gbps), SPI, I2C, I3C, UART Protocol RTL Design. **Module 4:** C/C++ Coding for Vivado SDK, Activation Function Verilog Implementation. **Module 5:** Classification Layer HDL Implementation, Optimization for FPGA-based Deep Learning..
9	**Text/ Reference Books**	1. "Efficient Processing of Deep Neural Networks" Morgan & Claypool Publisher by Vivienne Sze, Yu-Hsin Chen, Tien-Ju Yang, and Joel Emer 2. "Artificial Intelligence Hardware Design: Challenges and Solutions" Wiley-IEEE Press publisher by Albert Chun Chen Liu and Oscar Ming Kin Law 3. "From CNN to DNN hardware Accelerators: A Survey on Design, Exploration, Simulation, and Frameworks" Now publisher by Leonardo Rezende Juracy, Rafael Garibotti and Fernando Gehm Moraes

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-063
4	**Title of the subject**	System-on-Chip Design
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	This course provides in-depth coverage of System-on-Performance Chip Design. Design, optimize, and program a modern System-on-a-Chip to analyze and characterize its computational requirements computational task, and identify performance bottlenecks. Characterize and develop real-time solutions. Implement both hardware and software solutions, formulate hardware/software tradeoffs, and perform hardware/software codesign.
8	**Brief Contents**	Hardware/software co-design: partitioning, real-time scheduling, hardware acceleration; Virtual prototyping: electronic system-level languages and hardware/software co-simulation; High-level synthesis: allocation, scheduling and binding algorithms for C-to-RTL synthesis; SoC integration: SoC communication architectures, IP interfacing, verification and test; FPGA prototyping of hardware/software systems.
9	**Text/ Reference Books**	1. P. Marwedel, Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems, Third Edition, Springer, 2018. (author's website) 2. D. C. Black, J. Donovan, B. Bunton, A. Keist, SystemC: From the Ground Up, Second Edition, Springer, 2010. 3. G. De Micheli, Synthesis and Optimization of Digital Circuits, McGraw-Hill, 1994.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-064
4	**Title of the subject**	Embedded Software
5	**Any prerequisite**	Nil
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Convert software programs into equivalent cycle-based hardware and vice versa. • Partition software into hardware and software components with proper interfaces. • Identify and optimize performance bottlenecks in hardware-software architectures
8	**Brief Contents**	Design of embedded systems, architectures and platforms for embedded systems, general purpose vs. application-specific architectures, reconfigurable systems, optimization techniques for design space exploration, software synthesis and code generation, system-level power/energy optimization, Security in embedded systems, embedded software for AI and IoT Applications, embedded system Testing & Validation
9	**Text/ Reference Books**	1. David E. Simon, “An Embedded Software Primer” 2. Daniele Lacamera, "Embedded Systems Architecture" 3. Mohamed Rafiquzzaman, "Microprocessors and microcomputer Based System Design"

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-066
4	**Title of the subject**	Special Topics in IC Design and Technology
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives of thesubject**	This will focus on special topics of contemporary relevance and interest toboth VLSI industry and state-of-the-art research.
8	**Brief Contents**	It will cover current research and development topics and in line with VLSI industry and may cover all aspects from Device Technology to chip design flow through ASIC and FPGA, Topics from state-of-the-art design methodologies. Architecture, circuit and layout level issues, Timing and Design closure. Deep sub-micron circuit design-logic and layout issues, FinFET and other novel devices.
9	**Text/ Reference Books**	1. Neil Weste and David Harris, "CMOS VLSI Design: A circuits and Systems perspective", 3rd Ed., Addison Wesley, 2004 2. RF microelectronics, Behzad Razavi, Prentice Hall, 1998. 3. William J. Dally, John W. Poulton, "Digital Systems Engineering, "Cambridge University Press 1999 4. Yaun Taur and Tak H.Ning, "Fundamentals of modern VLSI devices", Cambridge University Press 1999 5. Recent publications from IEEE, IEICE and ACM Journals

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-068
4	**Title of the subject**	Network on Chip
5	**Any prerequisite**	NIL
6	**L-T-P**	3-0-0
7	**Learning Objectives ofthe subject**	1. To learn the basic concepts of NoC design by studying the topologies, router design and MPSoC styles, 2. To learn sample routing algorithms on a NoC with deadlock and livelock avoidance, 3. To understand the role of system-level design and performance metrics in choosing a NoC design
8	**Brief Contents**	Introduction to NoC, OSI layer rules in NoC, Interconnection Networks in Network-on-Chip Network Topologies, Switching Techniques, Routing Strategies, Architecture Design, Switching Techniques and Packet Format, Asynchronous FIFO Design, Wormhole Router Architecture Design - VC Router Architecture Design - Adaptive Router Architecture Design, Routing Algorithms, Test and Fault Tolerance of NOC, 3-D integration of NOC.
9	**Text/ Reference Books**	1. N. Enright Jerger and L-S. Peh, On-Chip Networks, Synthesis Lectures on Computer Architecture, Morgan & Claypool, 2009, 2. A Jantsch and H. Tenhunen, Networks on Chip, Kluwer Academic Publishers, 2003. 3. W. J. Dally, Principles and Practices of Interconnection Networks, Morgan Kaufmann, 2004.

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-602
4	**Title of the subject**	System Design using HDL
5	**Any prerequisite**	None
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	• Understand the fundamentals of Hardware Description Languages (HDL) • Learn to design combinational and sequential logic circuits • Develop skills in both structural and behavioral modeling techniques and gain hands-on experience in writing testbenches and running simulations. • Apply synthesis tools and optimization techniques for efficient HDL code, focusing on area, speed, power
8	**Brief Contents**	Introduction to Hardware Description Languages (HDL), including VHDL and Verilog, and compares them to other programming languages. It explores HDL syntax, semantics, data types, operators, and constructs, with a focus on designing combinational and sequential logic circuits such as logic gates, multiplexers, flip-flops, counters, and state machines. Students will learn both structural and behavioral modeling techniques and gain experience in writing testbenches and running simulations using tools like ModelSim, Vivado etc. The course also introduces synthesis tools and optimization techniques for efficient HDL code in terms of area, speed, and power. Topics like finite state machine design, FPGA design, and timing constraints are covered, with real-world case studies and applications, including communication systems and embedded systems design using HDL.
9	**Lab Content**	Not Applicable
10	**Text/ Reference Books**	1. "Digital Design with Verilog" by Michael D. Ciletti 2. "Verilog HDL: A Guide to Digital Design and Synthesis" by Samir Palnitkar 3. "Verilog by Example: A Concise Introduction for FPGA Design" by Blaine C. Readler 4. VHDL: Programming by Example" by Douglas L. Perry 5. "FPGA Prototyping by Verilog Examples" by Pong P. Chu 6. "Verilog: Frequently Asked Questions" by Mike H. Godfrey

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-608
4	**Title of the subject**	Design Verification and Testing
5	**Any prerequisite**	CAD for VLSI
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	1. Acquire knowledge about fault modelling and collapsing. 2. Learn about various combinational automatic test pattern generation techniques. 4. Learn about various sequential automatic test pattern generation techniques. 5. Analyze different memory faults and its testing methods. 6. Develop the verification plan for the small to complex VLSI designs. 7. Develop testbench using HVL for testing and verification of VLSI designs
8	**Brief Contents**	Introduction and Fault Modeling, Testing Techniques, Time frame expansion methods, Boolean Satisfiability, Transitive-closure based and Neural Network based approaches, Fault Simulation, Design for Testability and Built-in-self-test, Controllability and observability measures, TEMEAS, SCOAP, Ad-hoc design built-in-logic-block- observer (BILBO), Linear feedback shift register (LFSR), Theory of LFSRs, Design for Trust Techniques: Different Types of Attacks, Counter Measures for different types of attacks, Prevention based Approaches, Importance of verification, Verification plan, Verification flow, Levels of verification, Verification methods and languages, Introduction to Hardware Verification methodologies, Verifications based on simulation, Analytical and formal approaches. Functional verification, Timing verification, Formal verification. Basics of equivalence checking and model checking.
9	**Text/ Reference Books**	1. M. Bushnell and Vishwani Agrawal, Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits, Springer, ISBN 978-0792379911. 2. Chris Spear, System Verilog for Verification, Springer, ISBN 978-1-4614-0714-0 3. M. Abramovici, M. Breuer, and A. Friedman, Digital System Testing and Testable Design, IEEE Press, 1994 4. Diraj K. Pradhan, “Fault Tolerant Computer System Design”, Prentice Hall. 5. L. T. Wang, C. W. Wu, and X. Wen, VLSI Test Principles and Architectures, Morgan Kaufmann, 2006, ISBN-13: 978-0-12-370597-6, ISBN-10: 0-12-370597-5. 6. System-on-a-Chip Verification-Methodology and Techniques, P. Rashinkar, Paterson and L. Singh, Kluwer Academic Publishers, 2001

1	**Semester**	I/II/III/IV
2	**Type of course**	Elective
3	**Code of the subject**	EE-610
4	**Title of the subject**	CAD for VLSI
5	**Any prerequisite**	Digital Design
6	**L-T-P**	3-0-0
7	**Learning Objectives of the subject**	1. Understand the general design process of modern VLSI chips. 2. Be able to identify and formulate design problems within a sound methodology. 3. Build capability to analysis a problem, and design efficient algorithms to solve it. 4. Become familiar with most algorithms and methods used in VLSI CAD. 5. Be able to implement algorithms in CAD tools.
8	**Brief Contents**	Introduction to VLSI-CAD, module generation, PLAs and FPGAs, digital hardware modelling, benchmark circuits (ISCAS'85, ISCAS'89, etc.), simulation algorithms, design verification, graph data structure and algorithms for VLSI-CAD, high-level synthesis, algorithms for physical design automation, slicing and non-slicing floorplans, polar graphs and adjacency graphs for floorplans, Placement: objective functions; partitioning based placement. Global routing: geometric spanning trees; Steiner trees; net ordering. Detailed Routing: shortest paths and maze search, Channel routing, introducing NoC as a future SoC paradigm, timing analysis, SDC, set-up and hold time concepts, timing exceptions, set-up and hold calculations, and noise analysis.
9	**Text/ Reference Books**	1. Sherwani, N., Algorithms for VLSI Physicsl Design Automation, Springer (2005) 3rd ed. 2. Gerez S.H., Algorithms for VLSI Design Automation, John Wiley (1998) 3. Sarrafzadeh, M. and Wong, C. K., An Introduction to VLSI Physical Design, McGraw Hill (1996). 4. Trimberger, S. M., An Introduction to CAD for VLSI, Kluwer (1987). 5. Sait, S. M. and Youssef, Habib, VLSI Physical Design Automation – Theory and Practice, World Scientific, 2004.