COEP Technological University, Pune

(A Unitary Public University of Govt. of Maharashtra)

School of Engineering and Technology

Curriculum Structure & Detailed Syllabus

F.Y. M. Tech

IoT and Sensor Systems

(Effective from: A.Y. 2026-27)

F.Y. M. Tech
IoT and Sensor Systems

List of Abbreviations

Abbreviation	Title	No of courses	Credits	% of Credits
PSMC	Program Specific Mathematics Course	1	4	5
PSBC	Program Specific Bridge Course	1	3	3.75
PCC	Program Core Course	6	24	30
PEC	Program Specific Elective	3	9	11.25
MLC	Mandatory Learning Course	2	5	6.25
OE	Open Elective	1	3	3.75
SLC	Self-Learning Course	2	6	7.5
LLC	Liberal Learning Course	1	1	1.25
OJT	Internship	1	3	3.75
VSEC	Vocational and Skill Enhancement Course (Project)	2	22	27.5
	Total	20	80	100%

F.Y. M. Tech
IoT and Sensor Systems

Semester I

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1.	PSMC	PSMC-01	Applied Mathematics for IoT and Sensor	3	1	-	1	4	30	20	50	-	-
2.	PSBC	PSBC-01	Sensor technologies and measurement System	2	-	2	1	3	30	20	50	50	50
3.	PCC	PCC-01	Internet of Things Architecture and Applications	3	-	2	1	4	30	20	50	50	50
4.	PCC	PCC-02	Embedded System and RTOS	3	-	2	1	4	30	20	50	50	50
5.	PCC	PCC-03	Real-Time Sensor Signal Processing	3	-	2	1	4	30	20	50	50	50
6.	PEC-1	PEC-01	**Program Specific Elective –I** a) Radar and satellite communications b) Biomedical Edge Devices c) Intelligent Sensor System and Adaptive control for IIoT	3	-	-	1	3	30	20	50	-	-
7.	MLC	SET-25001	Research Methodology	2	1	-	1	3	30	20	50	-	-
			Total Credits	19	02	08	07	**25**					

Semester II

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1.	OE	OE-01	**Open Elective** – Beyond IoT and Sensor	3	-	-	1	3	30	20	50	-	-
2.	PCC	PCC-04	Data Analytics for IoT Applications	3	-	2	1	4	30	20	50	50	50
3.	PCC	PCC-05	Connected systems & Cloud Computing	3	-	2	1	4	30	20	50	50	50
4.	PCC	PCC-06	AI-ML For Edge Communication	3	-	2	1	4	30	20	50	50	50
5.	PEC-2	PEC- 02	**Program Specific Elective –II** a) Cognitive connectivity using wireless sensors b) Robotics & Humanoids c) Advanced IoT Networking and Secure Communication	3	-	-	1	3	30	20	50	-	-
6.	PEC-3	PEC-03	**Program Specific Elective –III** a) IoT- Non-Terrestrial Network b) Green IoT c) Vision and Intelligent System	3	-	-	1	3	30	20	50	-	-
7.	MLC	SET-25002	Technical Communication Skills	1	-	2	1	2	50	50	-	100	
8.	LLC	CCA	Liberal Learning Course	-	-	2	2	1	-	-	-	100	-
			Total Credits	19	00	10	09	**24**					

Semester -I

Applied Mathematics for IoT and Sensor						
Course Code	**PSMC01**		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Apply linear algebra and multivariable calculus to model sensor systems.
2. Analyse signals using transform techniques for IoT applications.
3. Model uncertainty using probability and stochastic processes.
4. Design estimation and filtering techniques for sensor data analysis.
5. Apply optimization and machine learning techniques for IoT problem-solving.

Linear Algebra & Matrix Computations with Machine Learning Math **[8 Hrs.]**

Vector spaces, basis, orthogonality, Eigenvalues, eigenvectors, diagonalization, Singular Value Decomposition (SVD), Sparse matrices and numerical stability; Linear and logistic regression, PCA and dimensionality reduction, Clustering (K-means), Time-series forecasting

IoT Relevance: Sensor fusion (multi-sensor data integration); Image/video processing in smart surveillance, Dimensionality reduction (PCA), Predictive maintenance, Smart agriculture analytics, Anomaly detection

Multivariable Calculus & Vector Calculus **[4 Hrs.]**

Partial derivatives and gradient, Jacobian and Hessian matrices, Line and surface integrals, Optimization using gradients

IoT Relevance: Optimization in embedded systems, Environmental modelling (temperature, pressure fields), Robotics and motion tracking

Probability Theory, Statistics & Stochastic Processes **[8 Hrs.]**

Probability distributions (Gaussian, Poisson, Exponential), Conditional probability and Bayes theorem, Expectation, variance, covariance, Statistical inference and hypothesis testing, Random processes (stationary, ergodic), Markov chains and Hidden Markov Models, Poisson processes, Time-series stochastic modelling.

IoT Relevance: Noise modelling in sensors, Fault detection and anomaly detection, Decision-making under uncertainty; Event detection in sensor networks, Smart traffic prediction, Behavior modelling in surveillance systems

Signal Processing Mathematics **[6 Hrs.]**

Fourier Series and Fourier Transform, Laplace and Z-transforms, Sampling theorem and aliasing, Wavelet transforms

IoT Relevance: Biomedical signal processing (ECG, EEG), Audio and vibration sensing, Data compression in IoT

Optimization Techniques **[5 Hrs.]**

Convex and non-convex optimization, Gradient descent, stochastic gradient descent, Lagrange multipliers, Distributed optimization

IoT Relevance: Energy-efficient IoT networks, Resource allocation in WSN, Smart grid optimization

Estimation & Filtering Theory **[5 Hrs.]**

Least squares estimation, Maximum Likelihood (MLE), MAP estimation Kalman Filter and Extended Kalman Filter, Particle filters

IoT Relevance: GPS positioning and tracking, Autonomous systems, Sensor noise filtering

Textbooks:

[1] Convex Optimization – Stephen Boyd & Lieven Vandenberghe

[2]	Convex Optimization for Signal Processing and Communications – Chong-Yung Chi et al.
Reference Books:	
[1]	Oppenheim & Willsky – *Signals and Systems*
[2]	Steven Kay – *Statistical Signal Processing*
[3]	Simon Haykin – *Adaptive Filter Theory*
[4]	Rajkumar Buyya – *IoT Principles and Paradigms*
Note:	
[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
[3]	To measure CO3, questions will be based on applications of core concepts.
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

Sensor technologies and measurement System						
Course Code	**PSBC-01**		**Examination Scheme**			
Teaching Scheme	2-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. To develop in-depth understanding of physical principles of sensing and measurement.
2. To analyse and design modern measurement systems and instrumentation.
3. To study advanced sensor technologies including smart and MEMS sensors.
4. To understand signal conditioning, data acquisition, and error analysis.
5. To explore applications in industrial, biomedical, and IoT domains.

Fundamentals of Measurement Systems	**[6 Hrs]**
Generalized measurement system architecture; Static and dynamic characteristics (accuracy, precision, sensitivity, linearity); Errors: systematic & random, uncertainty analysis; Calibration and standards (Primary, Secondary); Noise and interference in measurement systems	
Sensor Fundamentals and Transduction Principles	**[6 Hrs]**
Classification of sensors (Active/Passive, Analog/Digital); Transduction mechanisms: Resistive, Capacitive, Inductive, Piezoelectric, Thermoelectric, Optical; Smart sensors and self-calibration; Performance characteristics of sensors.	
Advanced Sensor Technologies	**[6 Hrs]**
MEMS and Nano sensors; Optical and Fiber optic sensors; Chemical and Biosensors; Environmental and Industrial sensors; Wearable and biomedical sensors (ECG, EEG, EMG basics);	
Signal Conditioning and Data Acquisition Systems	**[6 Hrs]**
Signal conditioning circuits: Amplifiers, Filters, Isolation; ADC/DAC, Sampling and Quantization; Data Acquisition Systems (DAQ): Architecture and components, Multiplexing and interfacing; Embedded measurement systems; Virtual instrumentation (LabVIEW concepts)	
Smart Measurement Systems and IoT Integration	**[6 Hrs]**
Intelligent and smart sensors; Wireless Sensor Networks (WSN); IoT-based measurement systems;	

Edge computing in sensing; Cyber-physical systems and Industry 4.0 applications	
Applications for Sensors and Measurement Systems	**[6 Hrs]**
Industrial automation and process instrumentation; Biomedical instrumentation; Environmental monitoring systems; Automotive and aerospace sensing; Smart cities and agriculture applications	

Textbooks:	
[1]	E.O. Doebelin – *Measurement Systems*
[2]	J.P. Bentley – *Principles of Measurement Systems*
[3]	Ramon Pallás-Areny & John Webster – *Sensors and Signal Conditioning*
Reference Books:	
[1]	Fraden – *Handbook of Modern Sensors*
[2]	Gerard Meijer – *Smart Sensor Systems*
[3]	D. Patranabis – *Sensors and Transducers*
[4]	Holger Karl – *Wireless Sensor Networks*
Note:	
[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
[3]	To measure CO3, questions will be based on applications of core concepts.
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages

Sensor Technologies and Measurement Systems-Lab
Course Outcomes: Students will be able to:
1. Perform calibration and testing of sensors. 2. Design signal conditioning circuits for sensor outputs. 3. Implement data acquisition and embedded measurement systems. 4. Analyze errors and uncertainties in measurements. 5. Develop IoT-based smart sensing solutions.
Experiment 1: Calibration of Temperature Sensor
Objective: To calibrate RTD/Thermistor/LM35 sensor Outcome Mapping: CO1, CO4 Key Concepts: Calibration curve, linearization, error estimation
Experiment 2: Pressure/Force Measurement using Strain Gauge
Objective: To measure force using strain gauge and Wheatstone bridge Outcome Mapping: CO1, CO2 Key Concepts: Bridge circuits, sensitivity, strain measurement
Experiment 3: Displacement Measurement using LVDT
Objective: To study working and characteristics of LVDT Outcome Mapping: CO1 Key Concepts: Inductive sensing, linearity, hysteresis
Experiment 4: Capacitive Sensor for Level/Proximity Measurement
Objective: To measure displacement/level using capacitive sensors

Outcome Mapping: CO1, CO2 Key Concepts: Capacitance variation, sensitivity
Experiment 5: Signal Conditioning using Operational Amplifiers
Objective: To design amplifier (inverting/non-inverting/instrumentation amplifier) Outcome Mapping: CO2 Key Concepts: Gain, filtering, noise reduction
Experiment 6: Data Acquisition using DAQ Card / Microcontroller
Objective: To acquire sensor data using DAQ or Arduino/STM32 Outcome Mapping: CO3 Key Concepts: Sampling, ADC, interfacing
Experiment 7: Study of Optical Sensor / Fiber Optic Sensor
Objective: To measure intensity/displacement using optical sensors Outcome Mapping: CO1 Key Concepts: Light modulation, optical sensing
Experiment 8: Measurement of Biomedical Signal (ECG/PPG Simulation)
Objective: To acquire and analyze biomedical signals Outcome Mapping: CO3 Key Concepts: Signal acquisition, filtering, noise removal
Experiment 9: Error Analysis and Uncertainty Measurement
Objective: To evaluate measurement errors in experimental setup Outcome Mapping: CO4 Key Concepts: Accuracy, precision, statistical analysis
Experiment 10: IoT-Based Sensor Node Development
Objective: To design a wireless sensor system using IoT (ESP32/Node MCU) Outcome Mapping: CO5 Key Concepts: IoT protocols, cloud integration
Experiment 11: MEMS Sensor Interfacing (Accelerometer/Gyroscope)
Objective: To develop a MEMS Sensor Interfacing Outcome Mapping: CO3 Key Concepts: GUI-based instrumentation, data visualization
Experiment 12: Virtual Instrumentation using LabVIEW / Python
Objective: To develop a virtual measurement system Outcome Mapping: CO3 Key Concepts: GUI-based instrumentation, data visualization

Internet of Things: Architecture and Applications						
Course Code	**PCC-01**		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Illustrate the fundamentals of IoT such as paradigms, architectures, possibilities, and challenges.
2. Identify suitable hardware elements and interfaces for IoT deployments.
3. Select IoT communication protocols for desired application.
4. Develop cloud computing model and service options.
5. Illustrate data analytics and security for IoT.
6. Design an IoT application in form of a prototype.

IoT Introduction and Fundamentals:	**[6 Hrs]**
IoT Introduction, Technological trends, deployment, impact on society, IoT components: sensors, actuators, embedded platforms, Digital Signal Processing techniques, Operating systems and protocols, Data transmission, Choice of channel (wired/wireless), back-end data analysis, cloud and edge computing	
IoT devices and components	**[6 Hrs]**
Different types of sensors, Specifications and selection criteria for sensors, Commercial IoT sensors, Signal conditioning modules of IoT system, Energy and power considerations, Different types of actuators, Interfacing challenges, Specifications of actuators, Modules of data acquisition system, positioning topologies for IoT infrastructure, IoT and architecture layers, IoT smart devices, Typical embedded computing systems, interfacing techniques	
Communication and Networking in IoT	**[6 Hrs]**
Interaction between software and hardware in an IoT device, Challenges in Networking of IoT Nodes, issues like range, bandwidth, data rates and power budget, Operating Systems need and requirements for IoT, Communications Standards for the IoT, Networking and communication aspects in IoT, Networking protocols, Cellular Networks and 5G for IoT Communication, Wireless communication in IoT, Various security issues related to IoT, security threats, vulnerabilities and protecting techniques	
Cloud, Edge Orchestration for IoT	**[6 Hrs]**
Cloud and Fog Ecosystem for IoT, Cloud computing, Cloud service options, Cloud Deployment models, Business concerns in the cloud, Comparison of Cloud providers, Edge computing, benefits, comparison of cloud and edge computing, IoT applications and their performance checking with used technology.	
IoT Data analytics and Deep learning for IoT	**[6 Hrs]**
Database types, IoT Data Analytics. Cryptographic algorithms, Analysis of Light weight Cryptographic solutions IoT security, Deep learning methods, developing model for past data analysis, prediction using data points, challenges in context of IoT	
IoT Applications	**[6 Hrs]**
Applications few examples like, IoT based Smart Home, Precision Agriculture, Smart vehicles, Smart Grid, Healthcare, Applications of IoT in robotics; Industrial IoT (IIoT), Industry 5.0, Smart remote monitoring.	
Self-Study (SS):	**(4 hrs)**

Review of multiple IoT application domains and design considerations. Embedded platform popularly used in IoT applications Differences of traditional OS and OS used in IoT and protocol comparison per usage type Cloud, edge and Fog computing comparison and service providers Study different deep learning algorithm for IoT to get better prediction

Textbooks:	
[1]	Arshdeep Bahga and Vijay Madisetti, “Internet of Things, a hands-on approach”, Universities Press (India) Pvt. Ltd. 2017, ISBN: 978-81-7371-954-7.
[2]	Rajkumar Buyya, Amir Vahid Dastjerdi, “Internet of Things Principles and Paradigms” Copyright © 2016 Elsevier Inc., ISBN: 978-0-12-805395-9.
Reference Books:	
[1]	William Stallings, “Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud” Publisher: Addison-Wesley 2015 ISBN: 9780134175393
[2]	Andrew Minteer, “Analytics for the Internet of Things (IoT)”
[3]	Man Young Rhee, “Internet Security: Cryptographic Principles, Algorithms and Protocols”
[4]	Gaston C. Hillar, “Internet of Things with Python”
[5]	Kai Hwang, Min Chen, “Big-Data Analytics for Cloud, IoT and Cognitive Computing”

Internet of Things Architecture and Applications - Lab

Course Outcomes: Students will be able to:

1. Develop advanced programming and system integration skills using Python and embedded platforms.
2. Design, prototype, and evaluate end-to-end IoT systems spanning sensors, edge computing, and cloud platforms.
3. Apply data analytics and machine learning techniques to IoT-generated data for intelligent decision-making.
4. Assess security requirements and implement secure communication protocols for IoT deployments.

List of Experiments

1. Design and deploy a multi-sensor IoT node integrating DHT11/DHT22, MQ135 (air quality), and MQ7 (CO) sensors. Implement edge preprocessing on ESP32/NodeMCU, transmit aggregated data to a cloud platform (AWS IoT / ThingSpeak), and build a real-time dashboard with threshold-based alerting. Apply MQTT protocol and analyse data using Python-based statistical tools.
2. Develop a layered security system combining PIR, Ultrasonic, and IR sensors with Raspberry Pi. Implement multi-factor detection logic to reduce false positives. Integrate with a cloud-based notification service for real-time SMS/email alerts and store event logs with timestamps in a time-series database. Evaluate system response latency and detection accuracy.
3. Interface DC, servo, and stepper motors with Raspberry Pi and implement closed-loop control algorithms. Attach vibration/current sensors to simulate predictive maintenance. Stream motor health data to the IoT cloud, apply basic ML anomaly detection (scikit- learn), and generate maintenance alerts. Evaluate power consumption and control accuracy under load conditions.
4. Build a precision agriculture prototype using soil moisture, temperature, humidity, and LDR sensors on Raspberry Pi. Implement automated irrigation control with relay-driven pumps and incorporate rule-based and ML decision logic (decision trees) for irrigation scheduling. Log data to a cloud platform and build a web dashboard for remote monitoring and manual override.

5. Deploy a home energy monitoring system using current/voltage sensors (ACS712) with NodeMCU. Measure power consumption of appliances, compute real-time energy metrics (kWh, power factor), and upload data to the cloud. Build a visualisation dashboard and apply regression models to predict energy usage. Implement automated load shedding logic triggered by thresholds.
6. Configure a Raspberry Pi as an IoT gateway aggregating data from multiple sensor nodes (Arduino/NodeMCU) using both Bluetooth (HC-05) and Wi-Fi. Implement MQTT, CoAP, and HTTP protocols and benchmark latency, throughput, and energy cost. Add TLS/SSL-based secure communication, device authentication (X.509 certificates), and compare protocol suitability for constrained IoT environments.
7. Deploy a lightweight image classification model (MobileNet/TinyML) on Raspberry Pi combined with LDR and PIR sensor inputs for context-aware scene understanding. Use OpenCV for image preprocessing and TensorFlow Lite for inference. Integrate with a cloud backend for model updates (OTA) and logging. Benchmark inference latency, accuracy, and power efficiency on edge hardware

Embedded System and RTOS

Course Code	**PCC-02**		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Understand the overview and characteristics of embedded systems.
2. Analyze the requirements and design challenges associated with embedded RTO Systems.
3. Gain insights into the design technology for embedded systems.

Introduction to Embedded Systems **[8 Hrs]**

Embedded Systems Overview; Characteristics; Components; Categorization; Requirements; Design challenges; Processor technology; IC technology; Design Technology; Processors (RT- level): custom single-purpose processor design, combinational logic, sequential logic. General Purpose Processors Introduction; Benefits; Basic architecture; Operations: Instruction execution, Pipelining; Programmer’s view; development environment; Selecting a microprocessor.

Embedded Hardware & Architecture **[6 Hrs]**

Microcontrollers vs Microprocessors, ARM / AVR / 8051 basics, Memory architecture (ROM, RAM, Flash) , Internal Peripheral Modules: Digital Input Output (DIO), Analog to Digital Converter (ADC) , Timer/Counters, Interrupts, UART, PWM. External Interfaces: Light Emitting Diodes (LEDs) and Switches, DC Motor and Stepper Motor, Relay and Motor Driver, Liquid Crystal Display (LCD), Matrix Keyboard, PC Communication.

Embedded RTOS **[8 Hrs]**

Embedded / RTOS Concepts and Digital Technology Architecture of the Kernel, Tasks and Task scheduler, Interrupt service routines, Semaphores, Mutex, Timers, Priority inversion problem. Logic synthesis, Behavioral synthesis, System synthesis, Hardware/Software co-design, Hardware/Software co-simulation, Flash memory-based file systems, device drivers.

Programming & Embedded C **[6 Hrs]**

Embedded C basics, Register-level programming, Interrupt Service Routines (ISR), Low-level driver development, Different types of IDE concepts (Keil µVision, ATMEL studio, ARDUINO)

Embedded SoC Platforms	**[8 Hrs]**
Embedded systems overview: CPU vs DSP vs PLC vs GPU vs ARM, Cortex A8 and A9, SoC memory subsystems, ARM architecture (cortex A8) Introduction to Zynq 7000 series SoC: Processing system (PS), Programmable logic (PL) – FPGA, DSP, RAM; general purpose AXI ports, high-performance AXI ports, timers, memory interfaces, clocking between PS and PL SoC interconnect (PS-PL interconnect): AXI signalling, AXI4Stream, SPI-AXI4 stream implementation, direct memory access (DMA), comparison of data movement methods.	
Self-Study (SS):	**[4 hrs]**
Compiler Tool Chain, Cross Compiler, Flashing Technique, Testing & Debugging Simulation in Proteus Software, Embedded C Programming, Flashing Technique, Testing & Debugging	

Textbooks:	
[1]	Kamal, R. (2011). Embedded Systems: Architecture, Programming and Design. India: Tata McGraw-Hill Education Private.
[2]	David Simon, "An Embedded Software Primer", Addison-Wesley, 2000
[3]	Jack Ganssle, "The Art of Designing Embedded Systems", Newnes, 1999
Reference Books:	
[1]	Embedded Systems: Real-Time Interfacing to Arm Cortex-M Microcontrollers – Jonathan W. Valvano
[2]	Programming Embedded Systems in C and C++ – Michael Barr
[3]	Real-Time Concepts for Embedded Systems -Qing Li, Caroline Yao
Note:	
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[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
[3]	To measure CO3, questions will be based on applications of core concepts.

Embedded System and RTOS - Lab

Course Outcomes: Students will be able to:

1. Design and develop embedded applications using microcontrollers and sensor interfaces.
2. Apply debugging and profiling techniques in embedded and RTOS environments.
3. Develop programming ability using C/C++/Python/Arduino.

List of Experiments-

1. Peripheral Programming: Switch interfacing using MCU (STM32 / Arduino / ESP32), Interrupt-based input handling.
2. Sensor & IoT Interfacing: Interface temperature, humidity sensors, Data acquisition, and calibration.
3. Sensor & IoT Interfacing: ADC & Data Acquisition, Analog sensor interfacing (LDR, gas sensor) , Real-time sampling.
4. Simulation in Proteus with an Embedded C Program: To simulate a microcontroller system using Proteus and run embedded C code.
5. End-to-End Embedded System Development: Design and implement an LED Blinking System with an interrupt-based button handling.
6. Embedded Linux on SoC: Emulate an ARM-based SoC using QEMU
7. , Boot a minimal Linux image, Analyse boot process and device tree
8. SoC Communication & Performance Analysis: (Python Simulation) Simulate a multi-core or multi-peripheral SoC, implement inter-module communication (UART/SPI-like)
9. RTOS Task Management: Create multiple tasks using Free RTOS, Task states and scheduling
10. Inter-Task Communication: Queues, semaphores, mutex, Producer-consumer problem
11. RTOS-based IoT Application: Transmit the Sensor data to the cloud (MQTT / HTTP). Use ESP32 and Free RTOS.

Real-Time Sensor Signal Processing						
Course Code	**PCC-03**		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--
Course Outcomes: Students will be able to:						
1. Analyse sensor signals and real-time system constraints. 2. Apply data acquisition and preprocessing techniques. 3. Perform time and frequency domain analysis of streaming data. 4. Design real-time filtering and feature extraction methods. 5. Develop intelligent, embedded, and scalable sensor processing systems using modern tools.						
F**undamentals of Sensor Signals and Real-Time Systems**						**[6 Hrs]**
Types of sensor signals and characteristics, Real-time data streams and constraints, Deterministic and stochastic signals, LTI systems, convolution, correlation, Sampling theorem, and aliasing. **S:** Types of sensor signals; sampling theorem and aliasing						
Real-Time Data Acquisition and Preprocessing						**[8 Hrs]**
Sensor interfacing and data acquisition systems (DAQ), Analog-to-Digital Conversion (ADC), Timing, latency, and synchronization issues, Noise sources in sensor data, Signal conditioning techniques (filtering, normalization, amplification), Buffering and streaming basics **S:** Sensor interfacing; noise and signal conditioning						

Time–Frequency Analysis of Sensor Data	[8 Hrs]
Statistical analysis (mean, variance, RMS), Smoothing and event detection, Fourier Transform, DFT, FFT, Power spectral density (PSD), Real-time spectral analysis. **S:** Statistical analysis; FFT basics.	
Digital Filtering and Advanced Processing	**[8 Hrs]**
FIR and IIR filters, Real-time filter design and constraints, Wavelet transform basics, Signal denoising and feature extraction, Multi rate processing. Sensor calibration and sensor fusion , Handling missing and noisy sensor data **S:** FIR and IIR filters	
Intelligent, Edge and Scalable Processing	**[8 Hrs]**
Machine learning basics for sensor data; embedded platforms (Arduino, ESP32, Raspberry Pi); edge vs cloud processing; IoT protocols (MQTT, CoAP); TinyML (TensorFlow Lite Micro); Digital Twin concepts; Apache Kafka and edge streaming pipelines. **S:** Embedded platforms; TinyML basics	
Self-Study (SS):	**[5 Hrs]**
1. Short-Time Fourier Transform (STFT) 2. Basics of Real-Time Operating Systems (RTOS) 3. TinyML optimization techniques (quantization, pruning) 4. Digital Twin architecture and applications 5. Apache Kafka architecture and real-time streaming	

Textbooks:	
[1]	Oppenheim & Schafer, *Signal Processing*, Pearson
[2]	Proakis & Manolakis, *Digital Signal Processing*, Pearson
Reference Books:	
[1]	Pete Warden & Daniel Situnayake, *TinyML*, O'Reilly
[2]	Raj Kamal, *Internet of Things: Architecture and Design Principles*, McGraw Hill

Real-Time Sensor Signal Processing - Lab

Course Outcomes: Students will be able to:

1. Interface sensors and acquire real-time data using embedded platforms.
2. Implement basic signal processing techniques on sensor data.
3. Analyse signals using time and frequency domain methods.
4. Design and implement filtering and feature extraction algorithms.
5. Develop real-time IoT-based sensor processing applications using modern tools

List of Experiments

1. Sensor data acquisition and real-time interfacing- Interfacing sensors (temperature, motion, light); real-time data acquisition using Arduino/ESP32; serial communication; live data plotting using Python/MATLAB.
2. Live data visualization using Python/MATLAB
3. Noise filtering using smoothing techniques- Noise identification in sensor data; smoothing techniques (moving average); normalization and basic signal conditioning.
4. FIR/IIR filter implementation- Design and implementation of FIR/IIR filters; real-time filtering of sensor data.
5. FFT-based real-time spectral analysis- FFT implementation; spectral analysis of

sensor signals; interpretation of frequency components. 6. Event detection system using thresholds 7. Feature extraction using sliding windows 8. TinyML implementation on microcontrollers (basic classification task)- Feature extraction techniques; TinyML implementation (basic classification using TensorFlow Lite Micro); streaming sensor data using MQTT/Kafka (basic setup or simulation). 9. Streaming sensor data using MQTT / Kafka pipeline (simulation or setup) 10. Mini Project (Compulsory): a. Development of a real-time sensor processing system integrating: Edge processing, Intelligent analytics, Optional Digital Twin visualization
Tools & Platforms- Arduino / ESP32 / Raspberry Pi Python (NumPy, Matplotlib) / MATLAB, TensorFlow Lite Micro, MQTT / Kafka (basic exposure)

Program Specific Elective –I **A) Radar and satellite communications**						
Course Code	**PEC-01**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--
Course Outcomes: Students will be able to:						
1. Understand the fundamentals of Kepler's Laws of motion applicable to satellite launching and orbital placement. 2. Understand various subsystems of communication satellite 3. Understand the functionalities of satellite transponder and other subsystems. 4. Understand and analyses various multiple access technology used in satellite 5. Illustrate data analytics and security IN Satellite Communications for IoT. 6. Design a Satellite for IoT Communications application in form of a prototype.						

Basics of Satellite Communication	**[6 Hrs]**
Evolution and growth of communication satellites, Kepler's laws of motion, orbits, altitude control; Principles of Satellite Communication: Satellite frequency allocation & Band spectrum, Advantages of satellite communication, Active & Passive satellite.	
Develop an understanding about link design between satellite and earth station	**[8 Hrs]**
Satellite launch vehicles-Arianne, SLV space shuttle; Subsystems of communication satellite; Spectrum allocation and Bandwidth considerations; Propagation characteristics, Satellite Link Design: Introduction, General link design equations, System noise temperature, C/N & G/T ratio, Atmospheric & Ionospheric effects on link design, Earth station parameters.	
Multiple access techniques used in satellite communication	**[6 Hrs]**
Satellite transponders and other sub systems; Earth station technology; Multiple Access Techniques: Introduction, TDMA, TDMA-Frame structure, TDMA-Burst structure, TDMA Frame efficiency, TDMA-super frame, TDMA-Frame acquisition & Synchronization, TDMA compared to FDMA, TDMA Burst Time Plan, Multiple Beam (Satellite switched) TDMA satellite system, Beam Hopping (Transponder Hopping) TDMA, CDMA & hybrid access techniques	
About the use of optical signal in satellite communication	**[6 Hrs]**

Laser Satellite Communication: Introduction, Link analysis, Optical & satellite link transmitter, Optical satellite link receiver, Satellite Beam Acquisition, Tracking & Positioning, Deep Space Optical Communication Link	
Develop the concepts of orbital motions of satellites	**[6 Hrs]**
Satellite Orbits & Inclination: Introduction, Synchronous orbit, Orbital parameters, Satellite location with respect to earth, look angles, Earth coverage & slant range, Eclipse effect, Satellite placement in geostationary orbit, station keeping, Satellite stabilization	
Acquire an information of different satellites used for communication purpose	**[6 Hrs]**
Special Purpose Communication Satellites: BDS, INMARSAT, INTELSAT, VSAT (data broadband satellite), MSAT (Mobile Satellite Communication technique), Sarsat (Search & Rescue satellite) & LEOs (Lower earth orbit satellite).	
Self-Study (SS):	**[6 Hrs]**
Comparison of different IoT applications that can be realized using satellite communication in urban and rural areas w.r.t education and health, Read and collect information of various Government and ISRO activities related to IoT domain	

Textbooks:	
[1]	Satellite Communication by Timothy Pratt, Charles Bostian, and Jeremy Allnutt, Wiley India Pvt. Ltd.
[2]	Satellite Communications Dennis Roddy TMH
[3]	Satellite Communications Timothy Pratt, Charles W. Bostian, Jeremy E. Allnutt Wiley India Pvt Ltd

Reference Books:	
[1]	Satellite Communication T.T.Ha MHE
[2]	Satellite Communications Systems by G. Maral and M. Bousquet, John Wiley & Sons.
[3]	Pete Warden, *TinyML*, O'Reilly
[4]	Kevin Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press

Note:	
[1]	To measure CO1, questions may be of the type – define, analyze, and model biomedical systems.
[2]	To measure CO2, questions may be of the type – explain, compute, and implement signal processing techniques.
[3]	To measure CO3, questions will be based on analysis and interpretation of biomedical data.
[4]	To measure CO4, questions may include system design and optimization of edge devices.
[5]	To measure CO5, questions may include case studies, AI-based healthcare applications, and real-world problems.

Program Specific Elective –I B) Biomedical Edge Devices						
Course Code	**PEC-01**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Analyse advanced biomedical signals and edge device architectures for healthcare systems.
2. Apply signal acquisition, preprocessing, and real-time processing techniques on physiological data.
3. Evaluate multi-modal biomedical data using advanced analytics and AI methods.
4. Design intelligent, low-power, and secure biomedical edge systems.
5. Develop autonomous and connected healthcare solutions integrating edge, cloud, and AI technologies.

Biomedical Signals and Sensing Systems: **[8 Hrs]**

Introduction to biomedical engineering; physiological signals (ECG, EEG, EMG, PPG); multi-modal sensing systems; wearable and implantable biosensors; bio-signal variability and stochastic modelling; noise and artifact characterization; clinical signal standards.

Edge Device Architecture and Low-Power Biomedical Systems: **[8 Hrs]**

Biomedical edge architectures; ultra-low power embedded systems; analog front-end design; ADC optimization; power management (DVFS, sleep modes); wearable and implantable device design; energy harvesting for medical devices.

Biomedical Signal Processing and Analytics: **[8 Hrs]**

Time-frequency analysis (Wavelets, STFT); adaptive filtering; artifact removal; feature extraction (HRV, QRS detection); compression techniques; real-time signal analytics; anomaly detection in biomedical signals.

AI-Driven Edge Intelligence in Healthcare **[6 Hrs]**

Machine learning and deep learning for biomedical data; TinyML for wearable devices; federated learning for healthcare; explainable AI (XAI); predictive diagnostics; edge-cloud collaborative intelligence.

Connected Healthcare Systems, Security and Digital Twins **[6 Hrs]**

IoT-based healthcare systems; remote patient monitoring; communication protocols (BLE, MQTT); medical data security and privacy (HIPAA concepts); blockchain for healthcare; Digital Twin for patient-specific modeling; regulatory standards (FDA, CE).

Self-Study (SS): Emerging Trends in Biomedical Edge Devices- **[4 Hrs]**

1. Smart wearables and implantable medical devices
2. Edge AI for real-time diagnostics
3. Brain-computer interfaces (BCI)
4. Digital health ecosystems and telemedicine
5. Ethical and legal aspects of AI in healthcare
6. AI-driven personalized medicine.

Textbooks:

[1] John G. Webster, *Medical Instrumentation: Application and Design*, Wiley

[2] Rangaraj M. Rangayyan, *Biomedical Signal Analysis*, Wiley

Reference Books:

[1] Joseph J. Carr, John M. Brown, *Introduction to Biomedical Equipment Technology*, Pearson

[2]	Metin Akay, *Biomedical Signal Processing*, Academic Press
[3]	Pete Warden, *TinyML*, O'Reilly
[4]	Kevin Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press
Note:	
[1]	To measure CO1, questions may be of the type – define, analyze, and model biomedical systems.
[2]	To measure CO2, questions may be of the type – explain, compute, and implement signal processing techniques.
[3]	To measure CO3, questions will be based on analysis and interpretation of biomedical data.
[4]	To measure CO4, questions may include system design and optimization of edge devices.
[5]	To measure CO5, questions may include case studies, AI-based healthcare applications, and real-world problems.

Program Specific Elective –I

C) Intelligent Sensor System and Adaptive control for IIoT

Course Code	**PEC-01**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Analyse sensor networks and IIoT-based sensing architectures
2. Apply adaptive control techniques for dynamic systems
3. Design intelligent control systems integrating sensors & IIoT

Fundamentals of Intelligent Sensor Systems	**[6 Hrs]**
Introduction to Intelligent Sensors & Smart Systems, Architecture of intelligent sensors (sensing, processing, communication), Sensor characteristics: accuracy, resolution, hysteresis, response time, Signal conditioning: amplification, filtering, ADC/DAC, Sensor classification: mechanical, thermal, optical, MEMS, Sensors & Actuators in IIoT and Sensor interfacing (Arduino, Raspberry Pi, Node MCU).	
IIoT Architecture & Communication	**[6 Hrs]**
IoT vs IIoT, layered architecture, IIoT system components (sensor → gateway → cloud), Communication protocols: MQTT, CoAP, OPC-UA, ZigBee, BLE, LoRaWAN, Data acquisition and edge computing, Cybersecurity basics in IIoT	
Adaptive Control Systems	**[6 Hrs]**
Basics of control systems (open-loop, closed-loop), Introduction to adaptive control, Model Reference Adaptive Control (MRAC), Self-tuning regulators, Parameter estimation techniques, Stability and convergence	
Intelligent Control & Applications	**[6 Hrs]**
AI-based control (Neural Networks, Fuzzy Logic) , Sensor fusion & data analytics, Real-time control in IIoT, Industrial automation systems	
Introduction to Security in IIoT Systems	**[6 Hrs]**

IIoT security: protecting devices, data, and communication in industrial systems, Common Threats in IIoT, Basic Security Principles (CIA Triad), Secure Communication in IIoT, Encryption Basics, Device-Level Security, Network Security, Security Challenges in IIoT		
Case studies		**[6 Hrs]**
Smart manufacturing, predictive maintenance, Automotive Industry, Healthcare, Agriculture, Defense		
Self-Study (SS)		**[4 Hrs]**
Mini Self-Study Projects		
Textbooks		
[1]	Industrial Internet of Things: Cybermanufacturing Systems — Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat	
[2]	Industrial Internet of Things — Alasdair Gilchrist	
Reference Books		
[1]	Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, "Industrial Internet of Things: Cyber manufacturing System (wireless Technology)", Springer Publication, 2017.	
[2]	Robert Barton, Patrick Grossetete, David Hanes, Jerome Henry, Gonzalo Salgueiro, "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", CISCO Press, 2017.	
[3]	Sensors and Actuators: Engineering System Instrumentation — Clarence W. de Silva	
[4]	Adaptive Control: Algorithms, Analysis and Applications — Ioan D. Landau, Rogério Lozano, Mohamed M'Saad, Alain Karimi	

Note:	
[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
[3]	To measure CO3, questions will be based on applications of core concepts.
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

Research Methodology						
Course Code	**SET-25001**		**Examination Scheme**			
Teaching Scheme	2-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Formulate research problems by defining objectives, hypotheses, variables, and feasibility.
2. Synthesize literature using reproducible search and screening strategies.
3. Apply research ethics, authorship norms, compliance rules, and FAIR data practices.
4. Produce research outputs through ethical analysis, documentation, and dissemination.

Introduction to Research	**[4 Hrs]**
What is scientific research, objectives of research, motivation, types of research, research approaches, research methodology, significance of research, indications of good research	
Designing a Problem	**[6 Hrs]**
Research problems, literature review, formulation of feasible problem, hypothesis, errors in problem selection, selection of variables,	
Methods- Simulations and Experiments:	**[7 Hrs]**
Conventional approaches, selection of tools, setting up production, validation of results, performance analysis, sensitivity analysis, errors in measurements	
Statistics and Uncertainty Quantification	**[7 Hrs]**
Data, importance of analyzing data, types of analyses, selection practices, statistics, sampling techniques, uncertainty quantification, errors analysis	
RCR and Ethics	**[5 Hrs]**
Responsible conduct of research, IEC compliance, what is plagiarism, QRPs, generative A.I. in research	
IPR, Research Ethics and Publishing	**[8 Hrs]**
Introduction to IPR, significance of IPR, types of IPR, recent developments, technical writing	

Textbooks:

[1] Melville, S., & Goddard, W. (1996). Research methodology: An introduction for science & engineering students. Juta & Co.

[2] Kothari, C. R. (2009). Research methodology: Methods and trends. New Age International Publishers

Reference Books:

[1] Goddard, W., & Melville, S. (2001). Research methodology: An introduction (2nd ed.). Juta Academic.

[2] Kumar, R. (2005). Research methodology: A step-by-step guide for beginners (2nd ed.). Sage Publications.

[3] Sharma, S. D. (2001). Operational research. Kedar Nath Ram Nath & Co.

Semester - II

Open Elective - Beyond IoT and Sensor						
Course Code	**OE-01**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Analyze next-generation IoT paradigms beyond conventional sensing systems.
2. Design intelligent, context-aware, and autonomous cyber-physical systems.
3. Evaluate edge-AI, digital twins, and federated learning frameworks.
4. Integrate advanced communication protocols for ultra-reliable low-latency systems.
5. Develop secure, scalable, and energy-efficient post-IoT architectures.

IoT architectures and System Evolution	**[4 Hrs]**
Limitations of traditional IoT architectures. Evolution towards Cyber-Physical Systems (CPS), Internet of Everything (IoE), and Internet of Behaviors (IoB). Human-in-the-loop systems. Context-aware and self-adaptive systems. Introduction to autonomous sensing-less environments. System-level abstraction for intelligent infrastructure.	
Edge Intelligence and Embedded AI	**[6 Hrs]**
Edge computing vs. fog computing vs. cloud continuum. TinyML and on-device intelligence. Neural network quantization and pruning for embedded platforms. Real-time inference constraints. Hardware-aware AI models. Co-design of hardware and ML models. Case studies: AI-enabled smart devices without continuous sensing.	
Integrated sensing & Communication	**[6 Hrs]**
Beyond 5G and 6G communication paradigms. Ultra-Reliable Low Latency Communication (URLLC). Massive Machine-Type Communication (mMTC). Terahertz communication basics. Backscatter communication and ambient RF systems. Network slicing and software-defined networking (SDN) for adaptive IoT ecosystems.	
Digital Twins and Virtualization	**[4 Hrs]**
Concept and architecture of digital twins. Real-time synchronization between physical and virtual systems. Modeling and simulation frameworks. Predictive maintenance using digital twins. Integration with Industry 4.0. Challenges in scalability, latency, and fidelity.	
Security, Privacy, and Trust in Post-IoT Systems	**[4 Hrs]**
Hardware-assisted security for distributed systems. Lightweight cryptography for constrained environments. Zero-trust architectures Case study-. Blockchain for decentralized trust management. Attack surfaces in CPS and mitigation strategies.	
Self-Study - IoT Applications (Next-Gen Systems)	**[4 Hrs]**
Case study-Autonomous vehicular technology with V2X communication. Case study- Healthcare system with wearable sensors. Case study-Smart agriculture with minimal sensing	

Textbooks:

[1]	Rajkumar Buyya, Amir Vahid Dastjerdi, *Internet of Things: Principles and Paradigms*, Elsevier.
[2]	Pethuru Raj, Anupama C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press.

Reference Books:

[1]	Ovidiu Vermesan, Peter Friess, *Internet of Things – From Research to Innovation*, River Publishers.
[2]	Schahram Dustdar et al., *Principles of Edge Computing*, Wiley.
[3]	Ying Zhang, *6G Mobile Wireless Networks*, Springer.
[4]	N. M. Karnik, *Cyber-Physical Systems: Foundations and Applications*, Academic Press.
Note:	
[1]	To measure CO1, questions may focus on analysis of post-IoT paradigms and system evolution.
[2]	To measure CO2, problems may involve design of intelligent edge-based systems.
[3]	To measure CO3, evaluation may include AI and digital twin-based architectures.
[4]	To measure CO4, questions may test communication protocol design and optimization.
[5]	To measure CO5, case studies on security, privacy, and scalable architectures may be included

Data Analytics for IoT Applications						
Course Code	**PCC-04**		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Develop advanced understanding of IoT data characteristics and pipelines.
2. Apply statistical, machine learning, and AI techniques to sensor data.
3. Design real-time analytics systems for IoT applications.
4. Integrate edge, cloud, and big data platforms.

IoT Data Ecosystem & Architecture	**[6 Hrs]**
IoT architecture: sensing → communication → cloud → analytics, Types of IoT data: time-series, event streams, spatial data, IoT protocols: MQTT, CoAP, HTTP, Data acquisition & ingestion pipelines, Edge vs Cloud analytics, Data lifecycle in IoT systems, **Case Study**: Smart city sensor network / Industrial IoT	
Statistical Methods for IoT Data	**[6 Hrs]**
Descriptive & inferential statistics, Time-series analysis (trend, seasonality, ARIMA basics), Probability models for sensor uncertainty, Outlier detection & anomaly detection; Data cleaning & preprocessing for IoT **Insight**: IoT data is noisy, incomplete, and high frequency	
Machine Learning for IoT Analytics	**[8 Hrs]**
Supervised learning: regression, classification, Unsupervised learning: clustering, dimensionality reduction, Deep learning basics for IoT (CNN, RNN, LSTM for time-series), Feature engineering for sensor data, Model evaluation & deployment	
Big Data & Stream Analytics for IoT	**[6 Hrs]**
Big data frameworks: Hadoop, Spark, Stream processing: Kafka, Spark Streaming, Flink,Real-time	

analytics vs batch analytics, Data storage: NoSQL (MongoDB, Cassandra),Scalable IoT analytics architectures.		
Advanced IoT Analytics & Applications		**[6 Hrs]**
Edge AI and TinyML, Predictive maintenance (Industry 4.0), Smart healthcare analytics Smart agriculture & environmental monitoring, Security & privacy in IoT analytics, Digital twins and intelligent systems **Case Studies**: Smart grid analytics, Autonomous systems, Surveillance & anomaly detection		
Textbooks:		
[1]	Internet of Things: A Hands-On Approach by Arshdeep Bahga and Vijay Madisetti.	
[2]	Analytics for the Internet of Things (IoT) by Andrew Minteer	
Reference Books:		
[1]	Digitising the Industry: Internet of Things Connecting the Physical, Digital and Virtual Worlds by Ovidiu Vermesan	
[2]	Practical Time Series Analysis by Aileen Nielsen	
[3]	Hands-On Machine Learning for IoT by Rashmi Nanjundaswamy	
[4]	Streaming Data: Solutions for real-time decision making by Andrew Psaltis	
[5]	NoSQL Distilled by Pramod Sadalage	
[6]	TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers by Pete Warden & Daniel Situnayake	
[7]	Digital Twin: The Groundbreaking New Strategy by John Grieves	
Note:		
[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.	
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.	
[3]	To measure CO3, questions will be based on applications of core concepts.	
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.	
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.	

Data Analytics for IoT Applications -Lab

Course Outcomes: Students will be able to:

1. Acquire and preprocess IoT sensor data using appropriate data handling techniques.
2. Perform time-series analysis to identify trends and patterns in IoT data.
3. Apply anomaly detection techniques to identify irregularities in sensor data.
4. Develop and evaluate predictive models for IoT applications using machine learning methods.
5. Implement clustering techniques to analyze and group IoT devices or data based on behaviors

List of Experiments

1. **IoT Data Acquisition & Preprocessing**- Import real sensor dataset (temperature, humidity, etc.), Handle missing values, noise filtering, Perform normalization & scaling Tools: Python (Pandas, NumPy)
2. **Time-Series Analysis of IoT Data-** Plot and analyse time-series sensor data, identify trend, seasonality, Apply moving average / smoothing.

Tools: Pandas, Matplotlib **3. Anomaly Detection in Sensor Networks-** Detect outliers using statistical methods, Apply Isolation Forest / LOF, Visualize anomalies *Use Case:* Fault detection in industrial sensors **4. Predictive Modelling on IoT Data -** Build regression model (e.g., temperature prediction), Evaluate using RMSE, MAE, compare models Tools: Scikit-learn **5. Clustering of IoT Devices/Data -** Apply K-means / DBSCAN clustering, Group sensors based on behaviour, visualize clusters Use Case: Smart building energy zones **6. IoT Data Stream Processing-** Simulate streaming data using Python, Process real-time data (windowing concept), Basic event detection Tools: Python / lightweight streaming 7. **IoT Data Visualization Dashboard -** Create dashboard for sensor data, Real-time plotting, Alerts for threshold crossing Tools: Plotly/ Dash / ThingsBoard 8. **End-to-End IoT Analytics Mini Project -** Build pipeline: data → preprocessing → ML → visualization, Use real dataset (air quality / smart home)

Connected Systems & Cloud Computing						
Course Code	**PCC-05**		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--
Course Outcomes: Students will be able to:						
1. Define and explain architectures of connected systems and cloud computing models. 2. Apply networking and communication protocols for IoT systems. 3. Analyse cloud platforms and real-time data streaming techniques. 4. Design scalable and secure IoT-cloud integrated system 5. Develop intelligent connected systems using modern tools and technologies.						
Connected System Architecture and Fundamentals						**[6 Hrs]**
Evolution from IoT to Cyber-Physical Systems (CPS), Layered architecture: Device–Edge–Cloud continuum, Components of connected systems (sensors, gateways, cloud) Communication stack (TCP/IP, HTTP, MQTT, CoAP), Middleware and interoperability frameworks, System-level challenges: latency, scalability, reliability, Introduction to digital communication in IoT. **S:** CPS case studies; interoperability standards; comparison of IoT architectures						
Advanced Connectivity and Networking for IoT						**[8 Hrs]**
Network architectures (PAN, LAN, WAN), LPWAN technologies (LoRaWAN, NB-IoT), Wireless technologies (Wi-Fi, Bluetooth, Zigbee), Software Defined Networking (SDN) basics, Network slicing, and Quality of Service (QoS), Time-Sensitive Networking (TSN), Secure communication protocols (TLS, DTLS), Routing and addressing in IoT systems						

Cloud-Native Computing for IoT Platforms	**[8 Hrs]**
Cloud computing fundamentals (IaaS, PaaS, SaaS), Deployment models (public, private, hybrid), Microservices architecture for IoT, Containerization (Docker) and orchestration (Kubernetes), Serverless computing (Faas), IoT cloud platforms (AWS IoT, Azure IoT, Google Cloud IoT), Cloud storage: NoSQL, time-series databases, API gateways and service integration	
Real-Time Data Streaming and Analytics	**[8 Hrs]**
IoT data pipelines and data flow architecture, Data ingestion and message brokers, Stream processing frameworks (Apache Kafka, Spark Streaming), Event-driven architecture, Edge analytics vs cloud analytics, Data visualization and dashboarding, Big data tools for IoT, Performance considerations in real-time systems	
Intelligent, Secure and Scalable Connected Systems	**[8 Hrs]**
AI/ML integration in IoT systems, Edge intelligence and TinyML concepts, Anomaly detection and predictive analytics, Digital Twin concepts and system modelling, Security in IoT-cloud systems (authentication, encryption, IAM), Blockchain basics for IoT security, Load balancing, auto-scaling, fault tolerance, Monitoring, observability, and optimization, emerging trends (5G/6G IoT, smart systems)	
Self-Study (SS):	**[4 Hrs]**
• Digital Twin architecture and simulation • Apache Kafka and real-time streaming pipelines • Cloud-native DevOps practices • Edge vs cloud performance comparison	

Textbooks:	
[1]	Kai Hwang, Geoffrey Fox, Jack Dongarra, *Distributed and Cloud Computing: From Parallel Processing to the Internet of Things*, Morgan Kaufmann
[2]	Adrian McEwen, Hakim Cassimally, *Designing the Internet of Things*, Wiley
Reference Books:	
[1]	Pete Warden, Daniel Situnayake, *TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers*, O'Reilly - useful for edge intelligence and Tiny-ML concepts
[2]	Brendan Burns, Joe Beda, Kelsey Hightower, *Kubernetes: Up and Running*, O'Reilly
[3]	Neha Narkhede, *Kafka: The Definitive Guide*, O'Reilly
Note:	
[1]	To measure CO1, questions may be of the type – define, identify, state, list.
[2]	To measure CO2, questions may be of the type – explain, describe, illustrate
[3]	To measure CO3, questions will be based on analysis and applications
[4]	To measure CO4, questions may include design and system-level problems
[5]	To measure CO5, questions may include case studies, self-study topics, and real-world applications.

Connected Systems & Cloud Computing - Lab
Course Outcomes: Students will be able to:
1. Interface IoT devices with cloud platforms and enable real-time communication. 2. Implement communication protocols such as MQTT and HTTP for data exchange. 3. Analyze and visualize sensor data using cloud-based tools and dashboards. **4.** Develop containerized and scalable IoT-cloud applications.
List of Experiments
1. IoT device interfacing and cloud connectivity 2. MQTT/HTTP protocol implementation 3. Sensor data transmission to cloud platform 4. Real-time data visualization using dashboards 5. Implementation of data streaming using Kafka (basic/simulation) 6. Deployment of containerized IoT application (Docker basics) 7. Basic anomaly detection on sensor data 8. Mini Project: Connected IoT-cloud system

AI-ML For Edge Communication						
Course Code	**PCC-06**		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--
Course Outcomes: Students will be able to:						
1. Simulate wireless communication channels and analyze system performance metrics such as SNR and BER. 2. Develop AI/ML models for communication tasks such as modulation classification and channel estimation. 3. Deploy machine learning models on edge devices and evaluate latency and inference performance. 4. Optimize AI models using compression techniques (quantization, pruning) for efficient edge deployment. 5. Implement federated and distributed learning techniques for communication systems. (Apply – L3) 6. Design AI-based solutions for adaptive communication systems using reinforcement learning or intelligent optimization.						
Edge Communication Paradigm & Intelligent Networks						**[6 Hrs]**
Evolution: Cloud → Fog → Edge → AI-native networks, Multi-access Edge Computing (MEC) architecture, Role of AI in 5G and emerging 6G systems**,** Network slicing, QoS/QoE in intelligent networks, Latency-critical communication systems **Case Study**: Autonomous vehicle communication / Tactile internet						
AI Techniques in Wireless Communication Layers						**[6 Hrs]**
AI in Physical Layer: Channel estimation using ML, Signal detection & modulation classification; AI in MAC Layer: Resource allocation & scheduling, Traffic prediction; AI for spectrum						

management: Spectrum sensing, Cognitive radio networks	
Edge AI Model Engineering	**[6 Hrs]**
Model optimization for edge: Quantization, pruning, knowledge distillation, Lightweight ; Deep learning models: Mobile-Net, Squeeze-Net, Tiny-ML; On-device vs edge-server inference Hardware-aware AI: Edge TPU, FPGA, embedded GPUs; Energy-efficient inference design	
Distributed & Federated Intelligence at the Edge	**[6 Hrs]**
Distributed learning architectures, Federated learning: Architecture & workflow, Communication-efficient updates, Privacy-preserving AI: Secure aggregation, Differential privacy (conceptual), Edge–cloud collaboration strategies	
AI-Driven Network Management & Future Systems	**[6 Hrs]**
Self-Organizing Networks (SON), AI-based network orchestration & automation, Reinforcement learning for adaptive networking, AI in UAV/drone communication networks, Security challenges in AI-enabled communication, Future directions: 6G, AI-native air interface, digital twins	

Textbooks:	
[1]	Mobile Edge Artificial Intelligence: Opportunities and Challenges; Authors: Yuanming Shi et al. Publisher: Elsevier
[2]	*Wireless Communications and Machine Learning,* Publisher: Cambridge University Press
[3]	Artificial Intelligence: A Modern Approach – Artificial Intelligence: A Modern Approach ; Authors: Stuart Russell & Peter Norvig
Reference Books:	
[1]	Federated Learning for Future Intelligent Wireless Networks ; Publisher: Wiley
[2]	Federated Learning Over Wireless Edge Networks; Authors: Lim et al.
Note:	
[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.(Apply/Analyze – L3/L4)
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc. *(Apply – L3)*
[3]	To measure CO3, questions will be based on applications of core concepts. *(Apply/Evaluate – L3/L5)*
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc. *(Analyze/Evaluate – L4/L5)*
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.
[6]	To measure CO6, application development (mini project, Case study)like- design adaptive communication between edge devices with reinforcement learning *(Design/Create – L6)*

AI-ML For Edge Communication - Lab
Course Outcomes: Students will be able to:
1. Apply machine learning techniques to wireless communication problems. 2. Analyze and optimize communication systems using AI-based approaches. 3. Deploy and evaluate ML models on edge devices under real-time constraints. **4.** Compare performance of traditional signal processing and AI-based methods
List of Experiments
1. **Wireless Channel Simulation**- Simulate fading channel (Rayleigh/AWGN), Analyze signal distortion. Study SNR vs BER

Tools: MATLAB / Python

2. **ML-Based Modulation Classification-** Train ML/DL model to classify modulation schemes, Compare accuracy with traditional methods
   Tools: TensorFlow / PyTorch
3. **AI-Based Channel Estimation-** Use ML model to estimate channel parameters, Compare with conventional estimation
   Insight: AI replacing signal processing
4. **Edge Deployment of ML Model-** Convert model to TensorFlow Lite, Deploy on edge device (Raspberry Pi / emulator) ,Measure inference time
5. **Model Compression for Edge AI-** Apply pruning/quantization Compare: Model size, Accuracy, Latency
6. **Federated Learning Simulation-** Train distributed model across multiple nodes Aggregate updates centrally Compare with centralized learning
   Tools: Flower / PySyft
7. **Reinforcement Learning for Network Optimization-** Implement RL for: Routing OR, Resource allocation, Evaluate performance improvement,
   Use Case: Adaptive communication systems
8. **Latency & Energy Benchmarking in Edge Systems -** Measure: Latency, Energy consumption (approx.) Compare cloud vs edge inference

Program Specific Elective –II
A) Cognitive connectivity using wireless sensors

Course Code	**PEC-02**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Explain the fundamental concepts of cognitive radio networks.
2. Design the cognitive radio, as well as techniques for spectrum holes detection that cognitive radio takes advantages in order to exploit it.
3. Describe technologies to allow an efficient use of TVWS for radio communications based on two spectrum sharing business models/policies.
4. Describe the fundamental issues regarding dynamic spectrum access, the radio-resource management and trading, as well as a few optimization techniques for better spectrum exploitation.
5. Understanding of machine learning algorithms as an application to Cognitive Radio.
6. Understanding of the applications of auction theory as an economic approach to enable the emerging cognitive radio systems very useful.

Radio resource management in wireless networks	**[4 Hrs]**
Overview of Wireless networks considering their spectrum usage, Radio frequency bands and spectrum management, (RRM) framework, Next generation heterogeneous wireless access networks and cognitive radio	
Introduction to Cognitive Radio:	**[8 Hrs]**
Spectrum hole/spectrum opportunity, Software-defined radio, Cognitive radio features and capabilities, Cognitive radio architecture, Functions of cognitive radio, Components of cognitive radio, Potential applications of cognitive radio	
Spectrum Sensing	**[8 Hrs]**

Detection of spectrum holes, Practical spectrum sensing approaches: Non- Cooperative Sensing, Cooperative Sensing, collaborative sensing using relay transmission, Replacement of sensing devices in secondary users, New cognitive cycle with separate sensing devices, Maximum likelihood estimator, Maximum a posteriori (MAP)/Bayesian estimator	
Dynamic spectrum	**[6 Hrs]**
Spectrum access models, Dynamic spectrum access architecture, Open issues in dynamic spectrum access, Distributed dynamic spectrum access: learning algorithms and protocols	
Spectrum Trading	**[6 Hrs]**
Introduction to spectrum trading, classification to spectrum trading, radio resource pricing, brief discussion on economics theories in DSA(utility, auction theory),classification of auctions (single auctions, double auctions, concurrent, sequential).	
Research Challenges in Cognitive Radio	**[6 Hrs]**
Network layer and transport layer issues, cross-layer design for cognitive radio networks, Cognitive radio architectures for Next Generation (XG) networks, Cognitive radio standardization	
Self-Study (SS):	**[4 Hrs]**
Advance topics in Cognitive radio like network security and coexistence mechanism Self-management capabilities of Cognitive radio	

Textbooks:	
[1]	Ekram Hossain, Dusit Niyato, Zhu Han, "Dynamic Spectrum Access and Management in Cognitive Radio Networks", Cambridge University Press, 2009.
[2]	Kwang-Cheng Chen, Ramjee Prasad, "Cognitive radio networks", John Wiley & Sons Ltd., 2009.
[3]	Bruce Fette, "Cognitive radiotechnology", Elsevier,2ndedition,2009.
[4]	Huseyin Arslan, "Cognitive Radio, Software Defined Radio, and Adaptive Wireless Systems", Springer, 2007
Reference Books:	
[1]	Huseyin Arslan, "Cognitive Radio, Software Defined Radio, and Adaptive Wireless Systems", Springer.
[2]	Francisco Rodrigo Porto Cavalcanti, Soren Andersson, "Optimizing Wireless Communication Systems", Springer, 2009.
[3]	Linda Doyle, "Essentials of Cognitive Radio", Cambridge University Press,
[4]	Discrete Time Speech Signal Processing: Thomas F. Quateri Pearson Principles and Practice Education

Program Specific Elective –II
B) Robotics & Humanoids

Course Code	**PEC-02**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Analyse advanced robotic architectures and humanoid system design principles.
2. Apply kinematic, dynamic, and control models to complex robotic systems.
3. Evaluate perception, localization, and sensor fusion techniques in autonomous robots.
4. Design intelligent and adaptive robotic systems using AI and learning algorithms.

5. Develop autonomous humanoid and robotic solutions for real-world and industrial applications.		
Advanced Robotic Architectures and Humanoid Design		**[8 Hrs]**
Evolution of robotics to intelligent and autonomous systems; humanoid robot architecture; bio-inspired and anthropomorphic design; degrees of freedom and redundancy; actuation systems (electric, hydraulic, soft actuators); system integration challenges. S**:** Bio-inspired robotics; humanoid design case studies (Boston Dynamics, Honda ASIMO)		
Robot Kinematics, Dynamics, and Motion Planning		**[8 Hrs]**
Forward and inverse kinematics; Denavit-Hartenberg (D-H) modeling; Jacobian analysis; singularities; dynamic modeling (Lagrangian and Newton-Euler methods); trajectory generation; optimal motion planning. S**:** Redundancy resolution; trajectory optimization techniques; Soft robotics and flexible actuators		
Perception, Localization and Sensor Fusion		**[8 Hrs]**
Advanced sensors (LiDAR, depth cameras, IMU); multi-sensor fusion; computer vision in robotics; SLAM (Simultaneous Localization and Mapping); object detection and environment understanding. S**:** SLAM algorithms; vision-based navigation,		
Control, Learning and Cognitive Robotics		**[6 Hrs]**
Advanced control (PID, adaptive, model predictive control); reinforcement learning for robotics; deep learning for perception and control; human-robot interaction; collaborative and cognitive robots. **S:** Reinforcement learning in robotics; human-robot interaction models		
Humanoid Locomotion and Autonomous Systems		**[6 Hrs]**
Bipedal locomotion and stability (ZMP concept); gait generation; balance control; autonomous navigation; swarm and multi-robot systems; industrial and service robotics applications; ethical considerations. S**:** Humanoid walking algorithms; swarm robotics case studies; Ethical, legal, and societal impacts of robotics; Autonomous vehicles and drones		
Self-Study (SS): Emerging Trends in Robotics & Humanoids		**[4 Hrs]**
1. Digital Twin for robotic systems 2. Edge AI and TinyML in robotics 3. Robot Operating System (ROS 2) architecture		
Textbooks:		
[1]	John J. Craig, *Introduction to Robotics: Mechanics and Control*, Pearson	
[2]	Bruno Siciliano et al., *Robotics: Modelling, Planning and Control*, Springer	
Reference Books:		
[1]	Mark W. Spong, *Robot Modelling and Control*, Wiley	
[2]	Sebastian Thrun et al., *Probabilistic Robotics*, MIT Press	
[3]	Richard S. Sutton, *Reinforcement Learning: An Introduction*, MIT Press	
[4]	Morgan Quigley et al., *Programming Robots with ROS*, O'Reilly	
Note:		
[1]	To measure CO1, questions may be of the type – define, analyse, identify advanced concepts.	
[2]	To measure CO2, questions may be of the type – derive, explain, compute, model systems.	
[3]	To measure CO3, questions will be based on perception and real-world applications	
[4]	To measure CO4, questions may include design, AI integration, and control strategies.	
[5]	To measure CO5, questions may include case studies, research-oriented problems, and emerging technologies.	

Program Specific Elective –II C) Advanced IoT Networking and Secure Communication						
Course Code	**PEC-02**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

1. Understand advanced IoT networking architectures and protocols
2. Analyze secure communication mechanisms in IoT systems
3. Apply modern cybersecurity frameworks like Zero Trust
4. Implement secure, scalable, and resilient IoT solutions

Advanced IoT Networking **[6 Hrs]**

Evolution from IoT to IIoT, later to Edge/Cloud IoT, IoT layered architecture (device, edge, cloud). Advanced networking protocols: 6LoWPAN, RPL, Software Defined Networking (SDN) in IoT Network virtualization & edge computing

Secure Communication in IoT **[6 Hrs]**

OT threat landscape and attack surfaces , Cryptography basics (symmetric, asymmetric, PKI) Secure communication protocols: TLS/DTLS, IPsec for IoT, authentication and authorization mechanisms, Key management in constrained devices.

Blockchain for IoT Security **[6 Hrs]**

Fundamentals of blockchain technology, Distributed ledger concepts, Smart contracts in IoT, Blockchain-based device authentication, Secure data sharing using blockchain

Zero Trust & AI-based Security **[6 Hrs]**

Zero Trust Architecture (ZTA) principles, never trust, always verify, Micro-segmentation, Identity & Access Management (IAM) in IoT, AI/ML for cybersecurity: Intrusion Detection Systems (IDS), Anomaly detection, AI-based intrusion detection models for IoT networks

Secure IoT Deployment & OTA Updates **[6 Hrs]**

Secure firmware and device lifecycle management, Secure Boot & Trusted Execution Environment (TEE) , Over-the-Air (OTA) updates: Threats in OTA , Secure OTA update mechanisms

Industrial Practices **[6 Hrs]**

Case studies: smart grid, smart vehicles, industrial IoT, Compliance & standards (ISO/IEC, NIST IoT security)

Self-Study (SS): **[6 Hrs]**

Software-based Mini Self-Study Projects

Textbooks:

[1]	Industrial Internet of Things — Alasdair Gilchrist
[2]	Machine Learning for Cybersecurity — Somdip Dey

Reference Books:

[1]	Internet of Things: A Hands-On Approach — Arshdeep Bahga, Vijay Madisetti
[2]	Zero Trust Networks — Evan Gilman, Doug Barth
[3]	Blockchain Basics — Daniel Drescher

Note:

[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.

[3]	To measure CO3, questions will be based on applications of core concepts.
[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages

Program Specific Elective –III A) IoT- Non-Terrestrial Network						
Course Code	**PEC-03**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	-	-	--

Course Outcomes: Students will be able to:

1. Explain the fundamentals of 5G architecture and its evolution towards Non-Terrestrial Networks.
2. Analyse radio interface technologies and deployment architectures relevant to NTN systems.
3. Interpret O-RAN concepts and evaluate different satellite-based NTN systems and constellations.
4. Design and analyse NTN architectures, including payload types, network integration, and system-level considerations.
5. Evaluate RF propagation effects, channel characteristics, and link performance in NTN environments.
6. Apply protocol mechanisms, procedures, and mobility management techniques for NTN and assess future trends toward 6G

Fundamentals of 5G and Evolution towards NTN:	**[6 Hrs]**
5G evolution and requirements, 5G service categories (eMBB, URLLC, mMTC), spectrum and bandwidth aspects, 5G system architecture and core network functions (AMF, SMF, UPF, UDM), control and user plane separation (CUPS), network slicing, roaming, and offloading, introduction to NTN in 5G ecosystem	
5G Radio Interface and Deployment Architecture:	**[8 Hrs]**
Principles of 5G radio transmission and reception, scalable OFDM numerology, frame structure (slots, mini-slots, cyclic prefix), radio access network architecture, deployment options, fronthaul, midhaul and backhaul concepts, multi-access edge computing (MEC), access, edge, and core network design.	
O-RAN Architecture and Introduction to NTN Systems	**[6 Hrs]**
Open RAN architecture, functional splits (O-RU, O-DU, O-CU), virtualization and orchestration, basics of satellite communication, IoT over NTN, satellite constellations (LEO, MEO, GEO), overview of commercial and private satellite systems.	
NTN Architecture and System Design	**[6 Hrs]**
5G NTN architecture, transparent and regenerative payloads, NTN NG-RAN design, inter-satellite links (ISL), integrated access backhaul (IAB), user equipment for NTN, spectrum considerations, network planning, orchestration and management aspects.	

RF Aspects and Channel Modelling in NTN	[6 Hrs]
NTN channel characteristics, large-scale fading, path loss and link budget analysis, propagation delay and round-trip time, Doppler shift effects, carrier frequency offset, UE power constraints, performance challenges and mitigation techniques.	
Protocols, Procedures, and Future Trends in NTN	**[6 Hrs]**
Applications few examples like, IoT based Smart Home, Precision Agriculture, Smart vehicles, Smart Grid, Healthcare, Applications of IoT in robotics; Industrial IoT (IIoT), Industry 5.0, Smart remote monitoring.	
Self-Study (SS): Frontier Topics in Green IoT	**[4 Hrs]**
NTN technology as ground breaking integration of satellite technology into 5G architecture Artificial Intelligence (AI)-powered deployments for NTN NTN based futuristic use cases	

Textbooks:

[1]	Alessandro Vanelli-Coralli, Nicolas Chuberre, Gino Masini, Alessandro Guidotti, Mohamed El Jaafari, 5G Non-Terrestrial Networks: Technologies, Standards, and System Design. WILEY JOHN
[2]	Jamshed, M.A. and Nauman, A. eds., 2025. *Integrated Terrestrial and Non-Terrestrial Networks*. Springer.

Reference Books:

[1]	Geraci, Giovanni, et al. "Integrating terrestrial and non-terrestrial networks: 3D opportunities and challenges." IEEE Communications Magazine 61.4 (2022): 42-48.
[2]	Azari, M.M., Solanki, S., Chatzinotas, S., Kodheli, O., Sallouha, H., Colpaert, A., Montoya, J.F.M., Pollin, S., Haqiqatnejad, A., Mostaani, A. and Lagunas, E., 2022. Evolution of non-terrestrial networks from 5G to 6G: A survey. *IEEE communications surveys & tutorials*, *24*(4), pp.2633-2672.

Program Specific Elective –III
B) Green IoT

Course Code	PEC-03		Examination Scheme			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	-	-	--

Course Outcomes: Students will be able to:

1. Analyse carbon-aware and energy-optimized IoT system architectures.
2. Apply advanced green communication and networking strategies in large-scale IoT deployments.
3. Evaluate and model energy consumption using analytical and data-driven techniques.
4. Design intelligent, self-optimizing, and sustainable IoT systems using AI and edge intelligence.
5. Develop net-zero and environmentally compliant IoT solutions aligned with global standards.

Green IoT Architecture and Sustainability Modelling	**[6 Hrs]**
Advanced Green IoT concepts; carbon footprint modeling; lifecycle assessment (LCA) of IoT systems; energy consumption modeling; sustainability metrics (PUE, CUE); circular economy principles; eco-design of IoT devices; regulatory frameworks (RoHS, WEEE).	
Ultra-Low Power Communication and Green Networking	**[8 Hrs]**
Energy-efficient communication protocols (BLE 5.x, LoRaWAN, NB-IoT); adaptive transmission power control; energy-aware routing algorithms; green SDN and network virtualization; time-synchronized networks; QoS-energy trade-offs in large-scale systems.	
Energy-Aware Edge Computing and TinyML	**[6 Hrs]**
Ultra-low power embedded systems; dynamic voltage and frequency scaling (DVFS); energy harvesting-aware scheduling; TinyML deployment pipeline; federated learning for edge devices; energy-efficient AI inference at the edge.	
Green Cloud, Data Engineering and Sustainable Analytics	**[8 Hrs]**
Energy-efficient cloud architectures; carbon-aware workload scheduling; green data centers; serverless and container optimization; data minimization and compression; sustainable big data analytics; edge-cloud workload partitioning.	
Autonomous and Intelligent Sustainable IoT Systems	**[6 Hrs]**
AI-driven energy optimization; Digital Twin for sustainability modeling; smart grids and demand-response systems; blockchain for green IoT; self-healing and self-optimizing systems; net-zero IoT infrastructures; ESG compliance and reporting.	
Self-Study (SS): Frontier Topics in Green IoT	**[6 Hrs]**
• Carbon-aware computing and green AI • Energy-efficient blockchain and distributed systems • Sustainable 5G/6G-enabled IoT • Edge intelligence for climate monitoring • Net-zero and carbon-neutral IoT systems • Environmental impact assessment frameworks	

Textbooks:	
[1]	Samee U. Khan, Albert Y. Zomaya, *Handbook on Green Information and Communication Systems*, Academic Press
[2]	Raj Kamal, *Internet of Things: Architecture and Design Principles*, McGraw Hill
Reference Books:	
[1]	Arshdeep Bahga, Vijay Madisetti, *Internet of Things: A Hands-on Approach*, Universities Press
[2]	Zaigham Mahmood, *Green Computing and Cloud Computing*, IGI Global
[3]	Qiang Yang et al., *Federated Learning: Privacy and Efficiency*, Morgan & Claypoo
Note:	
[1]	To measure CO1, questions may be of the type – define, analyze, model sustainability metrics
[2]	To measure CO2, questions may be of the type – explain, compare, evaluate networking techniques
[3]	To measure CO3, questions will be based on energy modeling and analytical evaluation.
[4]	To measure CO4, questions may include system design, optimization, and AI-based solutions.
[5]	To measure CO5, questions may include case studies, ESG compliance, and real-world sustainability challenges.

Program Specific Elective –III C) Vision and Intelligent System						
Course Code	**PEC-03**		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	-	-	--

Course Outcomes: Students will be able to:

1. Analyze intelligent systems using AI/ML approaches
2. Design vision-based intelligent applications
3. Implement real-world vision systems
4. Design secure intelligent systems for real applications

Vision Systems & Perception	**[6 Hrs]**
Role of vision in intelligent systems, Camera models and perception pipeline, Basic feature extraction (edges, key points – overview only), Sensor fusion (vision + LiDAR + radar basics) Introduction to perception in robotics & autonomous systems	
Intelligent Systems & Machine Learning	**[6 Hrs]**
Intelligent systems architecture, Machine Learning basics (Supervised, Unsupervised), Neural Networks and Deep Learning (CNN overview), Decision-making systems, Reinforcement learning basics	
AI Security	**[6 Hrs]**
Threat model in AI systems, Adversarial attacks (FGSM, evasion attacks), Data poisoning attacks Model extraction & inversion attacks, Defence techniques (robust training, detection methods)	
Secure Intelligent Architectures	**[6 Hrs]**
Secure system design principles, Trustworthy AI (fairness, robustness, explainability), Privacy-preserving ML (federated learning basics), Secure edge AI (TinyML security concepts), Zero Trust concepts for intelligent systems	
Applications & System-Level Security	**[6 Hrs]**
Autonomous systems (robotics, ADAS perception), Surveillance & smart city systems IIoT and Vision integration, Security threats: Sensor spoofing (camera/LiDAR attacks), Deepfake and visual spoofing, AI-based attack surfaces, Case studies (automotive, healthcare, Defence)	
Self-Study (SS):	**[6 Hrs]**
Simulation Project: Drone-Based Object Detection, Smart Surveillance System with Intrusion Detection, Vision-Based Driver Drowsiness Detection System	

Textbooks:

[1]	Security and Privacy in Machine Learning — Reza Shokri
[2]	Deep Learning — Ian Goodfellow, Yoshua Bengio, Aaron Courville
Reference Books:	
[1]	Artificial Intelligence: A Modern Approach — Stuart Russell, Peter Norvig
[2]	Security and Privacy in Machine Learning — Reza Shokri
Note:	
[1]	To measure CO1, questions may be of the type- define, identify, state, match, list, name etc

[2]	To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
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[4]	To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
[5]	To measure CO5, some questions may be based on self-study topics and comprehension of unseen passages.

S.Y. M. Tech
IoT and Sensor Systems

List of Abbreviations

Abbreviation	Title	No of courses	Credits	% of Credits
PSMC	Program Specific Mathematics Course	1	4	5
PSBC	Program Specific Bridge Course	1	3	3.75
PCC	Program Core Course	6	24	30
PEC	Program Specific Elective	3	9	11.25
MLC	Mandatory Learning Course	2	5	6.25
OE	Open Elective	1	3	3.75
SLC	Self-Learning Course	2	6	7.5
LLC	Liberal Learning Course	1	1	1.25
OJT	Internship	1	3	3.75
VSEC	Vocational and Skill Enhancement Course (Project)	2	22	27.5
	Total	20	80	100%

S.Y. M. Tech
IoT and Sensor Systems

Semester III

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	SLC	SLC-01	MOOC -1	3	-	-	1	3	-	-	100	-	-
2	SLC	SLC-02	MOOC -2	3	-	-	1	3	-	-	100	-	-
3	OJT	<tbd>	Internship	-	-	-	-	3	-	-	100	-	-
4	Project	VSEC01	Dissertation Phase – I	-	-	22	12	11	-	-	-	60	40
			Total Credits	06		22	14	**20**					

- **MOOC Courses Identified:**
- **ML & Deep Learning – Fundamentals**
- **Introduction to Industry 4.0 & IIoT**

Semester IV

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	Project	VSEC02	Dissertation Phase – II	-	-	22	12	11	-	-	-	60	40
			Total Credits			22	12	**11**					