ENGINEERING SCIENCE COURSE – I for ECE

INTRODUCTION TO ELECTRICAL ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – I/II

Subject Code	:	25EN1108	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	39 Hours
L–T–P	:	2–0–1			

Course Learning Objectives:

This course enables students to:

- **Demonstrate** a foundational understanding of electrical quantities, including current, voltage, power, and energy.
- **Apply** fundamental laws of electric circuits, such as Ohm's law and Kirchhoff's laws to evaluate electrical circuits.
- **Explain** fundamental concepts of electro-magnetic circuits.
- **Demonstrate** a foundational understanding of the working principles, construction, and characteristics of DC machines.
- **Illustrate** the construction, operation, and types of transformers, considering their significance in electrical systems.
- **Explain** the structure and components of electrical power system, highlighting their interconnections.
- **Explain** emerging trends of green energy technologies and smart metering.
- **Explain** the importance of earthing, protective devices, and proper wiring for ensuring electrical safety.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.

- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	**10 Hours**

Fundamentals laws of Electrical circuit and elements: Electrical charge, potential; current; power and energy; AC and DC current (mathematical treatment); Ohm's law; KCL and KVL in resistive circuits; series and parallel combination of resistors; voltage and current division rule; V-I relationships for inductor and capacitor under AC voltage; impedance and admittance (series RC, RL and RLC); Overview of active power, reactive power and power factor; Introduction to 3 phase systems; Simulation using LTspice software to demonstrate voltage division, current division in resistive circuits. Simulation using LTspice software to show voltage and current waveform for RC and RL circuit.

(TextBook-1: Chapter 1: 1.1 to 1.4, 1.6 to 1.8. Chapter 2: 2.1 to 2.3. Chapter 4: 4.1 to 4.4 Chapter 6: 6.1 to 6.4)

UNIT – II	**10 Hours**

Electromagnetic circuits:

Magnetic circuits: Basics of magnetic circuits (flux, MMF, permeability, reluctance, B and H); Relation between field theory and circuit theory; Faraday's and lenz's laws, Lorentz force; Self and Mutual inductance.

DC machines: Principle of operation of DC generator; generated EMF equation; classification; and applications. (Introductory treatment only); Principle of operation of DC Motor; back EMF; speed and torque; classification; and applications. Losses and efficiency in DC machines.

Transformers: Construction, working principle, induced emf equation; step-up and step down; losses and efficiency.

(TextBook-2: Chapter 7: 7.1 to 7.12; Textbook 1: 10.1, 10.2, 10.4, 10.5, 10.8, 10.9, 10.11 and 10.12; Chapter 8: 8.1, 8.2 and 8.9)

UNIT – III	**06Hours**

Powers system fundamentals: Power system structure; generation sources; green energy; smart meters; power tariff calculations; Electrical safety and standards (IS: 732-2019, IEC: 60446): Colour code of wires for single phase supply, earthing, fuse and MCB. ***(Textbook 1: , Chapter 16: 16.1 to 16.5; Textbook 2: Chapter 24: 24.1 to 24.6)***

Lab	**13Hours**
Verification of Ohm's Law, KCL and KVL; RC/ RL circuit under AC voltages; Introduction to Simulation Tools (LTSpice); Build and Analyze a Simple Two-Bulb Circuit (Series/Parallel with Switch Control)	

Course Outcome	**Description**	**Bloom's Taxonomy Level**
At the end of the course the student will be able to:		
CO1	**Solve** for voltage, current, power and energy in purely R, series RL and RC circuits under DC and AC voltages.	L3
CO2	**Demonstrate** understanding of principle of operation of DC machines and transformers and **solve** for voltage, current and speed of the machine in typical applications.	L3
CO3	**Build** and **analyze** simple electrical circuits under AC and voltages.	L4
CO4	**Demonstrate** understanding of the working principle of power system and the significance of renewable energy sources in electrical engineering, and safety practices.	L2
CO5	Demonstrate proficiency in using simulation software (e.g., LTSpice) to simulate and **solve** for electrical parameters.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	3											
CO2	3	3											
CO3	3	3			3								2
CO4	3	2											
CO5	3	3			3						2		2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. D.P.Kothari and I.J. Nagrath, "Basic Electrical Engineering", 4th Edition, Tata McGraw Hill, 2019.

2. B.L. Theraja and A.K. Therja, "A textbook of electrical technology, Vol. I (Basic electrical Engineering)", S. Chand Publishing, 23rd Rev Ed, 2006.

REFERENCE BOOKS:

1. Clayton Paul, Syed A Nasar and Louis Unnewehr, "Introduction to Electrical Engineering", 2nd Edition, McGraw-Hill, 1992.
2. William H Hayt and Jack E Kimberly and Steven M Durbin, "Engineering Circuit Analysis" 8th Edition, McGraw-Hill, 2013.

E-Resources:

- https://nptel.ac.in/courses/108/108/108108076

Activity Based Learning (Suggested Activities in Class):

1. Real world problem solving using group discussion and hands-on activities. E.g., Interfacing different types of sensors using Arduino.

2. Simulation of different electrical circuits. E.g., RL and RC circuits.

ENGINEERING SCIENCE COURSE – I for Mechanical Cluster

INTRODUCTION TO ELECTRICAL AND ELECTRONICS ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – I/II

Subject Code	: 25EN1109	**Credits**	:	03
Hours / Week	: 03Hours	**Total Hours**	:	39 Hours
L–T–P	: 3–0–0			

Course Learning Objectives:

1. To introduce fundamental electrical quantities such as charge, current, voltage, power, and energy, and their relationships in basic circuits.
2. To enable students to apply Ohm's Law and Kirchhoff's Laws to analyze simple resistive, series, and parallel electrical networks.
3. To impart a foundational understanding of AC and DC waveforms, including key parameters like RMS, peak, and average values.
4. To develop conceptual understanding of magnetic circuits and electrical machines, including transformers and DC machines, along with their working principles.
5. To familiarize students with the characteristics and applications of diodes and transistors, particularly in rectifier and switching circuits.
6. To introduce operational amplifiers and their basic configurations such as inverting, non-inverting, and summing amplifiers.
7. To provide a conceptual understanding of digital logic circuits, including logic gates, flip-flops, and binary counters.
8. To provide a high-level overview of microcontroller systems, focusing on block diagram architecture and their role in embedded applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
- **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show **Video/animation** films to explain functioning of various concepts.
- Encourage **Collaborative** (Group Learning) Learning in the class.
- To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
- Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every **concept can be applied to the real world -** and when that's possible, it helps improve the students' understanding.

UNIT – I	**07 Hours**

Electrical Circuit Fundamentals: Basic electrical quantities such as charge, voltage, current, resistance, power, and energy; Ohm's Law; Kirchhoff's Voltage and Current Laws (KVL and KCL); series and parallel resistor networks; voltage and current division rules; introduction to AC and DC waveforms including RMS, peak, and average values.

UNIT – II	**08 Hours**
Electrical Machines and Power Systems: Magnetic circuits including flux, flux density, magnetomotive force (MMF), and reluctance; working principle, types, and applications of transformers; working principle of DC generators and motors; basics of electrical power generation, transmission, and distribution; introduction to renewable energy sources.	
UNIT – III	**08 Hours**
Semiconductor Devices and its application: Overview of diode construction; diode under no-bias, forward bias, and reverse bias conditions; half-wave and full-bridge rectifiers; construction and operation of npn and pnp BJTs; input and output characteristics of the common-base configuration; regions of transistor operation active, cut-off, and saturation; transistor as a switch.	
UNIT – IV	**08 Hours**
Operational amplifiers: Op-amp symbols and terminals; modes of operation including single-ended, differential, and common mode; properties of ideal and practical op-amps; applications such as inverting amplifier, non-inverting amplifier, summing amplifier, differential amplifier, differentiator, and integrator.	
UNIT – V	**08 Hours**
Digital Electronics and Embedded applications: Binary number system; logic gates and their truth tables—AND, OR, NOT, XOR, NAND, NOR; combination of logic gates and basic numerical operations; sequential logic circuits including JK and D Flip-Flops; application of Flip-Flops in 4-bit binary counters; overview of microcontrollers at the block diagram level.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Demonstrate a clear understanding of the basic principles of electrical and electronic components**, including resistors, diodes, transistors, operational amplifiers, logic gates, and microcontrollers.	L2
2	**Apply basic circuit law's and priciples to analyze electrical circuits**, including resistive networks, AC/DC waveforms, and basic transformer and DC machines	L3
3	**Apply knowledge of semiconductor devices**, such as diodes and transistors, to explain rectification and switching behavior in electronic circuits.	L3
4	**Apply the principles of operational amplifiers** to configure basic circuits such as inverting, non-inverting, and summing amplifiers.	L3
5	**Demonstrate conceptual understanding of digital logic and microcontroller systems**, including logic gate combinations, flip-flops, counters, and block diagram-level microcontroller architecture.	L2

Table: Mapping Levels of COs to POs / PSOs														
COs	**Program Outcomes (POs)**												**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**
CO1	3	2										2		
CO2	3	3										2	2	
CO3	3	3										2	2	
CO4	3	3										2	2	
CO5	3	2										2		

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. R. L. Boylestad and L. Nashelsky, "Electronic Devices and Circuit Theory", 11th Ed, Pearson Education, 2013.
2. M. Moris. Mano and Michael D. Ciletti, "Digital Electronics", 4th Ed, Pearson Education, 2006.
3. D.P.Kothari and I.J. Nagrath, "Basic Electrical Engineering", 4th Edition, Tata McGraw Hill, 2019.
4. B.L. Theraja and A.K. Therja, "A textbook of electrical technology, Vol. I (Basic electrical Engineering)", S. Chand Publishing, 23rd Rev Ed, 2006.

REFERENCE BOOKS:

1. David A Bell, "Electronic Devices and Circuits", 5th Ed, Oxford university press, 2008.
2. Millman & Halkias, "Electronics Devices and Circuits", 2nd Ed, McGraw Hill, 2010.
3. William H Hayt and Jack E Kimberly and Steven M Durbin, "Engineering Circuit Analysis" 8th Edition, McGraw-Hill, 2013.

E-Resources:

1. NPTEL- https://nptel.ac.in/courses/122/106/122106025
2. NPTEL- https://nptel.ac.in/courses/108/108/108108076
3. Virtual Labs- http://vlabs.iitkgp.ac.in/be/

Activity-Based Learning (Suggested Activities in Class):

1. Simulation of different electronic circuits. E.g., Rectifiers and Amplifiers using LtSpice.

INTRODUCTION TO ELECTRONICS ENGINEERING

[For ECE Branch - As per Choice Based Credit System (CBCS) scheme]

SEMESTER – I/II

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	39 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. **Understand** the fundamental principles of diodes and their applications, including the band diagram of insulators, conductors, and semiconductors, diode construction, and V-I characteristics.
2. **Analyze** diode circuits under different biasing conditions and comprehend the behavior of diodes in applications such as AND gates, OR gates, rectifiers, and voltage doublers.
3. **Understand** how and why clipper and clamper are called wave shaping circuits.
4. **Comprehend** the construction, operation, and characteristics of bipolar junction transistors (BJTs), including input and output characteristics, different biasing techniques, and transistor amplification.
5. **Calculate** common emitter amplifier circuits with voltage divider bias.
6. **Demonstrate** an understanding of operational amplifiers (Op-amps), including their symbols, operation modes, properties, and applications such as amplifiers, comparators, and oscillators.
7. **Demonstrate** an understanding of digital electronics, including binary number systems, Boolean algebra, logic gates, sequential logic circuits, and the application of Flip-Flops.
8. **Verify** digital circuits and components with basic activities on simulators.
9. **Familiarize** themselves with microprocessors and microcontrollers, and understand their architecture and components.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	08 Hours
Semiconductor Diodes: Semiconductor types: intrinsic and extrinsic (n-type and p-type); diode construction; diode under no-bias, forward bias and reverse bias; V-I characteristics of diode; simplified equivalent circuit of practical diode and ideal diode; diode specifications: peak inverse voltage, reverse leakage current and maximum forward current; Zener diode; (Textbook 1: Chapter 1: 1.1 to 1.7, 1.9, 1.12, 1.15)	
UNIT – II	**06 Hours**
Diode applications: Series diode configuration with DC input, Rectifier Circuits: Half wave and full wave – Bridge Network and Centre tapped, Reservoir and smoothing circuits; Diode clipper – series and parallel; Clamper circuits, Voltage Doubler. (Textbook 1: Chapter 2: 2.3, 2.5, 2.6, 2.7, 2.8, 2.9, 2.12)	
UNIT – II	**08 Hours**
Transistors: Construction of npn and pnp BJT transistors; transistor operation; input and output characteristics of CB and CE configurations; significance of different regions of operation: active, cut-off and saturation (transistor as a switch); BJT Amplification; transistor amplifying action; numerical on current relations and amplification; Need for biasing: Q-point; types of biasing: fixed, and voltage divider, Introduction to Field Effect Transistor, Construction and Characteristics of JFET, MOSFET (MOS) (Depletion and Enhancement) Type, Transfer Characteristic. (Textbook 1: Chapter 3: 3.1 to 3.5, Chapter 4: 4.1 to 4.5, Chapter 6.1 and 6.2)	
UNIT – III	**08 Hours**
Operational amplifiers: Op-amp symbols, terminals and operation: single mode, differential mode and common mode; basic properties of ideal and practical Op-amp: input offset voltage, input resistance, output resistance, gain, bandwidth, CMRR, slew rate; basic Op-map applications: inverting amplifier, non-inverting amplifier, summing amplifier, differential amplifier, differentiator and integrator; Op-amp comparator; feedback: positive and negative feedback; criteria for stability and oscillations (Barkhausen criterion); RC phase shift oscillators; (Textbook 1: Chapter 10: 10.1, 10.4 to 10.7, Chapter 14: 14.5 to 14.7)	
UNIT – IV	**09 Hours**
Digital Electronics: Binary number system: conversion and representation; logic levels: high and low; Boolean algebra: operators and DeMorgan's law; Boolean Expression, logic gates with truth-table and representation: AND, OR, NOT, XOR, NAND, NOR; combination of gates and associated numerical; sequential logic circuits: SR latch using NAND/NOR gate, SR FLIP-FLOP, D Flip-Flop, J-K Flip- Flop. **Microprocessor Systems:** Overview of microprocessor and microcontroller architecture. (Textbook 2: Chapter 1: 1.1 to 1.3, Chapter 2: 2.1 to 2.5, Chapter 4: 4.1 to 4.3, Chapter 5.1 to 5.5, Chapter 6.1 to 6.4)	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
1	**Demonstrate** a solid understanding of the fundamental principles underlying electronic components, such as diodes, transistors, operational amplifiers, logic gates, and microcontrollers.	L2

2	**Apply** knowledge of electronic components to **analyze** circuits for various applications, such as rectification, amplification, filtering, and digital logic operations.	L4
3	**Apply** the acquired knowledge to construct small scale circuits consisting of semiconductor devices.	L4
4	**Analyze** the performance of operational amplifiers (Op-amps) in various circuit configurations, including amplifiers, comparators, and oscillators, to optimize their functionality and address design requirements.	L4
5	**Demonstrate** comprehension of microprocessor and microcontroller architecture, operation, and their applications.	L2
	Identify the need for modulation and demodulation in signal transmission.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)												PSOs		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO1	3	2	1									2	3		
CO2	3	3	2	1								2	3		
CO3	3	3	2	2								2	3	2	
CO4	3	3	2	2								2	3	2	
CO5	3	3	3	1								3	3	3	

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. R. L. Boylestad and L. Nashelsky, "Electronic Devices and Circuit Theory", 11th Ed, Pearson Education, 2013.
2. M. Moris. Mano and Michael D. Ciletti, "Digital Electronics", 4th Ed, Pearson Education, 2006.
3. Michael Tooley, "Electronic Circuits: Fundamentals and Applications" BA Elsevier Ltd., Third Edition,2006

REFERENCE BOOKS:

1. David A Bell, "Electronic Devices and Circuits", 5th Ed, Oxford university press, 2008.
2. Millman & Halkias, "Electronics Devices and Circuits", 2nd Ed, McGraw Hill, 2010.

E-Resources:

1. NPTEL- https://nptel.ac.in/courses/122/106/122106025
2. Virtual Labs- http://vlabs.iitkgp.ac.in/be/
3. https://nptel.ac.in/courses/117104072

Activity Based Learning (Suggested Activities in Class):

1. Real world problem solving using group discussion and hands-on activities. E.g., Interfacing different types of sensors using Arduino.
2. Simulation of different electronic circuits. E.g., Rectifiers and Amplifiers.

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Department of Electronics and Communication Engineering

ANALOG ELECTRONIC CIRCUITS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Subject Code	:	25EC2302	**Credits**	:	04
Hours / Week	:	03 Hours	**Total Hours**	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students to

1. Understand BJT biasing and determine various gains of BJT amplifier circuits using hybrid parameters.
2. Explain the internal structure and operation of operational amplifiers and their applications.
3. Design multivibrators, oscillator circuits, active filters, and data converter circuits.
4. Apply op-amp concepts in linear, nonlinear, switching, and signal conditioning applications.
5. Use simulation, Python/MATLAB-based analysis, and AI-assisted tools to evaluate and optimize analog circuit performance.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. **The lecture method** means it includes not only the traditional lecture method, but also different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

MODULE 1: Bipolar Junction Transistor - BJT	**09 Hours**
Introduction, transistor current, CE, CB and CC configurations, CE configuration characteristic curves (cutoff, active and saturation regions), requirement of biasing, DC load line, Q-point, biasing circuits: fixed bias, emitter bias and voltage-divider bias.	
AI / Simulation Tools: 1. Berkeley Analog Generator or LTspice for BJT bias design and verification. 2. Python/MATLAB for DC load-line plotting and Q-point sensitivity analysis.	
MODULE 2: Small Signal Analysis of Transistors	**10Hours**
Small-signal equivalent circuit, h-parameter and re model for CE configuration, RC-coupled single-stage amplifier, concept of feedback, positive and negative feedback, and introduction to power amplifiers: Class A, Class B, and Class AB.	
AI / Simulation Tools: 1. LTspice/Multisim for gain, bandwidth, and distortion simulation. 2. Python optimization for gain-bandwidth and power-efficiency trade-off analysis.	
MODULE 3: Operational Amplifier	**08 Hours**
Introduction to operational amplifiers, inverting amplifier, non-inverting amplifier, voltage follower, integrator, differentiator, direct- and capacitor-coupled op-amp amplifiers, and op-amp frequency response.	
AI / Simulation Tools: 1. MATLAB/Python for Bode-plot generation and cut-off frequency estimation. 2. Circuit simulation tools for validating op-amp linear applications.	
MODULE 4: Switching and Oscillator Circuits	**09Hours**
Op-amp as switching circuits: zero-crossing detector, comparator, Schmitt trigger. Oscillator circuits: Wien bridge, phase-shift, Hartley, and Colpitts oscillators. Analysis of bistable, monostable, and astable multivibrators, triangular waveform generator, and 555 timer circuits. Use AI tools to visualize oscillator frequency and stability analysis.	
AI / Simulation Tools: 1. LTspice/Multisim for transient switching and oscillator analysis. 2. Python/MATLAB for stability, duty-cycle, and frequency prediction.	
MODULE 5 : Filter and Data Converters	**09 Hours**
Filter and Data Converters: Frequency analysis, active filters: first-order and second-order active low-pass and high-pass filters. DAC and ADC converters: R-2R DAC, successive-approximation ADC, flash ADC, and binary-weighted DAC. AI-assisted active filter synthesis and converter performance analysis.	
AI / Simulation Tools: 1. Python scipy.signal/MATLAB for active filter synthesis and response plotting. 2. Simulation-assisted ADC/DAC transfer analysis including resolution, linearity, and quantization effects.	

AI Integration:

1. Introduction to Python-based analog circuit analysis workflow, including data preprocessing, parameter sweep generation, numerical computation, and visualization using NumPy, Pandas, Matplotlib, SciPy, and Scikit-learn.
2. Implementation of supervised learning and regression models for predicting amplifier gain, bandwidth, bias-point stability, filter cut-off frequency, oscillator frequency, and DAC/ADC transfer characteristics using simulated or measured datasets.
3. Use of optimization algorithms and AI-assisted design tools to select component values for bias networks, active filters, op-amp circuits, oscillators, and multivibrator circuits under practical constraints.
4. Simulation-driven learning using LTspice, Multisim, MATLAB/Simulink, and Python for Bode plots, transient response, frequency response, distortion, power efficiency, and sensitivity analysis.
5. Use of AI tools for documentation, circuit interpretation, troubleshooting support, and design-space exploration while verifying all outputs through circuit theory, datasheets, and laboratory measurements.

Authentic Intelligence:

1. Understand well-posed analog circuit design problems, practical constraints, and limitations of AI-generated circuit suggestions, especially with respect to datasheet limits, device tolerances, noise, power dissipation, and temperature variation.
2. Interpretability of simulation and machine learning outputs; students must explain why a circuit works rather than only reporting AI-generated component values or plots.
3. Responsible use of AI tools for circuit design, including verification of biasing conditions, stability, saturation/active-region operation, and safety constraints before hardware implementation.
4. Risks of overfitting simulated datasets, using unrealistic device models, or ignoring parasitic effects and measurement uncertainty in analog circuit analysis.
5. Ethical and transparent reporting of AI-assisted work, including clear distinction between theory-based derivation, simulation results, AI-generated suggestions, and physical laboratory observations.

ANALOG ELECTRONIC CIRCUITS LABORATORY

List of Laboratory/Practical Experiments activities to be conducted:

1. Design of diode clipping and clamping circuits.
2. RC-coupled single-stage BJT amplifier: determination of gain-frequency response, input impedance, and output impedance.
3. Design of summing amplifier using op-amp.
4. Design of integrator and differentiator using op-amp.
5. Design of comparators and zero-crossing detector using op-amp.
6. Design of Schmitt trigger using op-amp.
7. IC 555 timer as multivibrator.
8. Design of active filters: LPF and HPF for a given frequency range.
9. Design of phase-shift and Wien bridge oscillator using op-amp.
10. 4-bit DAC using op-amp.
11. Open-ended experiment.

Total Contact Hours: 30

Course Outcome:

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Apply** the concepts of BJT configurations and transistor biasing to analyze the operation and determine the Q-point of BJT amplifier circuits.	L3
2	**Analyze** the small-signal behavior, feedback characteristics, and performance of Class A, Class B, and Class AB power amplifiers.	L4
3	Apply operational amplifier concepts to evaluate the operation, gain, and frequency response of linear op-amp circuits.	L3
4	Analyze the operation and performance of switching circuits, multivibrators, waveform generators, and oscillator circuits.	L4
5	Analyze the operating characteristics and performance of active filters, digital-to-analog converters (DACs), and analog-to-digital converters (ADCs).	L4
6	Use AI-assisted and simulation tools to improve the stability and performance of analog circuits.	L4

Table: Mapping Levels of COs to POs / PSOs

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COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	1	–	2	–	–	–	1	–	1	3	2
CO2	3	3	1	1	2	–	–	–	1	–	1	3	2
CO3	3	2	1	–	2	–	–	–	1	–	1	3	2
CO4	3	3	2	1	2	–	–	–	1	–	1	3	2
CO5	3	3	2	1	2	–	–	–	1	–	1	3	2
CO6	2	3	2	2	3	–	–	1	1	–	2	2	3

3:Substantial (High) 2: Moderate (Medium) 1: Poor (Low

TEXT BOOKS:

1. Millman J. and Halkias C. C., Electronic Devices and Circuits, McGraw Hill, 2007.
2. David A. Bell, Electronic Devices and Circuits, Oxford Higher Education Press, 5th Edition, 2010.
3. David A. Bell, Operational Amplifiers and Linear ICs, 3rd Edition, PHI/Pearson, 2000.

REFERENCE BOOKS:

1. A. S. Sedra and K. C. Smith, Microelectronic Circuits, 5th Edition, Oxford University Press, 2004.
2. Donald A. Neamen, Electronic Circuit Analysis and Design, 2nd Edition, Tata McGraw Hill, 2009.
3. Robert L. Boylestad and Louis Nashelsky, Electronic Devices and Circuit Theory, 10th Edition, Pearson Education/PHI, 2008.
4. D. Roy Choudhury and Shail B. Jain, Linear Integrated Circuits, 4th Edition, Reprint 2006.
5. Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits, Pearson, 4th Edition, 2015.

E-Resources:

S.No.	Course / Resource Name	Instructor / Source	Host Institute / Link
1	Analog Electronics	NPTEL / IIT Faculty	https://nptel.ac.in
2	Operational Amplifiers and Linear ICs	NPTEL / IIT Faculty	https://nptel.ac.in
3	Circuit simulation and analysis tutorials	LTspice / Analog Devices	https://www.analog.com/en/resources/design-tools-and-calculators/ltspice-simulator.html
4	Python tools related to AI-assisted circuit analysis	Python / Scikit-learn / SciPy	https://scikit-learn.org, https://scipy.org

Department of Electronics and Communication Engineering

DIGITAL LOGIC DESIGN

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Subject Code	:	25EC2303	Credits	:	04
Hours / Week	:	03 Hours	Total Hours	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students to

1. Translate the elements of digital logic functions to digital system abstractions using Verilog.
2. Illustrate simplification of Boolean expressions using Karnaugh
3. Model combinational logic circuits for arithmetic operations and logical operations
4. Analyze and model sequential elements flip-flops, counter, shift registers.
   Outline the concept of Mealy Model, Moore Model and apply FSM to solve a given design problem.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. **The lecture method** means it includes not only the traditional lecture method, but also different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
   Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding

MODULE 1 : INTRODUCTION	**09 Hours**
Number System- Binary, Hexa, Decimal, Octal and its conversion, Addition and subtraction using 1's and 2's complement, Canonical Notation - SOP & POS forms, Minimization of SOP and POS forms. **ARITHMETIC CIRCUITS AND VERILOG MODELLING** Adders: Half adder, full adder, Ripple carry adder, parallel adder /subtractor, fast adders- CLA, comparator- 2 bit. Simplification using K-Maps Introduction to Verilog, Syntax of Verilog coding, Modelling styles in Verilog, Verilog Operators, Test bench for simulation	
MODULE 2: Combinational Circuit Building	**09 Hours**
Multiplexers 2:1, 4:1, 8:1, decoders 3:8, 2:4, demultiplexers 1:4, encoders 8:3, 4:2, code converters- B to G and G to B- Simplification using K-Maps **Verilog for combinational circuits**: Behavioral modelling- if else, case-casex, casez, structural modelling.	
MODULE 3: Sequential Circuits-1	**09 Hours**
Basic Latch, Gated latches, Flip Flops SR, D, JK, T, Race round condition, master-slave flip-flops JK, 0's and 1's Catching Problem, Conversion of flip-flops SR-JK, JK-T, shift registers- SISO, SIPO, PISO, PIPO, Universal Shift Register, Setup time, Hold time, Propagation delay.	
MODULE 4: Sequential Circuits-2	**09 Hours**
Binary counters– asynchronous and synchronous, mod-n counter, Verilog blocking and non-blocking, Mealy Model, Moore Model, State machine notation, Construction of Finite State Machine.	
MODULE 5 : Introduction to Electronic Design Automation	**09 Hours**
FPGA Design Flow, ASIC Design flow, architectural design, logic design, simulation, verification and testing, 3000 Series FPGA architecture. **Applications**: Design 4 Bit ALU, 7 Segment display, Vending Machine, 3 Pipeline.	

AI Integration:

1. Introduction to Model-Based Digital System Design uses MATLAB and Simulink to design digital systems at a high-level using block diagrams and algorithms.
2. Using HDL Coder, models are automatically converted into synthesizable Verilog for FPGA implementation.
3. Integration of AI tools like GitHub Copilot further enhances the process by assisting in code generation, optimization, and debugging.
4. AI integration using matlab copilot improves design efficiency, reduces development time, and helps students focus on system-level understanding.

Authentic Intelligence

1. Model-based digital system design using MATLAB, Simulink, and HDL Coder, enhanced with AI Copilot tools like GitHub Copilot, reflects the principles of **Authentic Intelligence** by combining automation with responsibility and transparency.
2. Modeling of digital systems and simulation at a high level, ensuring correctness and clarity before hardware implementation.
3. Understanding the generation of reliable and synthesizable code using HDL coder, while AI Copilot assists in improving design efficiency, suggesting optimizations, and explaining system behavior.
4. Using MATLAB, Simulink, and HDL Coder, students can clearly trace the process from model → simulation → HDL → FPGA, making the system behavior explainable.

List of Laboratory/Practical Experiments activities to be conducted:

Experiments can be conducted using Verilog tool /Kits

1. Introduction to Xilinx tool, FPGA flow
2. Adder – HA, FA using data flow and behavioral modelling styles
3. Adder – HA, FA using structural modelling style
4. Combinational designs – I
   a. Multiplexer: 4:1, 8:1 MUX.
   b. De Multiplexer: 1:4, 1:8 DEMUX.
5. Combinational designs – II

   c. Encoder with and without Priority: 8:3 and 4:2.

   d. Decoder: 3:8 and 2:4.
6. Design of 4-bit ALU
7. Flip Flop: D FF, T FF, JK FF
8. Design of Mod – n Up/Down Counter with Synchronous reset
9. Design of Mod – n Up/Down Counter with Asynchronous reset.
10. Open Ended Experiment-

    (e.g: Design of ALU and Design of Up/ Down Counter using MATLAB and HDL coder)

	Table: Mapping Levels of COs to POs / PSOs												
Cos	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	**3**	**1**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**-**
CO2	**3**	**2**	**1**	**2**	**3**	**-**	**-**	**-**	**1**	**-**	**1**	**2**	**1**
CO3	**3**	**2**	**3**	**1**	**2**	**-**	**-**	**1**	**1**	**-**	**1**	**2**	**1**
CO4	**3**	**3**	**2**	**3**	**3**	**1**	**-**	**1**	**-**	**1**	**2**	**2**	**2**
CO5	**3**	**3**	**2**	**3**	**3**	**1**	**1**	**-**	**1**	**1**	**2**	**2**	**2**

3:Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

Course Outcome	**Description**	**Bloom's Taxonomy Level**
At the end of the course the student will be able to:		
1	**Interpretation** of Boolean Expressions of digital design in simplified form	L2
2	**Build** the various elements of digital logic system with Verilog	L3
3	**Construct** Combinational and Sequential logic circuits	L3
4	**Analyze** the hardware model of a digital system at different levels of abstraction in Verilog	L4
5	**Modeling** of digital systems using FSM and **Evaluate** the functionality of digital design by implementing on FPGA kits.	L5

TEXT BOOKS:

1. M. Morris Mano Michael D. Ciletti, "Digital Design with an Introduction to the Verilog HDL", 6th Edition, Pearson Education, 2014.
2. Stephen Brown, Zvonko Vranesic, "Fundamentals of Digital Logic with Verilog design", McGraw Hill, 2014.
3. Nazein M. Botros, "HDL programming (VHDL and Verilog)", Dreamtech Press, 2006.
4. Douglas J Smith, "HDL Chip Design", Doone publications 199.

REFERENCE BOOKS:

1. John M Yarbrough, “Digital Logic Applications and Design”, Thomson Learning, 2014.
2. Donald D. Givone, “Digital Principles and Design”, McGraw Hill, 2015.
3. Samir Palnitkar, “Verilog HDL: A Guide to Digital Design and Synthesis”, Pearson , 2016

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Hardware Modeling using Verilog https://nptel.ac.in/courses/106105165	Prof. Indranil Sengupta	IIT Kharagpur
2	Digital System Design https://nptel.ac.in/courses/117105080	Prof. D.Roy Choudhury	IIT Kharagpur

IoT ENABLED SENSOR ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Subject Code	:	25EC2304	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students:

1. To understand the principles and characteristics of sensors and transducers used in IoT systems.
2. To study the types of sensors — temperature, pressure, optical, gas, and motion — and their working principles.
3. To learn signal conditioning, data acquisition, and the communication of sensor data over standard IoT protocols.
4. To explore how AI and machine learning techniques are applied to sensor data for intelligent monitoring, anomaly detection, and predictive analytics.
5. To familiarise students with real-world IoT sensor applications across agriculture, healthcare, smart cities, and manufacturing
6. To develop awareness of relevant standards, security considerations, and ethical implications

Teaching-Learning Process (General Instructions):

1. Interactive Teaching: Adopt Active Learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and role-playing.
2. Show Video / Animation films to explain the functioning of sensors such as how a PIR sensor detects motion, how a gas sensor responds to different concentrations, and how an ADC converts analog signals to digital data.
3. Encourage Collaborative (Group) Learning by assigning groups to compare sensor datasheets and justify sensor selection for a given application.
4. To make Critical Thinking, ask Higher Order Thinking questions in every class.
5. Adopt Problem-Based Learning which fosters students' analytical skills, develop thinking skills such as the ability to evaluate, generalise, and analyse information utilising AI tools.
6. Discuss how every concept can be applied to the real world and connect each sensor type to familiar devices students use daily such as smartphones, fitness trackers, and air quality monitors.

COURSE CONTENT:	
MODULE 1: Introduction to Sensors, Transducers, and IoT Architecture	**09 Hrs**
Sensors and Transducers: Active and passive sensors; analog and digital sensors, Sensor characteristics, Classification of sensors based on measurand **IoT System Architecture:** Four-layer IoT reference model, Role of sensors and actuators at the Perception Layer; Edge computing vs. cloud computing: **Applications:** Smart home motion sensing, industrial temperature monitoring, soil moisture measurement for precision agriculture, GPS-based fleet tracking.	
MODULE 2: Types of Sensors and Principles of Operation	**09 Hrs**
Temperature and Humidity Sensors, Pressure, Force, and Inertial Sensors, Optical and Proximity Sensors: Gas and Chemical Sensors, Position and Flow Sensors **Applications:** Weather station with DHT22 and BMP280, industrial vibration monitoring with MEMS accelerometers, smart water meters, air quality index monitoring stations in Indian cities.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course Fundamentals of Deep Learning, Applications of AI for Anomaly Detection : https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1	
MODULE 3: Signal Conditioning, Data Acquisition, and IoT Communication	**09 Hrs**
Signal Conditioning, Microcontrollers and Edge Platforms for IoT, IoT Communication Protocols: **Cloud IoT Platforms:** AWS IoT Core, Azure IoT Hub, and Google Cloud IoT Core ThingSpeak, Blynk, and Node-RED	
NVIDIA DLI Courses (Relevant to this Module) **Getting Started with AI on NVIDIA Jetson Nano: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2**	
MODULE 4: AI and Machine Learning for IoT Sensor Data	**09 Hrs**
Data Preprocessing for Sensor Streams, Supervised Learning for Sensor Data Classification, Anomaly Detection for IoT Monitoring, Deep Learning for Sensor Data, Edge AI and TinyML Applications: predictive maintenance, smart cities and traffic management, healthcare monitoring systems	
MODULE 5: IoT Sensor Applications, Standards, Security, and Future Trends	**09 Hrs**
IoT Sensor Applications Across Domain, IoT Security for Sensor Networks, Sensor Standards and Certifications, Future Trends **Applications:** India's Smart Cities Mission sensor deployments, ISRO remote sensing satellite sensor systems, Bosch IIoT sensor platforms, and autonomous UAV swarms for precision agricultural mapping.	
NVIDIA DLI Courses (Relevant to this Module) **Computer Vision for Industrial Inspection** : https://www.nvidia.com/en-sg/training/instructor-led-workshops/computer-vision-for-industrial-inspection/	

AI Integration:

1. Collection of temperature and humidity data from DHT22 sensor over 24 hours; loading the dataset into Python using Pandas, plotting time-series graphs, and identifying diurnal patterns and anomalous spikes.
2. Application of Scikit-learn Random Forest classifier on a provided labelled vibration sensor dataset to classify normal operation vs. bearing fault conditions; evaluation using accuracy, precision, recall, and F1-score.
3. Implementation of Isolation Forest anomaly detection on a provided air quality sensor time-series dataset using Scikit-learn; visualisation of detected anomalies and interpretation of results in the context of pollution events.
4. Training a keyword-spotting model on microphone sensor data using Edge Impulse Studio (free browser-based platform) and deployment to an ESP32 or Arduino Nano; evaluation of on-device inference accuracy and latency for TinyML edge deployment.
5. Group design exercise: end-to-end IoT sensor pipeline design for a chosen application domain (smart farm, hospital ward, factory floor, or campus energy monitor) covering sensor selection and justification, communication protocol choice, AI model type, and identification of potential failure modes and data privacy risks.

Authentic Intelligence:

1. Evaluation of sensor calibration drift: understanding the risks of acting on uncalibrated sensor data in safety-critical systems, and the engineering responsibility to implement regular calibration and validation routines in deployed IoT systems.
2. Alert fatigue in AI-based monitoring systems: analysis of the consequences of high false-positive rates in anomaly detection, the impact on operator trust, and design strategies to improve signal-to-noise ratio in real-world IoT alert systems.
3. Privacy implications of industrial IoT sensing: ethical boundaries of always-on acoustic and environmental sensors in workplaces, obligations under India's Digital Personal Data Protection Act 2023, and design of consent-aware sensor deployments.
4. Equity in public IoT sensor infrastructure: analysis of cases where air quality or water quality sensor networks reveal disproportionate pollution exposure in low-income communities, and the engineer's responsibility in transparent public data sharing and policy advocacy.
5. Cross-domain model deployment risks: consequences of applying AI models trained on sensor data from one operational environment to a different context without revalidation; importance of domain-specific testing, continuous monitoring, and responsible deployment practices.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Define sensors and transducers, explain their key characteristics, and describe the layered architecture of an IoT system and the role of the perception layer within it.	L2
CO2	Classify common IoT sensor types by operating principle, compare their specifications using datasheets, and select the most appropriate sensor for a given measurement requirement.	L3
CO3	Explain signal conditioning concepts including amplification, filtering, and ADC, identify suitable microcontroller platforms and communication protocols for an IoT sensor node, and describe sensor data transmission to cloud platforms.	L3
CO4	Apply machine learning techniques including classification, regression, and anomaly detection to IoT sensor datasets, and evaluate model performance using standard metrics..	L5
CO5	Assess real-world IoT sensor applications across engineering domains, evaluate relevant standards, security mechanisms, and privacy requirements, and critically analyse the ethical implications of sensor data collection and AI-driven decision-making.	L5

COs	PO											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	-	2	1	1	1	-	2	2	1
CO2	3	2	2	-	2	2	1	1	1	-	2	2	2
CO3	3	3	2	2	2	2	1	1	1	-	3	2	2
CO4	2	3	3	3	3	2	1	1	1	1	3	2	3
CO5	2	2	2	2	2	3	2	2	1	1	3	2	2

TEXT BOOKS:

1. Fraden, J. (2016). Handbook of Modern Sensors: Physics, Designs, and Applications. 5th ed. Springer.
2. Peckol, J.K. (2020). Introduction to Embedded Systems: Using ANSI C and the Arduino Development Environment. Wiley.
3. Buyya, R. and Dastjerdi, A.V. (Eds.) (2016). Internet of Things: Principles and Paradigms. Morgan Kaufmann / Elsevier.

REFERENCES:

1. Misra, S., Mukherjee, A. and Roy, A. (2021). Introduction to IoT. Cambridge University Press.
2. Goodfellow, I., Bengio, Y. and Courville, A. (2016). Deep Learning. MIT Press. Available at: https://www.deeplearningbook.org
3. IEEE Standard 1451: Smart Transducer Interface for Sensors and Actuators. IEEE.
4. MeitY. (2021). IoT Reference Architecture. Ministry of Electronics and Information Technology, Government of India. Available at: https://www.meity.gov.in
5. NVIDIA Developer. (2024). NVIDIA Deep Learning Institute Course Catalogue. Available at: https://learn.nvidia.com

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Introduction To Industry 4.0 And Industrial Internet Of Things https://onlinecourses.nptel.ac.in/noc21_cs20/preview	Prof. Sudip Misra	IIT Kharagpur
2	Industrial Automation and Control https://onlinecourses.nptel.ac.in/noc21_me67/preview	Prof. Siddhartha Mukhopadhyay	IIT Kharagpur
3	Sensors and Actuators https://onlinecourses.nptel.ac.in/noc26_ee13/preview	Prof. Hardik J. Pandya	IISc Bangalore
4	Introduction to Machine Learning https://nptel.ac.in/courses/106106139	Prof. Balaraman Ravindran	IIT Madras
5	Deep Learning for Computer Vision https://nptel.ac.in/courses/106106224	Prof. Vineeth N. Balasubramanian	IIT Hyderabad

Department of Electronics and Communication Engineering

DATA STRCUTURES & ALGORITHMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Subject Code	:	25EC2305	**Credits**	:	02
Hours / Week	:	03 Hours	**Total Hours**	:	30 Hours
L–T–P	:	2–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand fundamental data structures and algorithmic paradigms.
2. Apply problem-solving techniques using structured programming.
3. Analyse time and space complexity of algorithms.
4. Implement efficient solutions using C/C++/Python/MATLAB.
5. Develop industry-relevant coding and optimization skills.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. Emphasize ***hands-on coding and lab-based learning***
2. Use ***problem-based learning (PBL)*** and ***competitive coding platforms***
3. Encourage ***collaborative learning and GitHub-based submissions***
4. Integrate ***real-world datasets and case studies***
5. Conduct ***coding contests and hackathons***

Module 1: Algorithm Analysis & Recursion	**06 Hours**

Introduction to algorithms, characteristics, asymptotic notations (Big-O, Omega, Theta), time-space tradeoff, recursion fundamentals, recurrence relations.

Hands-on Experiments:

1. Factorial using recursion vs iteration
2. Fibonacci (recursive vs DP)
3. Tower of Hanoi visualization

Module 2: Linear Data Structures	**06 Hours**

Arrays, pointers, dynamic memory allocation, linked lists (SLL, DLL), stacks, queues, circular queues.

Hands-on Experiments:

1. Array operations and memory analysis
2. Singly linked list implementation
3. Stack implementation (array & linked list)
4. Queue implementation and applications

Module 3: Trees & Graphs	**06 Hours**
Binary trees, BST, tree traversals, graph representation, BFS, DFS. **Hands-on Experiments:** 1. Tree traversal (inorder, preorder, postorder) 2. Binary Search Tree operations 1. Graph traversal using BFS & DFS	
Module 4: Searching & Sorting	**06 Hours**
Linear search, binary search, sorting techniques: bubble, selection, insertion, merge, quick sort. **Hands-on Experiments:** 1. Binary search implementation 2. Sorting algorithms comparison 3. Time complexity visualization	
Module 5: Advanced Problem Solving	**06 Hours**
Hashing, greedy algorithms, dynamic programming, shortest path algorithms. **Hands-on Experiments:** 1. Hash table implementation 2. Dijkstra's shortest path algorithm	

AI Integration:

1. Use Python libraries (NumPy, Pandas) for performance analysis
2. Apply ML models for algorithm performance prediction
3. Visualization of complexity using Matplotlib
4. Use GitHub Copilot / AI tools for assisted coding
5. Automated benchmarking of algorithms

Authentic Intelligence:

1. Understanding limitations of algorithm efficiency in real-world systems
2. Avoiding overfitting in optimization strategies
3. Ethical coding practices and plagiarism awareness
4. Trade-offs between memory and performance
5. Responsible use of AI-assisted coding tools

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand data structures and algorithms	L2
2	Apply algorithms to solve problems	L3
3	Analyze time and space complexity	L4
4	Design optimized solutions	L5
5	Evaluate algorithm performance	L5

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	1	-	2	-	-	-	-	-	-	2	1
CO2	3	3	2	1	2	-	-	-	1	1	-	3	2
CO3	2	3	3	2	3	-	-	-	1	1	-	3	2
CO4	2	2	3	2	3	1	1	1	2	2	2	3	3
CO5	2	3	3	3	3	1	1	2	3	3	3	2	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXTBOOKS:

1. Cormen, T.H., Leiserson, C.E., Rivest, R.L. and Stein, C., 2009. *Introduction to Algorithms*. 3rd Edition, MIT Press.
2. Weiss, M.A., 2014. *Data Structures and Algorithm Analysis in C++*. 4th Edition, Pearson.
3. Goodrich, M.T., Tamassia, R. and Goldwasser, M.H., 2013. *Data Structures and Algorithms in Python*. 1st Edition, Wiley.

REFERENCE BOOKS:

1. Karumanchi, N., 2011. *Data Structures and Algorithms Made Easy*. 1st Edition, CareerMonk Publications.
2. Lafore, R., 2002. *Data Structures and Algorithms in Java*. 2nd Edition, SAMS Publishing.
3. Skiena, S.S., 2008. *The Algorithm Design Manual*. 2nd Edition, Springer.
4. Sedgewick, R. and Wayne, K., 2011. *Algorithms*. 4th Edition, Addison-Wesley.
5. Horowitz, E., Sahni, S. and Anderson-Freed, S., 2008. *Fundamentals of Data Structures in C*. 2nd Edition, Universities Press.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Data Structures and Algorithms https://roadmap.sh/datastructures-and-algorithms	Prof. Naveen Garg	IIT Delhi (NPTEL)
2	Programming, Data Structures and Algorithms using Python https://nptel.ac.in/courses/106106145	Prof. Madhavan Mukund	IIT Madras (NPTEL)
3	Algorithms Specialization https://online.stanford.edu/courses/soe-ycsalgorithms2-algorithms-specialization	Tim Roughgarden	Stanford University (via Coursera)
4	Data Structures https://en.wikipedia.org/wiki/Data_structure	Prof. Erik Demaine	MIT (OpenCourseWare)

COMPUTER ORGANIZATION AND ARCHITECTURE

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Subject Code	:	25EC2306	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. **Understand** the Architecture and programming of ARM microprocessor .
2. **Explain** the computational requirements of AI workloads.
3. **Describe** architectures of AI hardware.
4. **Develop** program using Arm instruction set and appreciate the advanced features provided in the ARM
5. **Understand** the exception handling techniques.
6. **Study in** detail the concept of instruction level parallelism and concepts of pipelining.
7. **Understand** various cache memory mapping techniques and memory Organization.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. The lecture method means it includes not only the traditional lecture method, but also different type of teaching methods may be adopted to develop the course outcomes.
2. Interactive Teaching: Adopt the Active learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show Video/animation films to explain functioning of various concepts.
4. Encourage Collaborative (Group Learning) Learning in the class.
5. To make Critical thinking, ask at least three Higher order Thinking questions in the class.
6. Adopt Problem Based Learning, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding

Module 1:Computer Architectures	**08 Hrs**
An Overview of Computing Systems: History of Computers, The Computing Device, comparision between CISC and RISC architectures The ARM7TDMI RISC architecture, Programmers' Model: Introduction, Data types, Processor Modes, Registers, Program Status Registers, The vector Table. Assembler Rules and Directives:Structure of Assembly Language Modules, Registers, Directives and Macros. Loads, Stores and Addressing:LOADS and STORES instructions, Operand Addressing , ENDIANNES Applications: programming for data transfer applications	
NVIDIA DLI Courses (Relevant to this Module): 1. AI for All: From Basics to Gen AI Practice (2 hrs) https://learn.nvidia.com/courses/course-detail 2. An easier Introduction to CUDA (1hr self paced) (free) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-01+V1	
MODULE 2: Programming	**07Hrs**
Constants and Literal Pools: The ARM Rotation Scheme, Loading Constants and address into Registers Logic and Arithmetic: Flags and their Use, Compare instructions, Data Processing Instructions Loops and Branches: Branching, Looping, Conditional Execution, Straight-Line Coding Subroutines and Stacks: Stack, Subroutines, Passing parameters to subroutines, The ARM APCS. Applications: programming with ARM and CUDA cores	
NVIDIA DLI courses (Relavant to this module): 1. GPU accelaration with C++ standard library (2hrs self paced) ($30) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-AC-07+V1 2. Fundamentals of accelerated computing with CUDA C/C++ (8hrs self paced) ($90) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-02+V1	
MODULE 3: Exceptional Handling and mixing languages	**06 Hrs**
Mixing C and Assembly Language: Inline Assembler Embedded Assembler, Calling Between C and Assembly. Exception Handling: Interrupts, Error Conditions, Processor Exception Sequence, The Vector Table, Exception Handlers, Exception Priorities, Procedures for Handling Exceptions. Applications: Multi-platform compatible programming and interacting with peripharals	
MODULE 4: Pipelining architectures	**12 Hrs**
Pipelining: Basic and Intermediate Concepts Introduction, The Major Hurdle of Pipelining, How Pipelining Implemented, What makes Pipelining hard to Implement, Extending the MIPS Pipeline to Handle Multicycle Operations, The MIPS R4000 Pipeline, Crosscutting Issues. **Applications:** parallel processing with improved performance speeds	
MODULE 5:Memory management	**12Hrs**
Memory Hierarchy: Introduction, Cache Performance, Six basic cache Optimizations, Virtual Memory, Protection and examples of Virtual Memory, Fallacies and Pitfalls. **Applications:** cost efficient and improved performance with memory management systems	

AI Integration:

1. Limitations of general-purpose processors for AI
2. comparison of CPU and GPU architectures for AI workloads
3. GPU architecture overview for AI workflow; CUDA cores and Tensor cores
4. CUDA Programming instructions

Authentic Intelligence:

1. CPUs are best for control logic and general tasks, but not for heavy AI computation because of its limitations. Key Insight of comparison of CPU with GPU:CPU = Brain (decision-making), GPU = Muscle (heavy computation), GPUs are designed to accelerate AI training and inference through parallel processing.
2. Core Components are:
   CUDA Cores which are the General-purpose processing units in NVIDIA GPUs,
   Handle standard arithmetic operations (floating-point, integer), Executing thousands of threads simultaneously with the Ideal for vector and matrix computations.
   Tensor Cores which are Specialized units for deep learning operations, performing matrix multiplications and accumulations (MMA) extremely efficiently, Supporting mixed precision, improving speed and reducing memory usage. They are Crucial for training deep neural networks.
3. CUDA (Compute Unified Device Architecture) is NVIDIA's parallel computing platform with Key Concepts: Kernel-A function executed on the GPU and Thread Hierarchy-Enabling massive parallel execution.
4. Modern AI systems rely heavily on specialized hardware (GPUs, TPUs) because: AI is computation-heavy and parallelizable, GPUs dramatically accelerate training and inference and

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Apply and compare** the knowledge of the internal architecture and organization of ARM microprocessors and computational requirements of AI workloads, to utilize their components and functionalities.	L3
2	**Apply** the instruction set of ARM Microprocessor by writing Assembly language programs.	L3
3	**Analyze and compare** the various exception handling techniques.	L4
4	**Examine** the concept of instruction-level parallelism and **analyze** the principles of Pipelining techniques.	L4
5	**Compare** and **contrast** memory hierarchy and its impact on computer cost/performance.	L4

CUDA enables developers to harness this power efficiently.

COs	POs											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	2	-	2	-	-	-	-	-	2	-	2
CO2	3	3	2	-	2	-	-	-	-	-	2	-	2
CO3	3	3	1	-	-	-	-	-	-	-	-	-	2
CO4	3	3	1	-	-	-	-	-	-	-	-	-	2
CO5	3	3	1	-	-	-	-	-	-	-	-	-	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. William Hohl, "ARM Assembly Language", 2nd Edition, CRC Press, 2009.
2. John L Hennessy, David A Patterson, "Computer Architecture, A Quantitative Approach", 6th Edition, Morgan Kaufmann publishers, 2019.
3. Sze, V., Chen, Y., Yang, T. J., & Emer, J., Efficient Processing of Deep Neural Networks, Morgan & Claypool, 2020.

REFERENCE BOOKS:

1. David A Patterson, John L Hennessy, "Computer Organization and Design", 5th Edition, Morgan Kaufmann publishers, 2012.
2. Steve Furber, "ARM System-on-chip Architecture", 2nd Edition, Pearson Publications, 2000.

E-Resources:

S. No.	Course Name	Instructor	Host Institute
1	ARM Cortex-M Courses: https://www.udemy.com/topic/arm-cortex-m/		UDEMY
2	**Embedded System Design With ARM** https://onlinecourses.nptel.ac.in/noc22_cs93/preview	By Prof. Indranil Sengupta, Prof. Kamalika Dutta	IIT Kharagpur
3	NVIDIA Deep Learning Institute: Introduction to AI Hardware https://www.nvidia.com/en-in/training/		NVIDIA
4	NVIDIA Developer Documentation (CUDA, Tensor Cores) 9https://developer.nvidia.com/blog/programming-tensor-cores-cuda-9/		NVIDIA
5	NPTEL: Advanced Computer Architecture https://nptel.ac.in/courses/106102229	**Prof. Smruti R.Sarangi**	IIT Delhi

Activity Based Learning (Suggested Activities in Class)

1. Comparative study of CPU and GPU, architectures for AI inference.
2. Mini project implementation using Assembly Language Programming.
3. Demonstration of solution to a problem through programming.

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ELECTROMAGNETIC FIELD THEORY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Subject Code	:	25EC2402	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Understand the applications of Coulomb's law and Gauss' law to different charge distributions.
2. apply Laplace's and Poisson's equations to solve practical problems involving potential, fields and capacitance.
3. Understand the significance of Biot-Savart's law and Ampere's circuital law for different current distributions.
4. Interpret divergence, curl and gradient for electromagnetic field analysis.
5. Understand Maxwell's equations under time-varying field conditions.
6. Analyze uniform plane waves and their characteristic features in different media.
7. Apply Poynting theorem for evaluating electromagnetic power flow.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. **The lecture method** means it includes not only the traditional lecture method, but also different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding

MODULE - I: Electrostatics - I	**10 Hrs**
Coulomb's Law and Electric Field Intensity; electric field due to line charge, volume charge and sheet charge; related problems. Gauss' Law: electric flux, electric flux density, Gauss' Law and applications of Gauss' Law; Maxwell's first equation; introduction to the del operator and Divergence Theorem; related problems. Text Book-1: Chapter 2: 26-43; Chapter 3: 48-69. **Applications:** 3D graphical representation and analysis of vectors, electric-field distributions and divergence using MATLAB/Python AI-assisted tools.	
MODULE- II: Electrostatics - II	**09 Hrs**
Energy and Potential: energy and potential of a moving point charge in an electric field, line integral, potential difference, potential field of a moving charge, potential gradient, conductor properties and boundary conditions. Boundary conditions for perfect dielectric materials; Poisson's and Laplace's equations; uniqueness theorem; applications of Laplace's and Poisson's equations; related problems. Text Book-1: Chapter 4: 75-94, 100-104; Chapter 5: 110-113, 119-123; Chapter 6: 143-168. **Applications:** AI-assisted visualization of electric fields and Laplace-equation solutions in rectangular, cylindrical and spherical coordinate systems.	
MODULE -III: The Steady Magnetic Field	**09 Hrs**
Biot-Savart Law and its applications; Ampere's Circuital Law; Curl; Stokes' Theorem; magnetic flux and flux density; scalar and vector magnetic potentials. Magnetic boundary conditions; energy stored in magnetic fields; related problems. Text Book-1: Chapter 7: 180-216. **Applications:** Plotting magnetic flux density and magnetic energy density using MATLAB/Python AI-assisted tools.	
MODULE -IV: Time-Varying Magnetic Field	**08 Hrs**
Faraday's Law of electromagnetic induction; inconsistency of Ampere's law; displacement current; Maxwell's equations in point and integral forms for different media; retarded potential. Boundary conditions: dielectric-dielectric boundary; related problems. Text Book-1: Chapter 9: 277-297. **Applications:** AI-based time-domain field evolution, displacement-current visualization and introductory CST/HFSS field simulation.	
MODULE 5: Uniform Plane Waves	**09 Hrs**
Wave propagation in free space and dielectrics; propagation in conductors; skin effect; Poynting vector and power considerations; power loss in plane conductors. Wave polarization; reflection of uniform plane waves at normal incidence for perfect conductor-dielectric and dielectric-dielectric boundaries; standing wave ratio; introduction to transmission lines and waveguides. Text Book-1: Chapter 11: 367-390; Chapter 12: 406-425. **Applications:** MATLAB/Python visualization of wave propagation, polarization, skin depth, Poynting vector, reflection coefficient and SWR.	

AI Integration :

1. Use MATLAB/Python/AI Copilot tools for vector-field visualization, gradient, divergence and curl analysis.
2. Apply symbolic and numerical solvers to compute electrostatic potential, capacitance and field distributions for standard charge configurations.
3. Use MATLAB/Python/CST/HFSS-assisted workflows to visualize magnetic flux density, magnetic energy density and boundary-condition effects.
4. Implement time-domain visualization of Faraday's law, displacement current and Maxwell-equation field evolution using simulation tools.
5. Evaluate plane-wave propagation, skin depth, Poynting vector, reflection coefficient, SWR and polarization using computational and AI-assisted plotting tools.

Authentic Intelligence:

1. Validate AI-generated field plots and symbolic results using Coulomb's law, Gauss' law, Ampere's law, Faraday's law and Maxwell's equations.
2. Understand assumptions, coordinate-system choices, sign conventions and unit consistency before accepting computational or AI-generated answers.
3. Interpret boundary conditions, media properties and material parameters carefully to avoid physically unrealistic solutions.
4. Cross-check numerical and simulation results with analytical solutions, convergence checks and mesh/step-size sensitivity wherever applicable.
5. Use AI tools ethically as learning and visualization aids while maintaining academic integrity in assignments, laboratory reports and assessments.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand basic scalar and vector fields and apply vector operations for electromagnetic field calculations.	L2
2	Apply Coulomb's law and Gauss' law to solve numerical problems involving electric fields and flux density.	L3
3	Analyze different charge distributions using electrostatic theorems, principles and boundary conditions.	L4
4	Classify and analyze different current distributions using magnetostatic theorems and principles.	L4
5	Apply Maxwell's equations to describe plane waves and their propagation in different media.	L3
6	Analyze electromagnetic power flow using Poynting theorem and evaluate power associated with plane waves.	L4

COs	PO											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	-	-	-	-	-	-	-	-	-	-	2	-
CO2	2	3	-	-	-	-	-	-	-	-	-	3	-
CO3	3	3	2	3	-	-	-	-	-	-	-	-	2
CO4	-	3	3	2	3	-	-	-	-	-	-	3	3
CO5	-	2	3	3	2	3	-	-	-	-	-	3	3
CO6	3	-	-	-	-	-	-	-	-	-	-	2	-

3:Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Engineering Electromagnetics - William H. Hayt Jr. and John A. Buck, Tata McGraw Hill, 6th Edition, 2001.
2. Electromagnetic Waves and Radiating Systems - E. C. Jordan and K. G. Balmain, PHI, 2nd Edition.

REFERENCE BOOKS:

1. Electromagnetics - Joseph Edminister, Schaum Outline Series, McGraw Hill, 2nd Edition, 1993.
2. Field and Wave Electromagnetics - David K. Cheng, Pearson Education Asia, 2nd Edition, 1989; Indian Reprint, 2001.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Electromagnetic Theory https://nptel.ac.in/courses/108104087	Prof. Pradeep Kumar K	IIT Kanpur
2	Electromagnetic Fields https://nptel.ac.in/courses/108106073	Prof. Harishankar Ramachandran	IIT Madras
3	Transmission Lines and EM Waves https://nptel.ac.in/courses/117101056	Prof. R. K. Shevgaonkar	IIT Bombay

CMOS VLSI DESIGN

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Subject Code	:	25EC2403	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	45+30 Hours
L–T–P		3–0–2			

Course Learning Objectives:

This course enables students to

1. **Familiarize** themselves with fabrication techniques and scaling applied to various MOS parameters, used in modern semiconductor manufacturing techniques.
2. **Comprehend** the construction, operation, and characteristics of a nMOS considering both ideal and non-ideal characteristics and their impact on device performance.
3. **Demonstrate** and **Build** various combinational logic circuits using CMOS design and its families for optimized digital circuit performance.
4. **Analyz**e bistable elements and memory cells using CMOS technology, understanding their operational principles and performance characteristics.
5. **Explain** delay elements in CMOS circuits, RC delay models, Elmore delay, and logical effort.
6. **Draw** and **Simulate** combinational and sequential circuits using schematic and layouts.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:	
Module 1: MOS transistor basics	**10 Hrs**
Introduction, long-channel I–V characteristics, C–V characteristics and MOS capacitance models including gate and diffusion capacitances. Non-ideal I–V effects: mobility degradation, velocity saturation, channel length modulation, threshold voltage effects, leakage currents, body effect, tunneling, and temperature dependence. Scaling of MOS circuits: scaling models and scaling factors. **Applications:** Understanding MOSFET behavior in digital circuits and predicting device performance under different operating conditions. Basis for transistor-level circuit design and scaling in VLSI systems.	
MODULE 2: Static CMOS Logic Design	**09 Hrs**
Introduction to CMOS logic design and static CMOS logic. CMOS inverter: DC characteristics, beta ratio effect, and noise margins. CMOS realization of universal gates: NAND and NOR gates and their voltage transfer characteristics. CMOS realization of basic logic gates: AND, OR, XOR, and XNOR gates. CMOS implementation of Boolean expressions using complementary pull-up and pull-down networks. Pass transistor logic and transmission gates. Transient analysis of CMOS logic circuits. **Applications:** Design and analysis of digital logic gates used in processors and digital systems. Implementation of efficient and reliable CMOS-based logic circuits.	
MODULE 3: Timing and Delay Analysis	**08 Hrs**
Transient analysis of CMOS inverter; delay definitions including propagation delay, rising and falling contamination delay, rise time and fall time. Unit step response of CMOS inverter. Delay modeling techniques: RC delay model, Elmore delay model and linear delay model. Delay calculation of universal gates (NAND and NOR). Logical effort, parasitic delay and logical effort of compound gates. Delay analysis in multistage logic networks. Skewed gates and delay optimization. **Applications:** Timing analysis and performance optimization of digital circuits. Design of high-speed VLSI circuits with reduced delay.	
MODULE 4: Combinational Circuit Design	**09 Hrs**
Different circuit families, including ratioed circuits, pseudo-nMOS, ganged CMOS, and CVSL logic. Dynamic circuits and domino logic. Tristate circuits and multiplexers. **Sequential Circuit Design:** CMOS latches and flip-flops, resettable and enabled latches and flip-flops, D-latch, edge-triggered flip-flop, and JK flip-flop, Behaviour of bistable elements. **Applications:** Design of complex digital systems such as processors, controllers, and memory elements. Implementation of high-performance combinational and sequential logic circuits.	
MODULE 5: CMOS fabrication technology	**09 Hrs**
Wafer formation, photolithography, well and channel formation, silicon dioxide (SiO_2), isolation, gate oxide formation, gate and source/drain formation, contacts and metallization, passivation, and metrology. MOS layers and fabrication processes: NMOS, n-well, p-well, and twin-tub technologies. Stick diagrams, layout concepts, and design rules. **Semiconductor memories:** DRAM cells (1T, 4T, pseudo-static DRAM) and 6T SRAM cell. **Applications:** Understanding fabrication processes and layout design for chip manufacturing. Designing of memory circuits and translating circuit designs into physical layouts.	

AI Integration:

1. Exposure to data-driven design approaches in the Cadence environment for improving circuit performance, including parameter sweeps, result analysis, and design optimization.

Authentic Intelligence:

1. Understanding the limitations of simulation results and the need to validate circuit behavior with theoretical concepts and physical device knowledge.
2. Interpretation of simulation outputs to identify incorrect designs, unrealistic waveforms, or improper parameter choices in CMOS circuits.
3. Awareness of trade-offs between power, delay, and area, and the importance of making design decisions based on engineering judgment rather than relying only on simulation outputs.

Use of tools for Lab Experiments:

S.No	Experiment	AI/Simulation Tool	Utility
1	Obtain the transfer and output characteristics of an NMOS transistor using DC simulations	Cadence Virtuoso	Understand device behaviour, extract I–V characteristics, and analyze operating regions
2	Design and simulate a CMOS inverter and analyse its voltage transfer characteristics (VTC)	Cadence Virtuoso	Evaluate switching behaviour, noise margins, and inverter performance
3	Design and simulate CMOS NAND and NOR gates to verify logic operation	Cadence Virtuoso	Validate logic functionality and understand basic gate implementation
4	Design and simulate CMOS AND & OR gates and analyse timing and power consumption	Cadence Virtuoso	Analyze delay, power dissipation, and performance trade-offs in logic circuits
5	Design and simulate CMOS XOR and XNOR gates and analyze switching characteristics	Cadence Virtuoso	Study complex gate design and switching behaviour in digital circuits
6	Implement a 2:1 multiplexer using transmission gate logic and compare with CMOS logic	Cadence Virtuoso	Compare logic styles in terms of performance, transistor count, and voltage swing
7	Perform layout design of a CMOS inverter and verify using DRC and LVS checks	Cadence Virtuoso	Understand layout design rules, physical verification, and post-layout effects
8	Perform layout design of CMOS NAND and NOR gates and verify using DRC and LVS checks	Cadence Virtuoso	Gain knowledge of layout implementation and circuit-to-layout correspondence
9	Design and simulate sequential circuits (SR latch, SR flip-flop, D flip-flop)	Cadence Virtuoso	Analyze timing behaviour, stability, and sequential logic operation
10	Design and simulate memory circuits (1T DRAM and 6T SRAM cells)	Cadence Virtuoso	Understand memory operation, read/write processes, and stability of storage elements

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Analyze and model** the electrical characteristics of MOS transistors, including I–V and C–V behavior, capacitance effects, and the impact of non-idealities and scaling on device performance.	L4
2	***Design*** and ***analyze*** CMOS logic circuits using static CMOS design principles, including inverters, universal gates, basic logic gates, and Boolean implementations using complementary pull-up and pull-down networks	L4
3	**Analyze** the timing behavior of CMOS circuits by applying delay definitions and delay models and **evaluate** circuit performance using logical effort and multistage delay analysis techniques.	L5
4	**Design** and **analyze** CMOS combinational and sequential circuits, including logic families, multiplexers, tristate circuits, latches, and flip-flops, to realize digital system functionalities.	L4
5	**Understand** CMOS fabrication processes and layout design principles and **examine** the operation and performance of semiconductor memory circuits such as dynamic random-access memory and static random-access memory.	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	-	2	2	-	-	-	-	-	1	3	2
CO2	3	3	2	-	3	-	-	-	-	-	1	3	3
CO3	3	3	2	2	3	-	-	-	-	-	1	3	3
CO4	3	3	2	-	3	-	-	-	-	-	1	3	3
CO5	3	2	1	1	3	-	-	-	-	-	1	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Neil Weste and David M Harris , "Principles of CMOS VLSI Design: A Circuit and System Perspective," Pearson Education (Asia) Pvt.. Ltd., 4th Edition, 2023.
2. Douglas A Pucknell & Kamran Eshragian, "Basic VLSI Design" PHI 3rd Edition
3. J. P. Uyemura "Introduction to VLSI Circuits and Systems", Wiley Publications, 3rd Edition.

REFERENCE BOOKS:

1. Wayne, Wolf, "Modern VLSI design: System on Silicon" Pearson Education, 2nd Edition
2. Eugene D Fabricius "Introduction to VLSI Design", McGraw-Hill International publications.
3. Sung Mo Kang & Yosuf Lederabic Law, "CMOS Digital Integrated Circuits: Analysis and Design", McGraw-Hill, 3rd Edition

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute	Link
1	CMOS Analog VLSI Design	Prof. Rajesh H Zele	IIT Bombay	https://www.cdeep.iitb.ac.in/vod/vodCloud/course_intra.php?ccode=296&referSrc=57dc9eb7be985a0e14aaa07846b0b9b4
2	CMOS Digital VLSI Design	Prof. Sudeb Dasgupta	IIT Roorkee	https://onlinecourses.nptel.ac.in/noc22_ee08/preview

Department of Electronics and Communication Engineering

SUSTAINABILITY ENGINEERING

[AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME]

SEMESTER – IV

Subject Code	:	25EC2404	**Credits**	:	02
Hours / Week	:	02 Hours	**Total Hours**	:	30 Hours
L–T–P	:	2–0–0			

Course Learning Objectives:

This course enables students:

- Understand sustainability engineering principles in ECE.
- Learn ESG frameworks and reporting standards.
- Analyse environmental impacts of electronic systems.
- Apply sustainable and circular design principles.
- Understand governance, ethics, and policy aspects.

Teaching-Learning Process (General Instructions):

- Interactive Teaching:
- Adopt active learning methods such as brainstorming on sustainability challenges, ESG debates, group discussions, case-based reasoning, and reflective thinking exercises.
- Use of Multimedia & Case Studies:
- Show videos/animations explaining concepts like e-waste recycling processes, carbon footprint in telecom networks, lifecycle of electronic products, and ESG reporting practices in industries.
- Collaborative Learning:
- Encourage group activities where students analyze ESG reports of companies, compare sustainability strategies, and present findings on green electronics or communication systems.
- Problem-Based Learning (PBL):
- Assign real-world problems such as designing low-power communication systems, reducing carbon emissions in data centers, or creating sustainable IoT solutions.
- Data-Driven Learning with AI Tools:
- Integrate tools like Python, Excel, or AI platforms to analyze energy consumption datasets, carbon emissions, and ESG metrics for informed decision-making.
- Industry-Oriented Learning:
- Discuss real-world applications from semiconductor industries, telecom sectors, and smart cities with focus on sustainability practices and ESG compliance.
- Critical Thinking & Higher-Order Questions:
- Frame questions that require evaluation of trade-offs (performance vs sustainability), ethical considerations, and long-term environmental impacts.
- Experiential Learning:
- Encourage mini-projects such as energy audits of campus labs, ESG assessment of institutions, or design of green communication prototypes.
- Ethics & Responsibility Integration:
- Discuss ethical issues like greenwashing, data privacy in ESG reporting, environmental justice, and responsible innovation.
- Continuous Assessment & Feedback:
- Use quizzes, case study presentations, ESG report analysis, and project reviews to ensure continuous learning and improvement.

COURSE CONTENT:	
MODULE 1: Sustainability & ESG Fundamentals	**06 Hrs**
Sustainability concepts, triple bottom line, Introduction to ESG: Environmental, Social, Governance pillars, Global frameworks: UN SDGs, GRI, SASB, Role of engineers in sustainable development.	
MODULE 2: Environmental Impact in Electronics	**08 Hrs**
Energy consumption in electronics and communication systems, Carbon footprint, e-waste management. Green electronics and eco-design, Lifecycle assessment (LCA) of electronic products.	
MODULE 3: Sustainable Communication Systems	**05 Hrs**
Energy-efficient wireless networks (5G/6G sustainability), Green IoT and smart systems, Renewable energy integration in telecom infrastructure, Edge computing vs cloud sustainability trade-offs.	
MODULE 4: Social and Governance Aspects	**06 Hrs**
Social responsibility in technology deployment, Data privacy, digital divide, inclusivity, Corporate governance, ESG reporting, Regulations: Indian ESG norms, DPDP Act.	
MODULE 5: ESG Applications and Case Studies	**05 Hrs**
Case studies: Smart cities, sustainable manufacturing, ESG in semiconductor industry, AI for sustainability monitoring, Future trends: circular electronics, carbon-neutral tech.	

AI Integration:

1. Use Python to analyse energy consumption datasets of communication systems.
2. Apply ML models to predict carbon emissions.
3. Use anomaly detection for power usage optimization.
4. Case study using AI for smart grid monitoring.
5. Group project: ESG analytics dashboard.

Authentic Intelligence:

1. Ethical responsibility in e-waste disposal.
2. Bias in ESG data reporting.
3. Privacy concerns in sustainability data.
4. Green washing risks and mitigation.
5. Responsible AI in sustainability decisions.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Understand sustainability and ESG concepts	L2
CO2	Analyse environmental impacts	L3
CO3	Apply sustainable design	L3
CO4	Evaluate ESG frameworks	L5
CO5	Assess real-world applications	L5

COs	PO											PSO	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	-	2	3	2	1	-	2	2	1
CO2	3	3	2	2	2	3	3	2	1	-	2	2	2
CO3	3	3	3	2	2	2	3	2	2	1	3	2	2
CO4	2	3	3	3	3	2	3	3	2	2	3	2	3
CO5	2	2	2	3	2	3	3	3	2	2	3	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Ana, F., Arya, S. and Mehraj, H. (Eds.) (2025). Sustainable Electronics: The Future Ahead. 1st Edition, CRC Press (Taylor & Francis Group), Boca Raton. ISBN: 978-1032744841
2. Jacob, Park, and Roome Nigel 1953-, eds. The ecology of the new economy: Sustainable transformation of global information, communications and electronics industries. Greenleaf, 2002

REFERENCES:

1. Sustainable and Resilient Engineering: Drivers, Metrics, Tools, and Applications
2. Reddy, K.R., Cameselle, C. and Adams, J.A. (2025). Sustainable and Resilient Engineering: Drivers, Metrics, Tools, and Applications. 2nd Edition, John Wiley & Sons.
3. Electronic Waste: Recycling and Reprocessing for a Sustainable Future
4. Holuszko, M.E., Kumar, A. and Espinosa, D.C.R. (Eds.) (2021). Electronic Waste: Recycling and Reprocessing for a Sustainable Future. Wiley-VCH.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Sustainable Engineering Concepts and Life cycle analysis https://onlinecourses.nptel.ac.in/noc21_ce47/preview	Prof. Brajesh Kumar Dubey	IIT Kharagpur
2	Introduction to Environmental Engineering and Science - Fundamental And Sustainability Concepts https://onlinecourses.nptel.ac.in/noc23_ge17/preview	Prof. Brajesh Kumar Dubey	IIT Kharagpur

Department of Electronics and Communication Engineering

EMBEDDED SYSTEM ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER - IV

Subject Code	:	25EC2402	**Credits**	:	04
Hours / Week	:	04 Hours	**Total Hours**	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students to:

1. **Understand** embedded system architecture and real-time constraints
2. **Design** embedded systems using STM32 and edge AI platforms
3. **Implement** real-time sensor data acquisition systems
4. **Apply** AI techniques for sensor fusion and intelligent decision-making
5. **Develop** and deploy edge AI systems using NVIDIA Jetson platforms

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Interactive Lectures:** Engage students through discussions, concept mapping, real-life embedded system examples, and AI-driven applications such as smart IoT and autonomous systems.
2. **Hands-on Projects:** Assign practical embedded and edge AI projects involving STM32 microcontrollers, sensor interfacing, and NVIDIA Jetson platforms to strengthen application-oriented learning.
3. **Group Discussions:** Encourage collaborative learning through brainstorming sessions on real-time system design challenges, AI model selection, and system optimization strategies.
4. **Case Studies:** Analyze real-world embedded system designs to understand their challenges and solutions.
5. **Simulations and Virtual Labs:** Utilize simulation tools (Proteus, MATLAB, Python environments) and virtual labs to model embedded systems and AI pipelines before hardware implementation.
6. **Guest Lectures:** Invite industry experts to share their experiences and provide insights into real-world embedded system design practices.
7. **Demonstrations and Prototyping:** Conduct live demonstrations of sensor interfacing, real-time data acquisition, and deployment of AI models on embedded platforms like Jetson.

MODULE 1: Embedded Systems & Edge AI Foundations	09 Hours

Introduction: What is an Embedded System, Embedded Systems VS. General Computing Systems, History of Embedded Systems, Classification of Embedded Systems, Major Application Areas of Embedded Systems, Purpose of Embedded Systems, Wearable Devices—The Innovative Bonding of Lifestyle with Embedded Technologies

Characteristics and Quality Attributes of Embedded Systems: Characteristics of an Embedded System, Quality Attributes of Embedded Systems

Introduction to Edge AI systems: Embedded AI vs Cloud AI , Overview of intelligent embedded applications (IoT, healthcare, automotive).

Introduction to GPU-based Embedded Platforms: NVIDIA Jetson architecture overview, Role of GPU acceleration in embedded AI.

Applications:

Smart home automation systems for lighting, security, and energy management

Wearable health monitoring devices (fitness trackers, ECG monitors)

NVIDIA DLI Courses (Relevant to this Module):

Getting Started with AI on Jetson Nano (8 hrs)

MODULE 2: EMBEDDED SYSTEM HARDWARE DESIGN	9 Hours

Arm Cortex Mx Processor family Overview: Features, Architecture, Memory System, Exception and Interrupts, Low Power Features

Memory: Overview on Various Types of memory sub systems used in Embedded systems and their selection

Sensors and Actuators: interfacing of LEDs, 7-segment LED Displays, Piezo Buzzer, Stepper Motor, Relays, Optocouplers, Matrix keyboard, Push button switches, Programmable Peripheral Interface Device (e.g. 8255 PPI), etc. with the I/O subsystem of the embedded system

Communication Interface: I2C, SPI, CAN, UART,1-wire, parallel bus, etc. RS-232C, RS-485, Parallel Port, USB, IEEE 1394, Infrared (IrDA), Bluetooth, Wi-Fi, ZigBee, GPRS, etc.

Other System Components: Reset Circuit, Brown-out protection circuit, Oscillator Unit, Real- Time Clock (RTC), Analog to Digital Converter (ADC), Timers and Watchdog Timer unit

Applications:

Environmental monitoring systems (temperature, air quality sensing)

Smart agriculture (soil moisture, irrigation control)

Automotive sensor systems (IMU, proximity sensing)

MODULE 3: EMBEDDED SYSTEM SOFTWARE DESIGN	9Hours

Programming Concepts and Embedded Programming in C: High -Level Language
C programming, C program elements (compiler build stages, interrupts,macros, functions, Bitwise Operations, Looping constructs, Pointers and AAPCS)
Embedded Firmware Design and Development: Embedded Firmware Design Approaches
Data Acquisition Firmware: Interrupt-driven acquisition, UART-based communication
Machine Learning Workflow: Data collection,Preprocessing,Model training
Applications:

1. Real-time sensor data logging systems
2. Smart energy monitoring with predictive analytics
3. Industrial predictive maintenance using sensor data

NVIDIA DLI Courses (Relevant to this Module):

Fundamentals of Deep Learning (8 hrs)

MODULE 4: REAL-TIME OPERATING SYSTEMS	10 Hours

Operating System Basics: The Kernel, Types of Operating Systems, Tasks, Process and Threads
Thread Management: Introduction to RTOS, Function pointers, Thread Management, Semaphores, Thread Synchronization, Process Management, Dynamic loading and linking
Time Management: Cooperation, blocking semaphores, First In First Out Queue, Thread sleeping, Deadlocks, Monitors, Fixed Scheduling
Real-time Systems: Data Acquisition Systems, AI workload scheduling ,Event-driven AI systems, Debouncing a switch, Available RTOS
Applications:

1. Real-time traffic signal control systems
2. Industrial automation and robotic control systems
3. Automotive control systems (ABS, airbag systems)

MODULE 5: Testing, Deployment & Sensor Fusion	08 Hours

Testing, Deployment & Sensor Fusion
Integration and Testing of Embedded Hardware and Firmware: Integration of Hardware and Firmware, Board Bring up **,** Tools used for testing and debugging**.**
Sensor Fusion Techniques: Multi-sensor systems, Basic Kalman filter concept
Applications:

1. Drone stabilization and control systems
2. Smart surveillance systems with anomaly detection
3. Fault detection and diagnostics in industrial machinery

AI Integration:

1. Introduction to embedded AI workflow: sensor data acquisition using STM32, data
2. preprocessing, feature extraction, and integration with Python-based machine learning frameworks using libraries such as NumPy, Pandas, and Scikit-learn.
3. Implementation of supervised learning algorithms (classification/regression) for sensor
4. based applications such as environmental monitoring, predictive maintenance, and smart control systems.
5. Implementation of real-time data processing pipelines, including streaming sensor data (UART/I2C/SPI) to external systems (PC/Jetson) for preprocessing, model inference, and visualization.
6. Introduction to sensor fusion techniques using statistical and machine learning methods for combining multi-sensor data (e.g., IMU + temperature + light sensors) to improve system accuracy and reliability.
7. Deployment of trained models on edge AI platforms (NVIDIA Jetson), including performance evaluation based on latency, throughput, and power constraints in real-time embedded systems.

Authentic Intelligence:

1. Understanding the challenges in designing real-time AI-enabled embedded systems, including latency constraints, limited computational resources, and reliability requirements in safety-critical applications.
2. Analysis of risks associated with incorrect predictions in embedded AI systems, such as failures in autonomous systems, industrial monitoring, and healthcare devices.
3. Interpretation challenges in sensor fusion systems, including noise, sensor drift, and incorrect data correlation leading to inaccurate decision-making.
4. Limitations of deploying machine learning models on resource-constrained embedded platforms, including trade-offs between model accuracy, memory usage, and power consumption.
5. Understanding issues such as overfitting, underfitting, bias-variance tradeoff, and the importance of proper validation, model selection, and robustness in real-time embedded AI applications.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	3						2	2	3	3
CO2	3	3	3	3	3	2	1	3			2	3	3
CO3	3	3	1	3	3						2	3	2
CO4	3	3	3	3	3	2						3	3
CO5						3	3						

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Apply** knowledge of embedded system design principles to solve real-world problems.	L3
2	**Design** and implement embedded systems using appropriate hardware and software components.	L5
3	**Develop** embedded software using C programming techniques.	L4
4	**Apply** RTOS concepts for task scheduling, synchronization, and resource management in embedded systems.	L3
5	**Analyze** and evaluate the performance of embedded systems through testing and debugging techniques.	L4

TEXT BOOKS:

1. Joseph Yiu," The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors", 3rd Edition, Newnes, 2013
2. Jonathan Valvano," Embedded Systems: Real-Time Operating Systems for ARM Cortex-M Microcontrollers", 2nd Edition, CreateSpace Independent Pub, 2012.
3. K.V. Shibu," Introduction to Embedded Systems", 2nd Edition, McGraw Hill Education, 2017.

REFERENCE BOOKS:

1. James K. Peckol, "Embedded Systems: A Contemporary Design Tool", Wiley, 2009.
2. Raj Kamal, "Embedded Systems- Architecture, Programming and Design", 3rd Edition, McGraw Hill Education, 2017.

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Hardware Modeling using Verilog https://nptel.ac.in/courses/106105165	Prof. Indranil Sengupta	IIT Kharagpur
2	Digital System Design https://nptel.ac.in/courses/117105080	Prof. D.Roy Choudhury	IIT Kharagpur

1. MOOC Course: "Introduction to Embedded Systems" by University of California, Irvine (Link: [www.coursera.org/embedded-systems])
2. Website: Embedded.com (Link: [www.embedded.com])
3. Online Tutorial: "Embedded Systems Tutorial" by Tutorials point (Link: [www.tutorialspoint.com/embedded_system])
4. ARM Procedure Call Standard (AAPCS) Standard documentation (Link: https://developer.arm.com/documentation/dui0041/c/ARM-Procedure-Call-Standard)

Activity Based Learning (Suggested Activities in Class)

1. **Project-based Learning:** Assign a semester-long project where students design and implement an embedded system for a specific application.
2. **Hackathons:** Organize hackathons where students work in teams to solve a given problem using embedded system design techniques.
3. **Guest Speaker Series:** Invite professionals from the industry to share their experiences and projects related to embedded system design.
4. **Case Studies:** Provide students with real-world case studies of successful embedded system designs and ask them to analyze and present their findings.
5. **Prototyping Sessions:** Conduct hands-on sessions where students build and test

EMBEDDED SYSTEM DESIGN LABORATORY

Total Contact Hours: 30

1. Introduction to Microcontrollers: Familiarize students with microcontroller architecture and programming.
2. C as implemented in Assembly: Modify and compile a C program and observe the assembly listing and the map file. (*Note: Mapped to module 5 of Efficient Embedded Systems Design and Programming Lab conducted by ARM University program)
3. General purpose I/O Lab: Implement a simple C program to read from and write to IO pins in the microcontroller. (*Note: Mapped to module 7 of Efficient Embedded Systems Design and Programming Lab conducted by ARM University program)
4. Interrupt Handling: Understand interrupt handling and implement interrupt-driven tasks. (*Note: Mapped to module 6 of Efficient Embedded Systems Design and Programming Lab conducted by ARM University program)
5. Analog-to-Digital Conversion: Learn how to perform analog-to-digital conversion using microcontrollers. (*Note: Mapped to module 8 of Efficient Embedded Systems Design and Programming Lab conducted by ARM University program)
6. Timer Lab Exercise: Signal Generator with precision Timing and Buffering (*Note: Mapped to module 9 of Efficient Embedded Systems Design and Programming Lab conducted by ARM University program)
7. PWM Generation: Generate Pulse Width Modulation signals for controlling motor speed.
8. Communication Protocols: Implement I2C or SPI communication protocols between microcontrollers. (*Note: Mapped to module 10 of Efficient Embedded Systems Design and Programming Lab conducted by ARM University program)
9. Wireless Communication: Implement wireless communication between two or more embedded systems.
10. Power Management Techniques: Design power-efficient embedded systems using sleep modes and power management techniques

11. Real-Time Operating Systems: Implement a simple real-time task scheduler on a microcontroller.
12. System Debugging and Testing: Learn techniques for debugging and testing embedded systems.
13. Embedded System Project: Design and implement a complete embedded system project, integrating various hardware and software components.

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Department of Electronics and Communication Engineering

SIGNALS AND SYSTEMS
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER – IV

Subject Code	:	25EC2406	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. To develop the ability to analyze and classify continuous and discrete-time signals based on their properties and transformations.
2. To understand system properties and analyze the behavior of linear time-invariant (LTI) systems using convolution techniques.
3. To introduce Fourier series representation for periodic signals and understand their properties in time and frequency domains.
4. To study Fourier transform techniques for representing aperiodic signals and performing frequency-domain analysis.
5. To understand discrete-time signal representation using Z-transform and analyze sampling and reconstruction processes.

Teaching-Learning Process (General Instructions)
These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** – and when that's possible, it helps improve the students' understanding

Module – I : Introduction to signal	**9 Hours**

Continuous and discrete time signals: Classification of Signals – Periodic aperiodic even – odd – energy and power signals – Deterministic and random signals – complex exponential and sinusoidal signals – periodicity – unit impulse – unit step – Transformation of the independent variable of signals: time scaling, time shifting.
Applications: Audio processing, biomedical signals, wireless communication, radar systems, IoT sensors.

Module – II : Introduction to Systems and Behavior of LTI systems	**8 Hours**

System properties: system with and without memory, invertibility and inverse system, causality, stability, time invariance, and linearity.
Time domain representation of LTI System: Discrete-Time LTI systems: convolution sum, Continuous-Time LTI systems: convolution integral, properties of LTI systems.
Applications: Digital filters, noise cancellation, robotics control, mobile networks, smart grids.

Relevant NVIDIA DLI Courses:
Course: Fundamentals of Deep Learning
NVIDIA Deep Learning Institute helps understand system behaviour using neural networks and data flow models, relating to LTI concepts like input-output relationships and system response.
Course Detail | NVIDIA

Module - III : Fourier Series Representation Of Periodic Signals	**08 Hours**

Representation of Fourier series for Continuous time periodic signals, properties of continuous time Fourier series, Fourier Series Representation of Discrete-Time Periodic Signal, Properties of Discrete-Time Fourier Series.
Applications: Power system harmonics, vibration analysis, music synthesis, AC circuits, heartbeat analysis.

Module –IV : Continuous and Discrete Time Fourier Transform	10 Hours
Continuous-Time Fourier Transform: Introduction, Representation of Aperiodic Signals: The Continuous-Time Fourier Transform, The Fourier Transform for Periodic Signals, Properties of the Continuous-Time Fourier Transform **Discrete-Time Fourier Transform:** Introduction, Representation of Aperiodic Signals: The Discrete-Time Fourier Transform, Fourier Transform for Periodic Signals, Properties of the Discrete-Time Fourier Transform. **Applications:** Image compression, MRI scans, speech recognition, spectrum analysis, 5G communication.	
Relevant NVIDIA DLI Courses: **Course: Fundamentals of Accelerated Data Science** This course focuses on fast data processing and frequency-domain analysis using GPU acceleration, useful for signal transformation, filtering, and real-time spectral analysis. Course Detail | NVIDIA	
Module- V : Z-Transform and Sampling Theorem	**10 Hours**
Representation of signals using Discrete Time Complex Exponentials: The Z-transform Introduction to z-Transform, region of convergence, properties of ROC and Properties of z-transform. **Sampling and Reconstruction:** Introduction: Representation of a Continuous-Time Signal by Its Samples: The Sampling Theorem, Impulse-Train Sampling, Sampling with a Zero-Order Hold, Reconstruction of a Signal from Its Samples Using Interpolation, The Effect of Under sampling: Aliasing. **Applications:** DSP design, control systems, audio sampling, ADC/DAC systems, digital receivers.	
Relevant NVIDIA DLI Courses: **Course: Fundamentals of Accelerated Computing with CUDA Python** This course focuses on parallel processing and discrete-time computation, closely related to Z-transform and sampling in digital signal processing. Course Detail | NVIDIA	

AI Integration

AI enables automatic signal classification and pattern recognition in audio, image, and biomedical signals.

1. Machine learning improves filtering, noise reduction, and feature extraction in signal processing systems.
2. AI supports adaptive systems that adjust parameters in real time for better performance.
3. Deep learning accelerates applications like speech recognition, image analysis, and communication systems.

Authentic Intelligence

1. Combines human expertise with AI for better interpretation of signals and system behaviour.
2. Engineers provide domain knowledge while AI handles large-scale data analysis.
3. Improves accuracy and reliability in critical applications like healthcare and communication.
4. Ensures ethical and responsible use of AI with human supervision in decision-making.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand and classify continuous and discrete-time signals based on their properties and transformations.**	Understand (L2)
2	**Analyze the behavior of LTI systems using system properties and convolution techniques.**	Analyze(L4)
3	**Analyze periodic signals using Fourier series for feature extraction and interpretation.**	Analyze (L4)
4	**Apply** Fourier transform techniques for frequency-domain analysis of signals.	(L3 – Apply)
5	**Evaluate** the effects of sampling and aliasing in signal reconstruction.	(L5 – Evaluate)

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	–	–	1	–	–	–	–	–	–	1	–
CO2	3	3	2	2	2	–	–	–	–	–	–	2	–
CO3	3	3	–	2	2	–	–	–	–	–	–	1	2
CO4	3	2	2	–	3	–	–	–	–	–	–	1	2
CO5	3	3	2	3	2	–	–	–	–	–	1	1	1

3: Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

TEXT BOOKS:

1. Alan V Oppenheim, Alan S, Willsky and A Hamid Nawab, —Signals and Systems Pearson Education Asia / PHI, 2nd edition, 1997. Indian Reprint 2002.
2. Simon Haykins and Barry Van Veen, —Signals and Systems, 2nd Edition, 2004

REFERENCE BOOKS:

1. Michael Roberts, —Fundamentals of Signals & Systems, 2nd edition,Tata McGraw-Hill, 2010, ISBN 978-0-07-070221-9.
2. H. P Hsu, R. Ranjan, —Signals and Systems‖, Scham's outlines, TMH, 2nd Edition, Tata McGraw-Hill, 2010, ISBN 978-0-07-163472-4.
3. B. P. Lathi, —Linear Systems and Signals‖, Oxford University Press, 2005, 2nd Edition, 2005, ISBN 978-0-19-515833-5.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Principles of Signals and Systems https://nptel.ac.in/courses/108104100	Prof. Aditya Jagannatham	IIT Kanpur
2	Signals and Systems https://nptel.ac.in/courses/117104074	Prof. K.S. Venkatesh	IIT Kanpur

MACHINE LEARNING FOR ENGINEERS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	04
Hours / Week	:	03 Hours	**Total Hours**	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students

1. To understand and apply fundamental machine learning concepts and algorithms to engineering problems. Specific objectives include:
2. To provide a solid mathematical foundation for machine learning including linear algebra, probability, and statistics.
3. To understand and implement supervised, unsupervised, and reinforcement learning algorithms.
4. To analyze and evaluate model performance using appropriate metrics and validation techniques using AI tools.
5. To apply deep learning frameworks and neural network architectures to real-world engineering datasets using AI tools for modeling and simulation.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where the teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** includes not only traditional lectures but also different *types of teaching methods* to develop the course outcomes.
2. **Interactive Teaching:** Adopt *Active Learning* that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and role-playing.
3. Show ***Video/animation*** *films* to explain functioning of ML algorithms and model training processes.
4. Encourage ***Collaborative (Group Learning)*** by assigning group ML projects and dataset analysis tasks.
5. To make ***Critical Thinking*** skills, ask at least three Higher Order Thinking questions in class.
6. Adopt ***Problem Based Learning*** which fosters students' analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze datasets utilizing AI tools.
7. Discuss how every ***concept can be applied to the real world*** – and when possible, it helps improve the students' understanding of practical ML deployment.

MODULE – I: Mathematical Foundations for Machine Learning	**09 Hours**

Introduction to AI: Linear Algebra: vectors, matrices, eigenvalues; Probability and Statistics: distributions, expectation, variance, Bayes' theorem; Optimization: gradient descent, convex optimization; Information Theory: entropy, KL divergence. Applications: Feature spaces, cost functions, parameter estimation.

MODULE – II: Supervised Learning Algorithms	09 Hours
Linear Regression and Polynomial Regression; Logistic Regression; Decision Trees and Random Forests; Support Vector Machines (SVM); k-Nearest Neighbors (kNN); Naive Bayes Classifier; Model evaluation: cross-validation, confusion matrix, ROC-AUC; Overfitting, underfitting, bias-variance tradeoff. Applications: Classification, regression, predictive analytics. Applications: Credit risk assessment and fraud detection using classification models (Logistic Regression, Random Forests)	
MODULE – III: Unsupervised Learning and Dimensionality Reduction	**09 Hours**
Clustering: k-Means, Hierarchical, DBSCAN; Expectation-Maximization (EM) algorithm; Principal Component Analysis (PCA); t-SNE and UMAP for visualization; Autoencoders; Anomaly detection techniques; Association Rule Mining. Applications: Pattern discovery, data compression, outlier detection. Applications: Customer segmentation in marketing analytics, Anomaly detection in industrial IoT sensor data for predictive maintenance and fault identification	
NVIDIA DLI Courses (Relevant to this Module): 1. **Application of AI for Anomaly Detection** (8 hrs.) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1 2. **Application of AI for Predictive Maintenance (8 hrs)** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-02+V1	
MODULE – IV: Neural Networks and Deep Learning	**09 Hours**
Perceptron and Multi-Layer Perceptron (MLP); Backpropagation and activation functions; Convolutional Neural Networks (CNN) for image data; Recurrent Neural Networks (RNN), LSTM for sequential data; Batch normalization, dropout, regularization; Transfer learning and fine-tuning; Deep learning frameworks: TensorFlow and PyTorch. Applications: Image recognition, time-series prediction, NLP tasks. **Applications:** Medical image analysis using CNNs and transfer learning, Sentiment analysis and text classification using RNN/LSTM architectures, Real-time object detection and video surveillance using deep learning.	
NVIDIA DLI Courses (Relevant to this Module): 1. **Fundamentals of Deep Learning** (8 hrs) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3 2. **Computer Vision for Industrial Inspection (8 hrs)** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2	
MODULE – V: Reinforcement Learning and ML Deployment	**09 Hours**
Introduction to Reinforcement Learning: agents, environments, rewards; Markov Decision Processes (MDP); Q-Learning and Deep Q-Network (DQN); Policy gradient methods; ML Pipeline: data collection, preprocessing, feature engineering, model selection; Hyperparameter tuning: Grid Search, Random Search, Bayesian optimization; Model deployment: REST APIs, containerization with Docker; Monitoring and retraining in production. Applications: Control systems, robotics, recommendation systems. **Applications:** Autonomous robotics and game-playing agents using Deep Q-Networks and policy gradient algorithms, Real-time recommendation systems and personalization engines using reinforcement learning feedback loops, End-to-end ML pipeline deployment with Dockerized REST APIs, CI/CD integration, and live model monitoring	

NVIDIA DLI Courses (Relevant to this Module):

1. **A Beginner's Guide to Autonomous Robots** (1 hrs)
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-35+V1
2. **Getting Started with Isaac Sim (1.5 hrs)**
   https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-sim/latest/index.html

AI Integration:

1. Introduction to Python-based machine learning workflow, data preprocessing and feature engineering techniques, usage of libraries like NumPy, Pandas, and Scikit-learn for building and evaluating models.
2. Implementation of supervised learning algorithms using Scikit-learn, training and evaluating models using real-world engineering datasets.
3. Implementing clustering and dimensionality reduction techniques using Scikit-learn, visualization of clusters using Python tools.
4. Building and training neural networks using TensorFlow/PyTorch, use of transfer learning and model evaluation with benchmark datasets.
5. Use of Grid Search and Bayesian optimization for hyperparameter tuning, implementation of model deployment pipelines, and application of regularization methods using Scikit-learn and cloud platforms.
6. to simulate dopant diffusion profiles.

Authentic Intelligence:

1. Understanding well-posed learning problems and their real-world engineering constraints, challenges in designing efficient ML systems, limitations of models, risks associated with poor feature selection and sampling bias, ethical considerations and responsible deployment of ML systems.
2. Interpretability of supervised learning models, risks of incorrect predictions in safety-critical engineering systems, and challenges in model fairness.
3. Risks of misinterpreting clusters, responsible interpretation of patterns discovered from engineering data, and biases in anomaly detection.
4. Limitations of deep learning models, overfitting risks, interpretability challenges (black-box nature), and importance of responsible model selection and explainable AI.
5. Understanding overfitting and underfitting, bias-variance tradeoff, limitations of optimization methods, importance of selecting appropriate validation strategies, and ethical deployment of ML models.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the foundation of AI & Mathematical foundations (linear algebra, probability, and optimization) underlying machine learning algorithms.	L2
2	Implement and evaluate supervised learning algorithms for engineering classification and regression tasks using appropriate metrics.	L3
3	Analyze unsupervised learning techniques and apply dimensionality reduction methods on engineering datasets for pattern discovery and feature extraction.	L3
4	Design and train deep neural network architectures including CNNs and RNNs by leveraging AI frameworks for engineering applications.	L4
5	Evaluate and deploy end-to-end ML pipelines, optimizing performance using hyperparameter tuning and assessing models with data-driven analysis and responsible AI practices.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	2	2	1	1	1	1	1	1	2	1
CO2	3	2	2	2	3	1	1	1	2	2	1	2	2
CO3	3	3	2	3	3	1	1	1	2	2	1	2	2
CO4	3	2	3	2	3	1	1	1	2	2	2	2	3
CO5	2	2	3	3	3	2	2	2	3	3	3	2	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Bishop, C.M. and Nasrabadi, N.M., 2006. Pattern Recognition and Machine Learning. Springer.
2. Géron, A., 2022. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. 3rd Edition, O'Reilly Media.
3. Mitchell, T.M., 1997. Machine Learning. McGraw-Hill.
4. Goodfellow, I., Bengio, Y. and Courville, A., 2016. Deep Learning. MIT Press.

REFERENCE BOOKS:

1. Murphy, K.P. Probabilistic Machine Learning: An Introduction. MIT Press.2022.
2. Hastie, T., Tibshirani, R. and Friedman, J., The Elements of Statistical Learning. 2nd Edition, Springer. 2009.
3. Deep Learning with Python. 2nd Edition, Manning Publications.Chollet, F., 2021.

LIST OF EXPERIMENTS:

Expt. No.	TITLE OF THE EXPERMENT	REMARKS
1	Data Preprocessing and Exploratory Data Analysis Using Python	Software
2	Linear Regression and Polynomial Regression for Predictive	Software
3	Logistic Regression for Classification Problems Using Python	Software
4	Decision Tree and Random Forest Classification Using Python	Software
5	Support Vector Machine (SVM) and k-Nearest Neighbour (kNN)	Software
6	K-Means, Hierarchical, and DBSCAN Clustering Algorithms	Software
7	Principal Component Analysis (PCA) for Dimensionality	Software
8	Artificial Neural Network (ANN) Model using Multi-Layer	Software
9	Convolutional Neural Network (CNN) for Image Classification	Software
10	Reinforcement Learning using Q-Learning and Deep Q-Network (DQN) Using Python	Software

E-Resources:

Sl. No.	Course / Resource Name	Instructor	Host Institute
1	Introduction to Machine Learning https://nptel.ac.in/courses/106105152	Prof. Sudeshna Sarkar, Prof. Sourangshu Bhattacharya	IIT Kharagpur / NPTEL
2	Deep Learning Specialization https://nptel.ac.in/courses/106106201	Andrew Ng	Coursera / DeepLearning.AI
3	Machine Learning with Python (https://www.coursera.org/learn/machine-learning-with-python)	Joseph Santarcangelo	IBM / Coursera
4	Practical Deep Learning for Coders (https://course.fast.ai/)	Jeremy Howard	fast.ai

DIGITAL SIGNAL PROCESSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course will enable students to:

1. Understand the theory and application of Discrete Fourier Transforms (DFT) in signal processing, including its properties and relationships with other transforms.
2. Master the implementation of Fast Fourier Transform (FFT) algorithms for efficient computation of DFT, utilizing both decimation-in-time and decimation-in-frequency techniques.
3. Design Finite Impulse Response (FIR) filters using various window methods and frequency sampling techniques, for desired filter characteristics and specifications.
4. Develop proficiency in designing Infinite Impulse Response (IIR) filters by transforming analog filter designs (Butterworth and Chebyshev) to digital using techniques like impulse invariance and matched z transforms.
5. Gain practical skills in implementing FIR and IIR filters on digital signal processors (DSPs), understanding their architectures, instruction sets, and fixed-point arithmetic formats.
6. Apply theoretical knowledge to real-world signal processing scenarios, analyzing and optimizing signal processing systems using DFT, FFT, FIR, and IIR filters for various applications

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. *The lecture method* means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. *Interactive Teaching: Adopt the Active learning* that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show *Video/animation* films to explain functioning of various concepts.
4. Encourage *Collaborative* (Group Learning) Learning in the class.
5. To make *Critical thinking*, ask at least three Higher order Thinking questions in the class.
6. Adopt *Problem Based Learning*, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the *different ways to solve* the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.

MODULE – I: Discrete Fourier Transforms	**08 Hours**

Frequency domain sampling and reconstruction of discrete time signals. DFT as a linear transformation, its relationship with other transforms. Properties of DFT, multiplication of two DFTs- the circular convolution, Additional DFT properties.

Applications: Role in every signal processing concepts.

NVIDIA DLI Courses (Relevant to this Module):

1. **AI for All: From Basics to Gen AI Practice** (2 hrs) | Path: AI Infrastructure Training – Fundamentals
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1

MODULE – II: FFT Algorithms	**08 Hours**

Use of DFT in linear filtering, overlap-save and overlap-add method. Direct computation of DFT, need for efficient computation of the DFT (FFT algorithms) Radix-2 FFT algorithm for the computation of DFT and IDFT decimation-in-time and decimation-in-frequency algorithms.
Applications: Role in frequency analysis of any signals.

MODULE – III: FIR Filter Design	**11 Hours**

Introduction to FIR filters (Direct Form, Transpose Form, Linear Phase Form), design of FIR filters using - Rectangular, Hamming, Bartlet and Kaiser Windows, FIR filter design using frequency sampling technique.
Applications: Filtering of digital signals.
Case Studies: Optimization of FIR filter co-efficients using AI techniques for noise removal in ECG signal or speech signal enhancement.

MODULE – IV: IIR Filter Design	**11 Hours**

Characteristics of commonly used analog filters Butterworth and Chebyshev filters, analog to analog frequency transformations. IIR filter structures (Direct Form I, Direct Form II, Transpose Direct Form), Design of digital IIR filters from analog filters (Butterworth and Chebyshev) - impulse invariance method. Mapping of transfer functions: Approximation of derivative (backward difference and bilinear transformation) method, Matched Z transforms.
Applications: Filtering of digital signals.
Case Studies: Optimization of IIR filter co-efficients using AI techniques for speech noise reduction, bio-medical signal filtering etc.

MODULE – V: Digital Signal Processor	**07 Hours**

DSP Architecture, DSP Hardware Units, fixed point and floating-point formats. FIR and IIR filter implementation in fixed point system.
Applications: Real time processing of any signals on DSP hardware and processors.

NVIDIA DLI Courses (Relevant to this Module):

1. Accelerated Computing with CUDA **Deep Learning Online Courses | NVIDIA**
   DLI link: Course Detail | NVIDIA

AI Integration:

1. Introduction to DSP fundamentals with AI context: signals and systems, sampling, convolution, Fourier Transform (FFT), and feature extraction from time-series data; use of Python libraries like NumPy, SciPy, and Matplotlib for signal analysis and preprocessing for machine learning models.
2. Implementation of AI-based signal processing techniques: applying supervised learning algorithms for tasks such as signal classification, noise detection, and pattern recognition using Scikit-learn and TensorFlow on real-world signal datasets (audio, biomedical signals, etc.).
3. Application of deep learning models in DSP: use of Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs/LSTMs) for speech recognition, audio classification, and time-series prediction; visualization and interpretation of learned features.
4. Integration of adaptive filtering and AI techniques: combining traditional DSP methods (FIR/IIR filters, adaptive filters like LMS) with machine learning models for noise cancellation, signal enhancement, and anomaly detection.
5. Optimization and deployment of AI-DSP systems: hyperparameter tuning, model evaluation using performance metrics (SNR, MSE, accuracy), real-time signal processing using edge devices, and implementation considerations for efficient and low-latency systems.

Authentic Intelligence:

1. Understanding well-posed DSP problems and real-world constraints such as noise, aliasing, quantization, and limited sampling rates; challenges in designing efficient signal processing systems, limitations of ideal assumptions (e.g., perfect reconstruction), risks due to improper filtering or sampling, and ethical considerations in applications like biomedical and surveillance signal processing.
2. Interpretability of processed signals and system outputs, risks of incorrect analysis in critical applications (e.g., ECG, speech recognition), and importance of validating signal transformations and frequency-domain interpretations.
3. Risks of misinterpreting spectral components and time-frequency representations (FFT, spectrograms), responsible interpretation of patterns in signals, and avoiding misleading conclusions due to noise, artifacts, or insufficient data.
4. Limitations of filtering techniques and adaptive systems, trade-offs between FIR and IIR filters, stability concerns, overfitting in adaptive filters (e.g., LMS), and importance of selecting appropriate models and parameters for reliable signal processing.
5. Understanding trade-offs such as time vs frequency resolution, bias-variance-like trade-offs in signal estimation, limitations of optimization in filter design, and importance of proper validation, windowing techniques, and regularization in achieving robust DSP system performance.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Able to analyze discrete-time signals in the frequency domain, understanding the properties and applications of the Discrete Fourier Transform (DFT), and its relevance in signal processing.	L4
2	Able to apply Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) algorithms in various signal processing tasks, including linear filtering and spectrum analysis.	L3
3	Able to design Finite Impulse Response (FIR) filters using different windowing techniques and frequency sampling methods, enabling precise control over filter characteristics and performance.	L3
4	Able to design and implement Infinite Impulse Response (IIR) filters by understanding analog filter characteristics, digital filter design methods, and mapping analog filters to digital domains, ensuring optimal filtering performance in practical applications.	L3
5	Able to understand digital signal processor architectures, instruction sets, and numerical formats, and apply this knowledge to efficiently implement FIR and IIR filters for real-time signal processing tasks on digital signal processors.	L2

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3		2	2	-	-	-	-	-	2	3	2
CO2	3	3	3	2	-	-	-	-	-	2	-	3	2
CO3	3	3		2	2	2	-	-	-	-	2	3	2
CO4	3	3	2	2	2	-	-	-	2	-	2	3	2
CO5	3	2	-	2	2	-	-	-	-	-	2	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Digital Signal Processing - Principles, Algorithms, and Applications by Proakis & Monalakis, Pearson Education, 4th Edition, 2017.
2. Li Tan, Jean Jiang, ''Digital Signal processing- Fundamentals and Applications", Academic Press, 2013, ISBN: 978-0-12-415893. 97
3. Digital Signal Processing, S.Salivahanan, A.Vallabraj & C. Gnanapriya, TMH Publishing Co.

4. Digital Signal Processing using MATLAB, Vinak K. Ingle, III Edition, Cengage Learning.

REFERENCE BOOKS:

1. Digital Signal Processing, P. Rameshbabu, Scitech Publications (India).
2. Digital Signal Processing-A Computer Based Approach, S.K Mitra, TMH Publishing Co.
3. Digital Signal Processing; A Hands on Approach, C. Schuler & M.Chugani, TMH Publishing Co.
4. Texas Instruments DSP Processor user manuals and application notes
5. D.Ganesh Rao and Vineeth P Gejji, "Digital Signal Processing" Cengage India Private Limited, 2017, ISBN: 9386858231

E-Resources:

1. https://nptel.ac.in/courses/117102060
2. https://onlinecourses.nptel.ac.in/noc19_ee50/preview

Activity Based Learning (Suggested Activities in Class)

1. Signal Processing Simulation Software: MATLAB
2. Peer Teaching and Collaborative Learning

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Digital Signal Processing https://nptel.ac.in/courses/108106151	C.S.Ramalingam	IIT Madras

ANALOG AND DIGITAL COMMUNICATION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	04
Hours / Week	:	03 Hours	**Total Hours**	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students to

1. Compare the various modulation and demodulation techniques using AI tools.
2. Understand the transreceiver design and the effect of noise in communication system by incorporating AI tools.
3. Understand the process of digitization through Sampling and Quantization.
4. Determine the performance of line codes and methods to reduce inter symbol interference.
5. Interpret the detection process using analytical methods.
6. Compute the probability of error of digital communication systems using AI tools.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Introduction to Communication System and Amplitude Modulation	**09 Hours**

Elements of Communication System, Need for Modulation, Amplitude Modulation-Conventional AM, DSB-SC, SSB, VSB, Time and Frequency Domain representation of AM, Modulation Index and Transmission Power Calculation. Generation of Conventional AM signals - Square Law Modulator, Detection of AM signals - Envelope detector. Generation of DSBSC signals - Balanced Modulator, Coherent detection of DSB-SC Modulated signals. Generation of SSB signals - Phase discrimination method. Demodulation of SSB Signals - Coherent detection, Frequency Division Multiplexing.

MODULE – II: Angle Modulation, Transmitter, Receiver and Noise	10 Hours
ANGLE MODULATION: Introduction - FM, NBFM, WBFM and PM, Modulation Index of FM and PM, Transmission bandwidth of FM signals, Relation between FM and PM. Generation of FM signals - Indirect FM, Direct FM. Demodulation of FM signals - Balanced frequency discriminator, Zero- crossing detector. **TRANSMITTER, RECEIVER AND NOISE:**AM Transmitter, FM Transmitter, Tuned radio frequency receiver, Superheterodyne receiver, Comparison of FM receiver with AM Receiver, Source of noise, Noise in AM, Noise in FM, Pre-emphasis & de-emphasis in FM.	
MODULE – III: Sampling and Quantization	**09 Hours**
Block diagram of Digital communication system, Sampling theorem, Practical aspects of sampling and signal recovery, Quantization, Quantization noise, Pulse Code Modulation (PCM) system, Differential PCM system, Delta modulation (DM) and its drawbacks, Adaptive Delta Modulation, Time Division Multiplexing.	
MODULE – IV: Baseband Shaping for Data Transmission	**08 Hours**
Introduction, Line Coding, Characteristics of Line coding, Discrete PAM signals, Power spectra of discrete PAM signals, Inter symbol Interference, Nyquist criterion for distortion less baseband binary transmission, Correlative coding, Eye pattern. **DETECTION OF SIGNALS**: Orthogonal signals, Geometric interpretation of signals, Correlation receiver, Matched filter, Properties of matched filter, ML detector.	
MODULE – V: : Digital Pass Band Transmission	**09 Hours**
Introduction, Pass band transmission model, Coherent modulation techniques - ASK, FSK, PSK, QPSK, M-ary PSK, QAM, M-ary QAM, Constellation diagram, Deriving probability of error for coherent ASK, FSK, PSK, Non coherent modulation techniques.	

AI Integration:

1. Use AI to identify the type of modulation (AM, DSB, SSB) from a given signal automatically.
2. Use AI to remove noise from received signals and improve clarity.
3. Use AI to choose the best modulation technique (ASK, PSK, QAM) based on channel conditions.
4. Authentic Intelligence:
5. Encourage students to clearly understand the need for modulation and the working of AM, DSB-SC, and SSB instead of just learning formulas.
6. Apply concepts to real-world scenarios like noise in mobile communication or signal distortion, improving analytical thinking.
7. Use simple lab setups to generate and detect AM signals (envelope detector, modulators) to connect theory with practice.
8. Compare AM, DSB-SC, SSB, and VSB techniques and decide the most efficient method based on bandwidth and power.
9. Analyze time and frequency domain representations of AM signals to better understand signal behavior.

Authentic Intelligence:

1. Encourage students to clearly understand the need for modulation and the working of AM, DSB-SC, and SSB instead of just learning formulas.
2. Apply concepts to real-world scenarios like noise in mobile communication or signal distortion, improving analytical thinking.
3. Use simple lab setups to generate and detect AM signals (envelope detector, modulators) to connect theory with practice.
4. Compare AM, DSB-SC, SSB, and VSB techniques and decide the most efficient method based on bandwidth and power.
5. Analyze time and frequency domain representations of AM signals to better understand signal behavior.

Lab Experiments (Applicable only for LAB Integrated courses)

S.No	Experiment	Utility
1	Design and testing of AM modulator and demodulator circuit.	Demonstrates practical transmission and recovery of signals using Amplitude Modulation.
2	Design and testing FM modulator and demodulator circuit	Illustrates how Frequency Modulation is used to transmit and accurately recover signals in communication systems.
3	Design and testing DSBSC modulator and demodulator circuit.	Demonstrates how Double Side band Suppressed Carrier enables efficient signal transmission and recovery.
4	To study and observe the effect on input signal using pre-emphasis and de-emphasis circuit.	Illustrates how Pre-emphasis and De-emphasis improve signal quality by reducing noise in communication systems.
5	Verification of sampling theorem, demonstrate over sampling and under sampling.	Highlights how Sampling Theorem ensures accurate signal reconstruction and reveals the effects of over sampling and under sampling.
6	To study the Pulse Amplitude Modulation & demodulation.	Demonstrates how Pulse Amplitude Modulation is used for transmitting and recovering sampled signals.
7	To study the Pulse width modulation and demodulation.	Demonstrates how Pulse Width Modulation is used for transmitting and recovering sampled signals.
8	To study the Pulse Position modulation and demodulation.	Demonstrates how Pulse Position Modulation is used for transmitting and recovering sampled signals.
9	To implement of μ-law companding for compression and expanding of a signal.	Provides insight into μ-law companding for compressing and expanding signals to improve dynamic range.communication systems.
10	To implement of A-law companding for compression and expanding of a signal.	Provides insight into A-law companding for compressing and expanding signals to improve dynamic range.
11	To analyse an ASK modulation systems and interpret the modulated & demodulated waveform.	Gives insight into ASK for interpreting modulated and demodulated waveforms.
12	To analyse an FSK modulation systems and interpret the modulated & demodulated waveform.	Illustrates how FSK is used for analyzing modulated and demodulated waveforms.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Illustrate and explain the basic elements of a communication system	L2
2	Analyze baseband signals in time domain and frequency domain.	L4
3	Interpret and explain AM, DSB-SC, SSB, FM, PCM, ASK, FSK, PSK, QAM modulation and demodulation techniques using AI tools.	L5
4	Analyze the behavior of a communication system in the presence of noise by incorporating AI.	L4
5	Estimate the performance of a communication system using analytical methods.	L5
6	Determine the probability of error for FSK, PSK, QPSK, M ary PSK, QAM, M-ary QAM by using AI tools.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	-	-	-	-	-	-	2	-	1	3	-
CO2	3	3	2	2	2	-	-	2	2	-	2	3	-
CO3	2	2	2	-	2	-	-	2	2	-	2	3	-
CO4	3	3	2	2	2	-	-	2	2	-	2	3	-
CO5	3	3	2	3	2	-	-	2	2	-	2	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Simon Haykin, Michael Moher, Introduction to Analog and Digital Communication 4th edition, John and Wiley & Sons
2. B. P. Lathi, Z. Ding "Modern Digital and Analog Communication Systems", Oxford University, Press, 2010.

REFERENCE BOOKS:

1. Principles of Communication Systems–Taub & Schilling, Gautam Sahe, TMH, 3rdEd
2. Communication Systems Second Edition – R.P. Singh, SP Sapre, TMH, 2007.
3. Modern Analog and Digital Communication Systems, 3rd Edition, Oxford University – B.P.Lathi.
4. Electronics & Communication System – George Kennedy and Bernard Davis, TMHLathi

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Analog communication https://nptel.ac.in/courses/117105143	Prof. Goutam Das	IIT Kharagpur
2	Introduction to Digital Communication https://nptel.ac.in/courses/117101051	Prof. Bikash Kumar Dey	IIT Bombay

DIGITAL DESIGN VERIFICATION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:
This course enables students to

1. Understand the fundamental concepts of testing, logical fault models (like stuck-at faults), and the principles of logic simulation for digital circuits.
2. Learn the principles and methods for generating tests for combinational and sequential logic circuits, and the corresponding design techniques to make them testable.
3. Explore Design for Testability (DFT) strategies, focusing on structured scan-based design methodologies and system-level approaches.
4. Study Built-In Self-Test (BIST) architectures, test pattern generation for BIST, and specialized test algorithms for memory circuits.
5. To understand verification concepts, planning, and flow, and to apply SystemVerilog-based techniques such as simulation, linting, and coverage for validating digital systems.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Basics Of Testing And Fault Modelling	09 Hours
Introduction to Testing - Faults in digital circuits -Modeling of faults - Logical Fault Models - Fault detection - Fault location -Fault dominance -Logic Simulation - Types of simulation - Delay models - Gate level Event-driven simulation. Applications: Used in chip manufacturing to model and detect faults before production. Helps improve reliability of digital systems in electronics and automotive applications.	
MODULE – II: Test Generation for Combinational and Sequential Circuits	**10 Hours**
Test generation for combinational logic circuits - Testable combinational logic circuit design -Test generation for sequential circuits. **Applications:** Applied in generating test patterns for combinational and sequential circuits. Ensures high fault coverage in processors, FPGAs, and embedded systems.	
MODULE – III: Design for Testability	**09 Hours**
Design for Testability - Ad-hoc design - Generic scan-based design - Classical scan-based design -System level DFT approaches. **Applications:** Used to design circuits that are easy to test using techniques like scan design. Reduces testing cost and improves reliability in VLSI systems.	
MODULE – IV: Self-Test and Test Algorithms	**08 Hours**
Built-In Self-Test - Test pattern generation for BIST - Circular BIST - BIST Architectures - Testable Memory Design - Test algorithms - Test generation for Embedded RAMs. **Applications:** Applied in Built-In Self-Test (BIST) for self-checking circuits. Widely used in memory chips and safety-critical systems.	
MODULE – V: Verification Techniques using System Verilog	**09 Hours**
Verification: Importance of verification, Verification plan, Verification flow, Levels of verification, Verification methods and languages. Verification Techniques using System Verilog: Linting, Simulation, Verification Intellectual Property, Waveform Viewers, Code Coverage, Functional Coverage. **Applications**: Used to verify digital designs before fabrication using System Verilog, improving reliability through simulation and coverage analysis.	

AI Integration

1. AI-based fault prediction and classification in digital circuits.
2. Intelligent test pattern generation for higher fault coverage.
3. Automated verification using System Verilog with AI-driven debugging and coverage analysis.
4. AI-enhanced Built-In Self-Test (BIST) for adaptive testing.
5. Optimization of simulation and verification processes using machine learning techniques.

Authentic Intelligence:

1. Applying domain knowledge to interpret verification results effectively.
2. Designing reliable and testable VLSI systems using engineering judgment.
3. Ensuring safety and reliability in real-time applications like automotive and embedded systems.
4. Making cost-effective decisions in test design and verification planning.
5. Integrating theoretical knowledge with practical testing strategies for robust system design.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Analyze digital circuits for fault modeling and apply ML-based techniques for fault detection and classification.	L4
2	Analyze and evaluate test generation techniques for combinational and sequential circuits using conventional and AI-based approaches.	L4
3	Apply design-for-testability techniques and utilize AI methods to optimize scan design and system-level testing.	L3
4	Evaluate and apply Built-In Self-Test (BIST) architectures, test pattern generation techniques, and test algorithms for memory and embedded RAM testing.	L3
5	Apply System Verilog techniques for verification planning, simulation, coverage analysis, and functional validation.	L3
6	Analyze digital circuits for fault modeling and apply ML-based techniques for fault detection and classification.	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	1	-	-	-	-	-	-	1	3	2
CO2	2	3	2	2	1	-	-	-	-	-	1	3	2
CO3	2	3	3	2	2	-	-	-	-	-	1	3	2
CO4	2	3	2	2	2	-	-	-	-	-	1	3	2
CO5	2	3	2	2	1	-	-	-	-	-	1	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. "Digital Circuit Testing and Testability", P.K.Lala. Academic Press, 2002.
2. VLSI Test Principles and Architectures, Wang Wu Wen, Morgan Kaufmann Publishers,2006.
3. Introduction to Formal Hardware Verification, T.Kropf, Springer Verlag, 2000
4. System-on-a-Chip Verification- Methodology and Techniques, P. Rashinkar, Paterson and L. Singh, Kluwer Academic Publishers, 2001
5. “Logic Design Theory”, N.N. Biswas, PHI publication,1993.

REFERENCE BOOKS:

1. A.L. Crouch, "Design Test for Digital IC's and Embedded Core Systems", Prentice Hall International.
2. M. Abramovici, M.A. Breuer and A.D. Friedman, "Digital Systems and Testable Design”, Jaico Publishing House.
3. Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", M. Bushnell and V. D. Agrawal, Kluwer Academic Publishers, 2000
4. Digital Systems Testing and Testable Design, M. Abramovici, M. A. Breuer and A. D. Friedman, IEEE Press, 1990

E-Resources:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Digital VLSI Testing https://nptel.ac.in/courses/117105137	Prof. Santanu Chattopadhyay	IIT Kharagpur

ANTENNA AND WAVE PROPAGATION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Understand the basic antenna parameters and radiation mechanism from an antenna.
2. Apply the principles and design considerations to develop and implement microstrip and other modern antenna structures for specified operational requirements.
3. Analyze and evaluate various antenna types and array configurations for different engineering applications.
4. Evalute appropriate techniques and methodologies for the measurement and characterization of antenna parameters.
5. Describe the concepts of wave propagation in ground, sky, and tropospheric regions.

Teaching-Learning Process (General Instructions)

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1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I Antenna Fundamentals	**09 Hours**

Introduction, Radiation Mechanism. Antenna Parameters- Radiation Patterns, Main Lobe and Side Lobes, Beam-width, Beam Area, Radiation Intensity, Beam Efficiency, Directivity, Gain and Antenna Apertures, Aperture Efficiency, Polarization, Antenna regions, Reciprocity in Antennas Friis Transmission equation-Path loss.

Applications: Signal power estimation in wireless link design systems (satellite, radar, line-of-sight communication systems).

NVIDIA DLI Courses (Relevant to this Module):

1. **AI for All: From Basics to Gen AI Practice**
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1

MODULE – II: Wire Antennas & Microstrip Patch Antennas	**09 Hours**
Introduction to Dipoles, Short and Half wave Dipole–Current Distributions, Evaluation of Field Components, Power Radiated, Radiation Resistance-only equations. MICROSTRIP Antenna - Introduction, Basic characteristics, Feeding methods, basic types – rectangular (with designing) & circular, Slot antenna, Babinet's Principle. Applications: Radio/TV broadcasting, mobile and satellite communication.	
MODULE – III: Antenna Arrays	**09 Hours**
Two element Arrays – different cases, Principle of Pattern Multiplication, N element Uniform Linear Arrays – Broadside, End-fire Arrays, EFA with Increased Directivity, Binomial Arrays, Effects of Uniform and Non-uniform Amplitude Distributions, Related Problems. Introduction to Phased array (Beam forming and Beam Steering). **Applications:** Massive MIMO & Intelligent Beamforming.	
NVIDIA DLI Courses (Relevant to this Module): 1. **Fundamentals of Accelerated Computing with CUDA** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-01+V2	
MODULE – IV: Special Antennas & Antenna Measurements	**10 Hours**
Helical Antennas – Significance, Geometry, Design considerations for monofilar helical antennas in Axial Mode and Normal Modes (Qualitative Treatment), Horn Antennas–Types, Design Characteristics of Pyramidal Horns. Introduction to MIMO, Smart antennas, Reconfigurable antennas and Millimeter wave (mmWave) antennas. Antenna measurement: Measurement of antenna ranges, directivity measurement, Anechoic chamber, CATR. **Applications**: Millimeter Wave & Terahertz Communication.	
MODULE – V: Wave Propagation	**08 Hours**
Concepts of Propagation – frequency ranges and types of propagations. Ground Wave Propagation, Sky Wave Propagation – Formation of Ionospheric Layers and their Characteristics, Critical Frequency, MUF & Skip Distance, Optimum working Frequency, Virtual Height. Space Wave Propagation – Mechanism, LOS. Tropospheric Wave Propagation – Radius of Curvature of path, Field Strength Calculations, Duct Propagation, Related problems. Applications: Future innovations in 5G/6G systems integrated with AI.	

AI Integration:

1. Introduction to Python-based machine learning workflow, data preprocessing and feature engineering techniques, usage of libraries like NumPy, Pandas, and Scikit-learn for building and evaluating models.
2. Implementation of supervised learning algorithms using Scikit-learn, training and evaluating models using real-world datasets
3. Implementing clustering and dimensionality reduction techniques using Scikit-learn, visualization of clusters using Python tools.
4. Implementation of graphical models and ensemble techniques using Scikit-learn, use of bagging and boosting methods, model evaluation with Out-of-Bag score.
5. Use of Grid Search and Random Search for hyperparameter tuning, implementation of validation techniques and performance metrics, application of optimization algorithms and regularization methods using Scikit-learn.

Authentic Intelligence:

1. Understanding well-posed learning problems and their real-world constraints, challenges in designing efficient learning systems, limitations of deep learning models, risks associated with poor feature selection and sampling bias, ethical considerations and responsible deployment of AI systems.
2. Interpretability of machine learning models, risks of incorrect predictions in automated decision-making systems.
3. Risks of misinterpreting clusters, responsible interpretation of patterns discovered from data.
4. Limitations of graphical and ensemble models, overfitting risks in boosting, interpretability challenges, and importance of responsible model selection.
5. Understanding overfitting and underfitting, bias-variance tradeoff, limitations of optimization methods, and importance of selecting appropriate validation and regularization techniques.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Summarize the fundamental concepts of antenna radiation mechanisms and key parameters such as radiation patterns, beamwidth, gain, directivity, polarization, and path loss using the Friis transmission equation.	L2
2	Apply electromagnetic theory to evaluate field components, power radiated, and radiation resistance of dipole antennas, and design basic rectangular and circular microstrip antennas using appropriate feeding techniques.	L3
3	Assess and evaluate the operating principles, design considerations, and performance characteristics of helical and horn antennas, and appraise modern antenna technologies and measurement techniques.	L5
4	Summarize the mechanisms of ground, sky, space, and tropospheric wave propagation and describe key propagation parameters such as critical frequency, MUF, skip distance, virtual height, and field strength.	L2
5	Analyze antenna array principles to design and evaluate uniform and non-uniform linear arrays, including broadside, end-fire, and binomial configurations, and examine beamforming and beam steering in phased arrays.	L4
6	Summarize the fundamental concepts of antenna radiation mechanisms and key parameters such as radiation patterns, beamwidth, gain, directivity, polarization, and path loss using the Friis transmission equation.	L2

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	2	-	-	-	-	-	-	3	1
CO2	3	3	2	2	2	-	-	-	-	-	-	3	2
CO3	3	3	3	2	2	-	-	-	-	-	-	3	2
CO4	2	3	2	2	2	-	-	-	-	-	-	3	2
CO5	3	2	-	-	-	-	-	-	-	-	-	3	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. John D Krauss, Ronald J Marhefka, Ahmad S Khan, “Antennas for all Applications”,3rd edition, McGraw-Hill, 2006
2. C.A Balanis, “Antenna Theory”, John Wiley & Sons, 2nded. 2001.
3. A R Harish and M Sachidananda, “Antenna and Wave Propagation” Oxford University Press, 2007

REFERENCES:

1. D Prasad, Satya Prakashan, “Antennas & Wave Propagation”, Tech India Publications, New-Delhi, 2001.

ALTERNATIVE NPTEL/SWAYAM COURSE:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Antennas https://nptel.ac.in/courses/108101092	Prof. Girish Kumar	IIT Bombay [12 weeks course]
2	Analysis And Design Principles of Microwave Antennas https://nptel.ac.in/courses/108105114	Prof.Amitabha Bhattacharya	IIT Kharagpur [8 weeks course]

Department of Electronics and Communication Engineering

ARTIFICIAL INTELLIGENCE OF THINGS (AIOT) SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		Credits	:	02
Hours / Week	:	03 Hours	Total Hours	:	30 Hours
L–T–P	:	2–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the convergence of Artificial Intelligence and Internet of Things (AIoT) architectures.
2. Apply AI/ML models on edge devices for real-time inference and decision-making.
3. Analyse sensor data streams using Python-based frameworks and cloud-IoT platforms.
4. Implement hands-on AIoT prototypes using Raspberry Pi, Arduino, and NVIDIA Jetson hardware.
5. Develop skills for deploying secure, scalable, and ethical AIoT solutions in industry contexts.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. Emphasize hands-on hardware-software integration and lab-based learning
2. Use project-based learning (PBL) with real IoT datasets and cloud dashboards
3. Encourage collaborative learning through GitHub-based submissions and team projects
4. Integrate NVIDIA Jetson, Raspberry Pi, and Arduino for embedded AI experiments
5. Conduct hackathons, demo days, and AIoT prototype showcases

Module 1: Introduction to AIoT – Architecture & Ecosystem	**06 Hours**

AIoT paradigm: convergence of AI and IoT; AIoT architecture layers (Perception, Network, Data, Application); IoT communication protocols (MQTT, CoAP, HTTP, BLE, Zigbee, LoRa); Edge vs. Fog vs. Cloud computing; Introduction to Raspberry Pi, Arduino, and NVIDIA Jetson Nano platforms; Overview of sensors and actuators (DHT11, PIR, ultrasonic, servo, relay); AIoT use cases in smart home, healthcare, agriculture, and industry.

Hands-on Experiments:

1. ***Experiment 1:*** Setting up Raspberry Pi and configuring GPIO pins for sensor interfacing
2. ***Experiment 2:*** Reading temperature and humidity data from DHT11 sensor and publishing via MQTT to a cloud broker (HiveMQ)
3. ***Experiment 3:*** Controlling an LED array and servo motor via a web-based IoT dashboard (Node-RED)

NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course

Getting Started with AI on Jetson Nano – NVIDIA DLI

Module 2: AI/ML Fundamentals for IoT Data	**06 Hours**

Introduction to supervised and unsupervised learning for IoT data; Feature engineering from sensor data; Regression for prediction (temperature forecasting); Classification for anomaly detection; Clustering for device grouping; Introduction to TensorFlow Lite and Edge Impulse for edge deployment; Model evaluation metrics: accuracy, precision, recall, F1-score; Concept of model compression: pruning, quantization, knowledge distillation.

Hands-on Experiments:

1. ***Experiment 4:*** Collecting multi-sensor IoT dataset (temperature, humidity, vibration) and performing EDA with Pandas and Matplotlib
2. ***Experiment 5:*** Training a linear regression model for energy consumption prediction using Scikit-learn on Raspberry Pi
3. ***Experiment 6:*** Building and deploying a binary classifier (normal vs. anomaly) on edge using TensorFlow Lite on Raspberry Pi

NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course

Disaster Risk Monitoring Using Satellite Imagery – NVIDIA DLI (AI Data Analytics)

Module 3: Computer Vision & Deep Learning for AIoT Systems	**06 Hours**

Convolutional Neural Networks (CNN) for image classification; Object detection architectures: YOLO, SSD, MobileNet; Transfer learning and fine-tuning pre-trained models; Real-time image/video inference on edge hardware (Jetson Nano, Raspberry Pi + Coral USB); OpenCV for image acquisition, processing, and annotation; NVIDIA DeepStream SDK overview; AIoT applications: smart surveillance, facial recognition, defect detection in manufacturing.

Hands-on Experiments:

1. ***Experiment 7:*** Image classification using a pre-trained MobileNet model with TensorFlow Lite on Raspberry Pi (camera module integration)
2. ***Experiment 8:*** Real-time object detection using YOLOv5 on NVIDIA Jetson Nano with USB camera – detecting persons and vehicles
3. ***Experiment 9:*** Training a custom image classifier with Edge Impulse on collected IoT camera images and deploying to Raspberry Pi

NVIDIA DLI Courses (Relevant to this Module): Building Real-Time Video AI Applications – NVIDIA DLI
Computer Vision for Industrial Inspection – NVIDIA DLI

Module 4: Natural Language Processing & Voice Interfaces for AIoT Systems	**06 Hours**

Introduction to NLP for IoT command and control; Speech recognition fundamentals (Wav2Vec, Whisper); Wake-word detection and voice assistants at the edge; Keyword spotting using TinyML; Text-based IoT control via chatbots and LLM APIs; Sentiment analysis for user feedback in smart products; Integration of voice/text interface with IoT actuators; Introduction to NVIDIA Riva for speech AI.

Hands-on Experiments:

1. ***Experiment 10:*** Implementing a wake-word detection system ("Hey Pi") using Edge Impulse MFCC-based TinyML model on Raspberry Pi with microphone
2. ***Experiment 11:*** Voice-controlled IoT actuator – converting spoken commands (on/off/dim) to GPIO actions using OpenAI Whisper API
3. ***Experiment 12:*** Chatbot-controlled smart home dashboard – integrating a GPT-based chatbot with MQTT to control IoT devices through text commands

NVIDIA DLI Courses (Relevant to this Module): (NA)
Building Conversational AI Applications – NVIDIA DLI (Riva Speech AI)

Module 5: Cloud-Edge Integration, Security & AIoT Deployment	**06 Hours**

Cloud platforms for AIoT: AWS IoT Greengrass, Google Cloud IoT Core, Azure IoT Hub; MLOps for edge: model versioning, OTA updates, and retraining pipelines; IoT security fundamentals: encryption (TLS/SSL), authentication, secure boot; Privacy-preserving AI: federated learning concept for IoT; Data governance and ethics in AIoT; End-to-end AIoT system design: from prototype to production; Case studies: smart agriculture, predictive maintenance, smart energy metering.

Hands-on Experiments:

1. ***Experiment 13:*** Connecting Raspberry Pi to AWS IoT Core using MQTT over TLS and visualizing sensor data on AWS IoT Dashboard
2. ***Experiment 14:*** Implementing OTA (Over-The-Air) model update pipeline – updating a deployed TFLite model on Raspberry Pi via cloud trigger
3. ***Experiment 15:*** End-to-end AIoT Capstone Project – Smart Predictive Maintenance System: sensor data collection, ML-based fault prediction, cloud dashboard alert, and edge actuation (buzzer/relay)

AI Integration:

1. Use Python libraries (NumPy, Pandas, Matplotlib, Scikit-learn, TensorFlow Lite) for sensor data analysis and model training
2. Deploy AI models on edge hardware (Jetson Nano, Raspberry Pi) using NVIDIA TensorRT and TFLite runtime
3. Apply OpenCV for real-time computer vision pipelines in AIoT applications
4. Use NVIDIA DeepStream SDK for multi-stream video analytics on edge devices
5. Automated benchmarking of AI model inference time, accuracy, and power consumption on edge devices

Authentic Intelligence:

1. Understanding limitations of algorithm efficiency in real-world systems
2. Avoiding overfitting in optimization strategies
3. Ethical coding practices and plagiarism awareness
4. Trade-offs between memory and performance
5. Responsible use of AI-assisted coding tools

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply knowledge of IoT sensors, actuators, and communication protocols to design connected systems.	L3
2	Implement AI/ML algorithms on edge devices for real-time data analysis and decision-making.	L3
3	Analyze data streams from IoT networks using Python-based AI frameworks and cloud platforms.	L4
4	Design and prototype end-to-end AIoT solutions integrating hardware, firmware, and AI pipelines.	L5
5	Evaluate AIoT system performance, security, and ethical implications in real-world deployments.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	-	2	-	-	-	-	-	-		
CO2	3	3	2	1	3	-	-	-	1	1	-	3	3
CO3	2	3	3	2	3	1	-	-	-	2	-	3	3
CO4	2	2	3	3	3	3	1	1	1	2	2	3	3
CO5	2	3	3	3	3	2	2	2	3	3	3	3	3

3: Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

TEXT BOOKS:

1. Raj, P. and Raman, A.C.: 2017. The Internet of Things: Enabling Technologies, Platforms, and Use Cases. 1st Edition, CRC Press.
2. Géron, A.: 2019. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. 2nd Edition, O'Reilly Media.
3. Warden, P. and Situnayake, D.: 2020. TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers. 1st Edition, O'Reilly Media.

REFERENCE BOOKS:

1. Buyya, R. and Dastjerdi, A.V.: 2016. Internet of Things: Principles and Paradigms. 1st Edition, Morgan Kaufmann.
2. Chollet, F.: 2021. Deep Learning with Python. 2nd Edition, Manning Publications.
3. Krumm, J. (Ed.): 2018. Ubiquitous Computing Fundamentals. 1st Edition, CRC Press.
4. Schwartz, R., Dodge, J., Smith, N.A. and Etzioni, O.: 2020. Green AI. Communications of the ACM, 63(12), pp.54-63.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Jetson AI Courses (Getting Started with AI on Jetson Nano)	NVIDIA DLI	https://courses.nvidia.com/courses/course-v1:DLI+S-RX-02+V2/
2	Building Real-Time Video AI Applications	NVIDIA DLI	https://courses.nvidia.com/courses/course-v1:DLI+C-RX-02+V1/
3	Introduction to AI in the IoT (IoT AI Fundamentals)	Coursera / IBM	https://www.coursera.org/learn/introduction-to-iot
4	TinyML and Efficient Deep Learning Computing	MIT OpenCourseWare	https://efficientml.ai

INFORMATION AND THEORY CODING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Understand the fundamental concepts of information theory, entropy, and probabilistic models used in communication
2. Apply source coding techniques for efficient data compression.
3. Analyze communication channels, mutual information, and channel capacity.
4. Understand error detection and correction techniques for reliable data transmission in digital and AI-enabled systems.
5. Analyze advanced coding techniques such as cyclic and convolutional codes and explore their relevance in AI-based sequence modeling and signal processing applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – 1: Information Theory	**09 Hours**

Introduction, Measure of information, Average information content of symbols in long independent sequences, Average information content of symbols in long dependent sequences. Markov statistical model for information source, Entropy and information rate of Markov sources.

NVIDIA DLI Courses (Relevant to this Module):

1. **AI for All: From Basics to Gen AI Practice** (2 hrs) | Path: AI Infrastructure Training – Fundamentals
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1

MODULE – II: Source Coding	09 Hours
Encoding of the source output, properties of codes, Kraft inequality, construction of instantaneous codes, code efficiency and redundancy, Shannon's encoding algorithm, Shannon-Fano Coding, Huffman minimum redundancy code, Extended Huffman coding, Arithmetic Coding	
MODULE – III: Information Channels	**09 Hours**
Communication Channels: Channel Models, Channel Matrix, Joint probability Matrix, System Entropies, Mutual Information, Properties of Mutual information, Channel Capacity, Special Channels, Channel Capacity of: Binary Symmetric Channel, Binary Erasure Channel, Muroga,s Theorem, Continuous Channels: Maximization of entropy Mutual information of continuous noisy channels, Shannon-Hartley law and its implications Joint and Conditional Entropies, Shannon Limit.	
MODULE – IV: Error Control Coding	**09 Hours**
Introduction, Examples of error control coding, Methods of controlling errors, types of codes, types of errors, Linear block codes matrix description of, minimum distance consideration Error detection and correction capabilities, single error correcting Block codes, single error correcting Hamming codes Table lookup for decoding using Standard array.	
MODULE – V: Types Of Coding	**09 Hours**
Binary cyclic code's Algebraic structure of cyclic codes Encoding using (n-k) bit shift register Syndrome calculation, Error detection and correction Convolution Codes, Time domain approach. Transform domain approach, State Diagram, tree diagram, Trellis diagram. Encoders and Decoders using Viterbi's algorithm for (n,k,l) convolutional codes	

AI Integration:

1. Markov models in AI systems such as speech recognition and activity recognition.
2. Markov models in AI systems such as speech recognition and activiy recognition
3. Use of mutual information in machine learning for feature relevance analysis and dependency measurement in intelligent communication systems

Authentic Intelligence:

1. Connect information measure with uncertainty and cross-entropy in AI models.
2. Relate coding techniques to data compression and efficient representation.
3. Link channel noise to robustness of AI systems under noisy data.
4. Associate error detection with anomaly detection and fault tolerance.
5. Map convolutional/Viterbi methods to sequence modeling and dynamic programming in AI

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Explain and compute measures of information such as entropy, information rate, and Markov source probabilities for given data sequences.	L2
2	Construct and implement source coding techniques such as Shannon, Shannon–Fano, Huffman, and Arithmetic coding to evaluate coding efficiency using Python or MATLAB.	L3
3	Analyze and evaluate communication channel characteristics by calculating mutual information, channel capacity, and Shannon limits for different channel models.	L4
4	Design and verify linear block codes and Hamming codes to detect and correct errors in digital communication systems**.**	L4
5	Implement and analyze cyclic and convolutional coding schemes and decode them using the Viterbi algorithm through MATLAB/Python-based simulations.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	1	-	-	-	-	-	1	-	-
CO2	3	2	2	-	2	-	-	-	-	-	1	-	-
CO3	3	3	2	1	2	1	-	-	-	-	1	-	1
CO4	3	3	2	1	2	1	-	-	-	-	1	-	1
CO5	3	3	2	1	2	1	-	-	-	-	1	-	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Digital and analog communication systems, K.SamShanmugam, John Wiley India Pvt.Ltd,2011
2. Communication, Simon Haykin, John Wiley India Pvt. Ltd,2012.
3. Information Theory and Coding, Muralidhar Kulkarni, K.S. Shivaprakash, Wiley India Pvt.Ltd, 2015, ISBN:978-815-265305

REFERENCE BOOKS:

1. ITC and Cryptography, Ranjan Bose, TMH, 2 ndedition,2012
2. Digital Communications - Glover and Grant; Pearson Ed. 2nd edition2010.
3. Digital Communications: Fundamentals & Applications, 2nd edition, Sklar, PearsonEducation India.
4. Error Control Coding-Fundamentals & Applications, Shulin, Daniel J. Costello, 2ndEdition,Prentice Hall Inc. Eagle wood Cliffs

E-Resources:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Information Theory and Coding https://nptel.ac.in/courses/117101053	Prof.S. N. Merchant	IIT Bombay
2	Information Theory, Coding and Cryptography. https://nptel.ac.in/courses/108102117	Prof. Ranjan Bose	IIT Delhi

ADAPTIVE SIGNAL PROCESSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the need for adaptive filtering and its applications in real-time systems.
2. Analyze different adaptive algorithms such as LMS, NLMS, and RLS.
3. Develop mathematical understanding of convergence, stability, and performance analysis.
4. Apply adaptive filtering in noise cancellation, system identification, and prediction.
5. Explore AI/ML-based adaptive signal processing techniques using modern tools
6. Describe the concepts of wave propagation in ground, sky, and tropospheric regions.

Teaching-Learning Process (General Instructions)

1. These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.
2. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
3. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
4. Show ***Video/animation*** films to explain functioning of various concepts.
5. Encourage ***Collaborative*** (Group Learning) Learning in the class.
6. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
7. Discuss how every ***concept can be applied to the real world*** – and when that's possible, it helps improve the students' understanding.
8. ***Problem-based learning*** (adaptive filter design cases)
9. ***GPU-based simulation*** demonstrations (NVIDIA tools)
10. Group discussions on ***real-world applications*** (5G, biomedical signals)
11. *Case studies on AI-enabled signal processing*
12. Encourage ***mini-projects*** on adaptive filtering applications

MODULE – I : Introduction to Adaptive Signal Processing	**09 Hours**

The filtering problem, Adaptive filters, linear filter structures, approaches to the development of linear adaptive filter algorithms, real and complex forms of adaptive filters, non-linear adaptive filters, **Applications**: Active Noise Control (ANC), Echo Cancellation, Wireless Channel Equalization, Biomedical Signal Enhancement: Noise reduction and feature extraction in ECG, EEG, and ultrasound signals.

NVIDIA DLI Courses

1. Fundamentals of Deep Learning
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3

MODULE – II: Filters	08 Hours
Wiener Filters, Linear optimum filtering problem statement, principle of orthogonality, minimum, mean squared error, wiener, Hopf equations, error performance surface. Channel equalization., Linearly constrained minimum variance filter, generalized side lobe cancellers. **Applications:** Optimal Signal Estimation, Image Denoising, Channel Equalization, Beamforming (Smart Antennas)	
NVIDIA DLI Courses 1. Fundamentals of Accelerated Data Science https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-DS-02+V2	
MODULE – III Linear Prediction	**09 Hours**
Forward Linear Prediction, backward Linear Prediction, Levinson-Durbin, algorithm, properties of prediction error filters, Schur-Cohntest, auto regressive modeling of a stationary stochastic process, Cholesky factorization, lattice predictors, joint process estimation, block estimation. Method of steepest descent: Steepest descent algorithm, stability of the Steepest descent algorithm. **Applications:** Speech Coding (LPC), Financial Time-Series Prediction, Radar Target Tracking, Autoregressive (AR) Modelling	
NVIDIA DLI Courses 1. CUDA Optimization Tools https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+T-AC-01+V1	
MODULE – IV: LMS and RMS Algorithm	**10 Hours**
Least Mean Square (Lms) Algorithm: Overview of the structure and operation of the Least Mean square Algorithm, Least Mean square adaptation Algorithm, stability and performance, analysis of the LMS algorithm. Normalized Least Mean Square (NLMS) Algorithm, Concept of, method of least squares, Recursive Least Squares (Rls) Algorithm: The matrix inversion lemma, the exponentially weighted RLS algorithm, update recursion for the sum of weighted error squares. Convergence analysis of the RLS algorithm. **Applications:** Adaptive Noise Cancellation, Adaptive Equalization (5G/6G), Acoustic Echo Cancellation, Biomedical & IoT Application	
NVIDIA DLI Courses 1. AI for Anomaly Detection https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1	
MODULE – V: Advanced Adaptive Signal Processing	**09 Hours**
Kalman Filters: Recursive minimum mean square estimation for scalar random variables, statement of the Kalman filtering problem, the innovations process, estimation of the state using the innovations process, filtering, initial conditions, variants of the Kalman filter, extended Kalman filtering. **Applications**: Navigation Systems: GPS, INS (Inertial Navigation Systems), Autonomous Vehicles: Sensor fusion (LiDAR, radar, camera integration), Robotics: State estimation and trajectory tracking, Financial Engineering: Recursive estimation in dynamic markets, Target Tracking: Missile guidance, air traffic control, IoT Sensor Fusion: Smart city and industrial automation systems	

NVIDIA DLI Courses 1. Deep Learning Learning Path https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1

AI Integration:

1. Data-driven Adaptation: AI enables adaptive systems to learn continuously from streaming data.
2. Improved Estimation: Deep learning enhances accuracy in signal prediction and filtering.
3. Real-time Processing: GPU acceleration supports high-speed, low-latency adaptive algorithms.
4. Emerging Applications: AI-driven DSP is critical for 6G communication, healthcare systems, and autonomous technologies.

Authentic Intelligence:

1. Hybrid Intelligence: Combines domain knowledge in engineering with AI techniques.
2. Model Interpretability: Improves transparency and understanding of adaptive models.
3. Human-in-the-Loop: Supports systems where human expertise guides AI decisions.
4. Ethical Deployment: Ensures responsible, fair, and reliable use of AI in signal processing applications.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the fundamental concepts of adaptive filtering and its applications in signal processing systems.	L2
2	Analyze the Least Mean Squares (LMS) algorithm and its variants for adaptive filtering applications.	L4
3	Evaluate the Recursive Least Squares (RLS) algorithm in terms of performance, convergence, and computational complexity.	L5
4	Apply adaptive filtering techniques to solve real-world signal processing problems such as noise cancellation and system identification.	L3
5	Integrate Artificial Intelligence techniques with adaptive signal processing for advanced applications such as intelligent filtering and predictive systems.	L5
6	Understand the fundamental concepts of adaptive filtering and its applications in signal processing systems.	L2

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	–	–	1	–	–	–	–	–	–	3	1
CO2	3	3	2	2	2	–	–	–	–	–	–	3	2
CO3	3	3	2	3	2	–	–	–	–	–	–	3	2
CO4	3	2	3	2	3	–	–	–	1	1	–	3	3
CO5	2	2	3	2	3	–	–	1	1	1	–	2	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Adaptive Filter Theory, S. Haykin, Prentice-Hall, 4-th edition, 2001.
2. Fundamentals of Adaptive Filtering, Ali H. Sayed, John Wiley, 2003.
3. Bernard Widrow, Samuel D. Stearns, Adaptive Signal Processing, Classic Edition, Publisher: Pearson/Prentice Hall, 1985, ISBN: 978-0130040299

REFERENCE BOOKS:

1. Monson H. Hayes , Statistical Digital Signal Processing And Modeling, Wiley India, 2008.
2. John G. Proakis, Dimitris G.Manolakis, Digital Signal Processing, Principles, Algorithms and Applications, Pearson Education / PHI, 2007.
3. B. Farhang-Boroujen, Adaptive Filters: Theory and Applications, John Wiley and Sons, 2013

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Introduction To Adaptive Signal Processing https://nptel.ac.in/courses/108105191	Prof. Mrityunjoy Chakraborty	IIT Kharagpur

E-Resources:

1. MATLAB Copilot
2. Demonstration of solution to a problem through MATLAB programming.

MIXED SIGNAL IC DESIGN
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:
This course enables students to

1. Analyse small signal and large signal model of MOSFETS
2. Analyse the characteristics of single stage amplifier and differential amplifier.
3. Understand and Analyze Op-Amp parameters
4. Study analog comparators
5. Infer VCO and PLL characteristics.
6. Understanding the working of different data converters: ADC and DAC.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I:CMOS Device Modelling and Single Stage Amplifiers	**09 Hours**

Small Signal Model. Analog CMOS Subcircuits: MOS Switch, MOS Diode, Current Sinks and Sources, Current Mirrors, Common Source with Resistive load, Source follower.
Applications: Analog front-end design, Sensor interfaces.

MODULE – II: Differential Amplifier and OPAMPs	**09 Hours**
Differential Amplifiers and Operational Amplifiers: Single Ended Differential operation, Basic differential Pair. OP- AMPS: General Consideration and Performance Parameters, One/Single Stage OP-AMP, Two stage Op-amp. Comparators, Characterization of a Comparator, Two Stage Open Loop Comparator. **Applications:** Signal conditioning circuits, Data converter building blocks.	
MODULE – III: VCO and PLL	**09 Hours**
Basic Concepts, Phase Detector, Type-I PLLs, Simple PLL, Frequency Multiplication, Drawbacks of Simple PLL, Phase/Frequency Detectors, Charge Pumps, Charge- Pump PLLs, Integer-N Frequency Synthesizers-General Considerations, Basic Integer-N Synthesizer **Applications:** Clock generation, Frequency synthesis in RF circuits.	
MODULE – IV: Digital to Analog Converters	**09 Hours**
Analog Versus Discrete Time Signals, Converting Analog Signals to Digital Signals, Sample-and-Hold (S/H) Characteristics, DAC specifications: INL, DNL, Offset, Gain Error, DAC Architectures, Digital Input Code, Resistors String, R- 2R Ladder Networks, Current Steering, Cyclic DAC, Pipeline DAC, Delta Sigma DAC **Applications**: Audio systems, Video signal processing, Actuator control.	
MODULE – V: Analog to Digital Converters	**09 Hours**
Topics: ADC Architectures, Flash, Pipeline ADC, Integrating ADC, Successive Approximation ADC, Sigma Delta ADC, INL, DNL, Offset, Gain Error. **Applications:** Wireless receivers, Medical imaging, Industrial instrumentation.	

AI Integration :

1. Apply machine learning techniques to automate transistor sizing, biasing, and performance tuning of CMOS amplifiers and OP-AMPs for improved gain, power, and bandwidth.
2. Use AI algorithms in analog front-end and sensor interfaces to enhance signal quality, filter noise, and improve accuracy in real-world environments.
3. Integrate AI methods to correct non-linearities (INL, DNL), reduce quantization errors, and dynamically optimize resolution and sampling in ADCs and DACs.
4. Employ AI-based predictive control to improve lock time, stability, and jitter performance in VCOs and PLL-based frequency synthesizers.
5. Develop systems that use AI for real-time calibration, fault detection, and performance adaptation in applications like wireless communication, medical devices, and instrumentation.

Sample Case:

Use AI ((Python + SPICE parametric sweep + ML regression for design optimization) for Mixed Signal Circuits

Sample student workflow - Single-Stage Amplifier:

- Run parametric SPICE sweep: vary W/L, bias current, load resistance
- Export results (gain, bandwidth, power) to CSV
- In Python/Jupyter:
    - Load data with pandas
    - Plot gain vs. power trade-off curves
    - Train a simple linear/RF model to predict gain from design params
    - Use model to suggest "good starting points" for new specs
- Students manually verify top suggestions in SPICE

Authentic Intelligence:

1. Integration of intelligent techniques to interpret and adapt to real-world analog signals (e.g., sensor interfaces, front-end circuits) for improved accuracy and noise resilience.
2. Use of intelligent algorithms to optimize transistor sizing, biasing, and performance parameters (gain, power, bandwidth) in amplifiers, OP-AMPs, and PLL circuits.
3. Application of AI in ADC/DAC systems to dynamically improve resolution, reduce non-linearities (INL/DNL), and enhance signal fidelity in varying conditions.
4. Enhancing VCO and PLL performance using predictive and adaptive techniques for stable clock generation and frequency synthesis in communication systems.
5. Designing reliable mixed-signal systems that adapt to real-world uncertainties in applications such as medical imaging, wireless communication, and industrial instrumentation.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Analyze the small-signal behavior of CMOS single-stage amplifiers and analog subcircuits	L4
2	Analyze the operation and performance parameters of differential amplifiers and multi-stage operational amplifiers.	L4
3	Apply basic concepts of PLL and Synthesizers for frequency multiplication.	L3
4	Explain data converter specifications and analyze performance of different types of DACs.	L4
5	Analyze ADC architectures and their performance specifications	L4

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	**2**	**3**	-	-	-	-	-	-	-	-	-	**2**	-
CO2	**2**	**3**	-	-	-	-	-	-	-	-	-	**2**	-
CO3	**3**	**2**	-	-	-	-	-	-	-	-	-	**2**	-
CO4	**2**	**3**	-	-	-	-	-	-	-	-	-	**2**	-
CO5	**2**	**3**	-	-	-	-	-	-	-	-	-	**2**	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Design of Analog CMOS Integrated Circuits, Behzad Razavi, 3rd Edition, 2002, Tata McGrawHill.
2. CMOS-Mixed Signal Circuit Design, R. Jacaob Baker, (Vol ll of CMOS: Circuit Design, Layout and Stimulation), IEEE Press and Wiley Interscience, 2002.
3. CMOS Analog Circuit Design, Phillip E Allen, Douglas R Holberg, 2rd Edition, 2006, Oxford University Press.

REFERENCE BOOKS:

1. Analysis and Design of Analog Integrated Circuits, Gray, Hurst, Lewis, and Meyer, John Wiley & Sons, 5th edition, 2009
2. Analog Integrated Circuit Design, Carusone, Johns, and Martin, 2nd edition, John Wiley, 2012.
3. Analog Design for CMOS VLSI Systems, Franco Maloberti, Kluwer Academic Publishers, 2001

E-Resources:

S. No.	NPTEL Course Name	Instructor	Host Institute
2	CMOS Analog VLSI Design https://nptel.ac.in/courses/117101105	Prof. A.N. Chandorkar	IIT Bombay

REAL TIME OPERATING SYSTEM

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Differentiate between general-purpose operating systems and real-time operating systems.
2. Explain key real-time system concepts, including multithreading, task and thread scheduling, and memory management.
3. Apply system-level programming constructs such as timers, signals, mutual exclusion, semaphores, message queues, and exception handling.
4. Develop real-time applications that operate effectively within realistic system environments.
5. Analyse and utilize artificial intelligence techniques in the context of RTOS and real-time applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Introduction to Real-Time Systems and Operating Systems	**10 Hours**

Real Time Applications V/S Non-Real Time Applications, Real-Time Systems V/S Non-Real-Time Systems, Characteristics And Requirements Of Real-Time Systems, Introduction To Operating Systems, Real-Time Operating System (RTOS) V/S General Purpose Operating System (GPOS)
Applications: Real-Time Applications (Robotics, Autonomous Systems, Smart Healthcare)

NVIDIA DLI Courses (Relevant to this Module):

1. **AI for All: From Basics to Gen AI Practice** (2 hrs) | Path: AI Infrastructure Training – Fundamentals
https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1

MODULE – II Thread Management in RTOS	08 Hours
Introduction to RTOS, Function pointers, Thread Management, Semaphores, Thread Synchronization, Process Management, Dynamic Loading and Linking	
MODULE – III: Time Management in RTOS	**08 Hours**
operation, Blocking Semaphores, FIFO Queue, Thread Sleeping, Deadlocks, Monitors, Fixed Scheduling	
MODULE – IV: RTOS Application Design	**10 Hours**
Task Decomposition techniques- Feature Based Decomposition, The Outside-In Approach to Task Decomposition (The Seven-Step Process – Use Case: Decomposing an IoT Thermostat), Setting Task Priorities (Task Scheduling Algorithms, Verifying CPU Utilization Using Rate Monotonic Analysis (RMA), Measuring Execution Time of the Tasks), RTOS Application Design Patterns (Publish and Subscribe Models, Low-Power Application Design Patterns)	
MODULE – V: Case Study: Free RTOS	**09 Hours**
Creating tasks and starting the scheduler, deleting tasks, Trying out the code, Task memory allocation, Understanding Free RTOS task states, Troubleshooting start-up problems.	
NVIDIA DLI Courses (Relevant to this Module): 1. **Building Real-Time Video AI Applications** (8 hrs) | Path: Computer Vision and Video Analytics Training https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-IV-01+V1	

AI Integration:

1. AI in real-time domains such as robotics, autonomous systems, and smart healthcare to enable intelligent, time-critical decision-making.
2. AI-Assisted Task Scheduling and Scheduling Techniques, Predictive Scheduling using AI
3. AI-based Optimization in Real-Time Systems, AI-based Deadlock Detection, Intelligent Resource Allocation
4. AI-Assisted Task Optimization and Predictive Scheduling in FreeRTOS

Authentic Intelligence:

1. Design of AI systems that make reliable, real-time decisions based on environmental context (e.g., robotics, healthcare monitoring) while respecting strict timing constraints.
2. Ensuring AI models used in real-time systems are interpretable, predictable, and verifiable, especially in safety-critical applications.
3. Incorporating fairness, accountability, and safety when deploying AI in autonomous and real-time applications such as smart healthcare and autonomous vehicles.environments without violating real-time constraints.
4. Developing systems that adapt to user behavior and interact effectively with humans, improving usability and performance in real-time environments.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply knowledge of operating systems to develop real-time operating system applications, and understand AI-enabled applications	L3
2	Examine the principles of thread management and time management in RTOS for implementing RTOS applications and AI-assisted task scheduling	L4
3	Design RTOS applications using decomposition techniques and task prioritization methods and AI-based resource allocation	L6
4	Develop problem-solving skills by applying RTOS concepts to practical scenarios in real-time systems	L3
5	Analyze the case studies on RTOS and evaluate the practical exercises on Free RTOS and apply AI-assisted predictive optimization	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	1	2	3	2	3	2	2	1	3	3
CO2	3	3	3	2	3	2	2	3	3	2	2	3	3
CO3	3	3	3	3	2	2	2	3	3	2	2	3	3
CO4	3	3	3	1	3	2	2	3	3	2	2	3	3
CO5	3	3	3	2	3	2	2	3	3	3	2	3	3

3:Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Jonathan Valvano," Embedded Systems: Real-Time Operating Systems for ARM Cortex-M Microcontrollers", 2nd Edition, CreateSpace Independent Pub, 2012.
2. Jacob Beningo," Embedded Software Design – A Practical Approach to Architecture, Processes, and Coding Techniques", 1st Edition, APress, 2022.
3. Brian Amos, "Hands-On RTOS with Microcontroller", 1st Edition, Packt Publishing Ltd., 2020.
4. M. Jim Jones, "Artificial Intelligence: A Systems Approach", Jones & Bartlett Learning, 2008

REFERENCE BOOKS:

1. Sam Siewert, "Real-Time Embedded Components And System with Linux and RTOS", Mercury Learning And Information LLC, 2016.
2. Jiacun Wang, "Real-Time Embedded Systems", 3rd Edition, Wiley, 2017.
3. Jane W. S Liu, "Real-Time Systems", 1st Edition, Pearson Education India, 2002.
4. Alan Burns & Andy Wellings, "Real-Time Systems and Programming Languages (with AI applications) ", Addison-Wesley, 2001

E-Resources:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Real-Time Operating System https://nptel.ac.in/courses/106105036	Prof. Rajib Mall	IIT Kharagpur
2	Real-Time Systems https://nptel.ac.in/courses/106105036	Prof. Rajib Mall, Prof. Durga Prasad Mohapatra	IIT Kharagpur, NIT Rourkela
3	Operating System https://nptel.ac.in/courses/106102132	Prof. Sorav Bansal	IIT Delhi
4	An Introduction to Artificial Intelligence https://nptel.ac.in/courses/106102220	Prof. Mausam	IIT Delhi

DATA ACQUISITION & PROCESSING SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the fundamental principles of data acquisition systems including sensors, signal conditioning, and ADC architectures.
2. Analyse various data conversion techniques, sampling theory, and anti-aliasing filter design for accurate signal digitization.
3. Apply digital signal processing techniques including filtering, FFT, and spectral analysis to process acquired data using AI tools.
4. Design data acquisition interfaces and communication protocols for real-time embedded and PC-based systems using AI tools for modeling and simulation.
5. Evaluate current trends in industrial data acquisition, IoT integration, and intelligent processing for engineering applications.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. *The lecture method* includes not only the traditional lecture method, but also different *types of teaching methods* may be adopted to develop the course outcomes.
2. Interactive Teaching: Adopt *Active Learning* that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show *Video/animation films* to explain functioning of various data acquisition circuits and signal processing concepts.
4. Encourage *Collaborative (Group Learning)* Learning in the class through hands-on lab sessions and mini-projects.
5. To make *Critical Thinking*, ask at least three Higher Order Thinking questions in the class.
6. Adopt *Problem Based Learning*, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the *different ways to solve* the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every *concept can be applied to the real world* - and when that's possible, it helps improve the students' understanding.

MODULE – I: Introduction to Data Acquisition Systems	09 Hours

Concept and Need for Data Acquisition Systems (DAS), Block diagram of a typical DAS: sensors/transducers, signal conditioning, multiplexers, sample-and-hold circuits, ADCs, and microcontrollers/PCs. Types of signals: analog, digital, single-ended, and differential. Noise sources and grounding techniques. Overview of DAQ hardware platforms: Arduino, Raspberry Pi, NI DAQ, and STM32.
Applications: Industrial process monitoring, biomedical signal acquisition, environmental sensing, and structural health monitoring.

MODULE – II: Sensors, Transducers & Signal Conditioning	09 Hours

Classification of sensors: resistive (RTD, strain gauge), capacitive, inductive (LVDT), piezoelectric, and optical sensors. Sensor characteristics: sensitivity, linearity, accuracy, and response time. Signal conditioning circuits: instrumentation amplifiers, Wheatstone bridge circuits, voltage/current converters, isolation amplifiers, and active filters (low-pass, high-pass, band-pass). Noise reduction: shielding, twisted pairs, and common-mode rejection.
Applications: Temperature measurement with thermocouples and RTDs, pressure measurement with piezoelectric transducers, vibration monitoring with accelerometers.

MODULE – III: Analog-to-Digital & Digital-to-Analog Conversion	09 Hours

Sampling theorem, Nyquist rate, aliasing, and anti-aliasing filter design. ADC architectures: Flash, Successive Approximation Register (SAR), Sigma-Delta, and Dual Slope. ADC parameters: resolution, accuracy, SNR, THD, ENOB, and conversion speed. DAC architectures: R-2R ladder, weighted resistor, and current steering DACs. DAC parameters: settling time, glitch energy, and linearity. Sample-and-Hold (S/H) circuit design and specifications.

Applications: Audio digitization, precision measurement instruments, function generators, closed-loop control systems, and waveform reconstruction.

MODULE – IV: Digital Signal Processing for Acquired Data	09 Hours

Discrete-time signals and systems: convolution, correlation, and Z-transform. FIR and IIR digital filter design: windowing method, bilinear transformation, and frequency sampling. Real-time filter implementation on microcontrollers. Spectral analysis: DFT, FFT algorithm, windowing functions, and power spectral density estimation. Short-Time Fourier Transform (STFT) and wavelet analysis for non-stationary signals. Feature extraction for machine health monitoring.
Applications: Vibration analysis, ECG/EEG signal processing, acoustic noise cancellation, and real-time spectrum analyzers.

NVIDIA DLI Courses (Relevant to this Module):

1. **Build High-Performance and AI-Enabled Sensor Processing Applications (3 hrs)**
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-30+V1

MODULE – V: Communication Interfaces, IoT Integration & Intelligent DAQ	**09 Hours**
Serial communication protocols: UART, SPI, I2C, RS-232/485. PC-based DAQ interfaces: USB, PCI/PCIe, Ethernet, and LabVIEW/Python integration. Wireless sensor networks: Zigbee, Wi-Fi, BLE, and LoRaWAN. IoT-enabled DAQ: MQTT protocol, cloud data logging (AWS IoT, ThingSpeak), edge computing with Raspberry Pi/NVIDIA Jetson. Introduction to AI/ML-based anomaly detection and predictive analytics on acquired data. **Applications:** Smart factory automation, remote environmental monitoring, predictive maintenance, and real-time condition monitoring systems.	
NVIDIA DLI Courses (Relevant to this Module): 1. Getting Started with AI on Jetson Nano (8 hrs) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2	

AI Integration:

1. Introduction to Python-based data acquisition and signal processing workflow, data preprocessing using NumPy and SciPy, and feature engineering techniques for sensor data using Pandas and Scikit-learn for building and evaluating predictive models.
2. Implementation of supervised learning algorithms (regression and classification) using Scikit-learn for fault detection and sensor calibration; training and evaluating models on real-world DAQ datasets.
3. Implementing clustering and anomaly detection techniques (k-Means, Isolation Forest) using Scikit-learn for process monitoring; visualization of clusters and signal patterns using Matplotlib and Seaborn.
4. Implementation of ensemble techniques (Random Forest, Gradient Boosting) using Scikit-learn for predictive maintenance; use of bagging and boosting methods and model evaluation with cross-validation scores.
5. Use of Grid Search and Bayesian optimization for hyperparameter tuning of ML models, implementation of validation techniques, performance metrics (RMSE, MAE, F1-score), and application of regularization methods using Scikit-learn.

Authentic Intelligence:

1. Understanding well-posed learning problems in DAQ contexts and their real-world engineering constraints; challenges in designing efficient learning systems for sensor data; limitations of deep learning models on noisy signals; risks associated with poor feature selection and sampling bias; ethical considerations and responsible deployment of AI-based monitoring systems.
2. Interpretability of ML models used for fault detection; risks of incorrect predictions in automated industrial decision-making systems; importance of explainability in safety-critical DAQ applications.
3. Risks of misinterpreting clusters in sensor data; responsible interpretation of patterns discovered from multivariate process data; avoiding confirmation bias in anomaly detection systems.
4. Limitations of ensemble models in DAQ applications; overfitting risks in boosting when data is scarce; interpretability challenges and importance of responsible model selection for embedded deployment.

5. Understanding overfitting and underfitting in signal classification models; bias-variance tradeoff with limited sensor datasets; limitations of optimization methods; importance of selecting appropriate validation and regularization techniques for real-time systems.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the architecture, components, and working principles of data acquisition systems including sensors, signal conditioning, and ADC/DAC fundamentals.	L2
2	Analyse sensor characteristics, signal conditioning circuits, and apply appropriate filter designs for accurate signal digitization and noise reduction.	L3
3	Apply digital signal processing techniques — including FIR/IIR filter design, FFT, and spectral analysis — to process and interpret acquired engineering data.	L3
4	Design PC-based and embedded data acquisition interfaces, integrating communication protocols and IoT platforms for real-time data logging and control.	L4
5	Evaluate and optimise intelligent DAQ systems using AI/ML-based anomaly detection and predictive analytics for industrial and IoT applications.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	1	2	1	1	1	1	1	1	3	2
CO2	3	3	2	2	2	1	1	1	1	1	1	3	2
CO3	3	3	2	3	3	1	1	1	2	2	1	3	2
CO4	2	2	3	2	3	2	2	1	2	2	3	2	2
CO5	2	3	3	3	3	2	2	2	3	3	3	2	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Northrop, R.B., 2005. Introduction to Instrumentation and Measurements. 2nd Edition, CRC Press.
2. Tompkins, W.J. and Webster, J.G., 1988. Interfacing Sensors to the IBM PC. Prentice Hall.
3. Proakis, J.G. and Manolakis, D.G., 2006. Digital Signal Processing: Principles, Algorithms, and Applications. 4th Edition, Pearson Prentice Hall.

REFERENCE BOOKS:

1. 1Bentley, J.P., 2004. Principles of Measurement Systems. 4th Edition, Pearson Prentice Hall.

2. Ott, H.W., 2009. Electromagnetic Compatibility Engineering. John Wiley & Sons.
3. Lyons, R.G., 2010. Understanding Digital Signal Processing. 3rd Edition, Prentice Hall.
4. James, K., 2000. PC Interfacing and Data Acquisition: Techniques for Measurement, Instrumentation and Control. Newnes.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Sensors and Actuators https://nptel.ac.in/courses/108108147	Prof. Hardik J. Pandya	IIT Bangalore
2	Digital Signal Processing https://nptel.ac.in/courses/117102060	Prof. S.C. Dutta Roy	IIT Delhi
3	Embedded Systems – Shape the World	Prof. Jonathan Valvano	University of Texas (edX)
4	Introduction to Internet of Things https://nptel.ac.in/courses/106105166	Prof. Sudip Misra	IIT Kharagpur

DEEP LEARNING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the fundamental principles of deep learning, neural network architectures, activation functions, forward and backward propagation, and gradient-based optimization using NVIDIA GPU-accelerated tools.
2. Analyse convolutional neural networks (CNNs) for computer vision tasks including image classification, object detection, and data augmentation using TensorFlow and Keras on NVIDIA GPUs.
3. Apply recurrent neural networks (RNNs), LSTMs, and transformer-based models for sequence and natural language processing tasks, leveraging pre-trained models and transfer learning.
4. Design and implement deep generative models including VAEs and GANs for tasks in image synthesis, data augmentation, and creative AI applications.
5. Evaluate advanced deep learning paradigms including deep reinforcement learning, large-scale parallel training, AI for science, and ethical considerations in modern AI systems

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. **Interactive Teaching:** Adopt Active Learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, and annotating using NVIDIA DLI hands-on Jupyter notebooks.
2. **Video/Animation Films:** Show NVIDIA DLI video tutorials and MIT 6.S191 lecture recordings to explain deep neural network operations, CNN architectures, and GPU-accelerated training workflows.
3. **Collaborative (Group) Learning:** Encourage group mini-projects using NVIDIA GPU cloud instances and TensorFlow/PyTorch frameworks for hands-on model training and evaluation.
4. **Critical Thinking:** Ask Higher Order Thinking questions about model generalization, ethical AI implications, bias in training data, and trade-offs between model complexity and performance.
5. **Problem Based Learning:** Adopt real-world DL challenges from NVIDIA DLI assessments, encouraging students to train models from scratch and leverage transfer learning to achieve target accuracy benchmarks.

Module I: Foundations of Deep Learning (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Fundamentals of Deep Learning – S-FX-01): Introduction to Artificial Intelligence and the Deep Learning landscape, Biological vs. artificial neurons, Activation functions, Forward propagation, Loss functions, Backpropagation and chain rule, Gradient Descent and optimizers. Hands-on NVIDIA DLI Lab: Training your first computer vision model using TensorFlow/Keras on NVIDIA GPU cloud; data loading, normalization, model definition, compilation, and training loop. MIT 6.S191 Supplementary (Lecture 1): Deep learning motivation and perceptron learning rule; linear classifiers and their limitations; introduction to deep neural networks.	
NVIDIA DLI Courses (Primary Reference): Fundamentals of Deep Learning – The Mechanics of Deep Learning **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1 **MIT 6.S191 Reference:** https://introtodeeplearning.com/	
Module II: Convolutional Neural Networks & Computer Vision (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Fundamentals of Deep Learning – S-FX-01): Limitations of fully connected networks for image data; motivation for convolutional architectures, Convolution operation, Pooling layers, CNN architectures, Regularization techniques, Data augmentation strategies & Transfer learning NVIDIA DLI Hands-on Lab: Building a CNN-based image classifier; applying data augmentation; transfer learning for fresh vs. rotten fruit object classification. MIT 6.S191 Supplementary (Lecture 3 – Deep Computer Vision): CNN feature visualization; object detection architectures (YOLO, R-CNN); semantic segmentation. Applications: Medical image analysis (collaboration with Mayo Clinic, CHLA), self-driving car perception, industrial defect detection.	
NVIDIA DLI Courses (Primary Reference): Fundamentals of Deep Learning – Pre-Trained Models & Transfer Learning Module **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1 **MIT 6.S191 Reference:** https://introtodeeplearning.com/	
Module III: Sequence Modeling – RNNs, LSTMs & Transformers (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Fundamentals of Deep Learning – S-FX-01): Introduction to sequential and time-series data; limitations of feedforward networks for sequences, Recurrent Neural Networks (RNNs), Vanishing/exploding gradient problem in RNNs, Long Short-Term Memory (LSTM), Gated Recurrent Unit (GRU), Attention mechanism, Transformer architecture overview. NVIDIA DLI Hands-on Lab: Training an RNN model to autocomplete text from New York Times headlines; building a language model. MIT 6.S191 Supplementary (Lecture 2 – Deep Sequence Modeling & Lab 3 – Fine-tune an LLM): Sequence-to-sequence models; MIT Lab: Music generation with RNNs; fine-tuning an LLM using transfer learning paradigms. Applications: Natural language processing, machine translation, speech recognition, time-series forecasting, music generation.	
NVIDIA DLI Courses (Primary Reference): Fundamentals of Deep Learning – Recurrent Networks Module; Building Transformer-Based NLP Applications **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1 **MIT 6.S191 Reference:** https://introtodeeplearning.com/	

Module IV: Deep Generative Modeling (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (Generative AI): Introduction to generative models, Autoencoders, Variational Autoencoders (VAEs), Generative Adversarial Networks (GANs), Advanced GAN variants, Diffusion models. MIT 6.S191 Supplementary (Lecture 4 – Deep Generative Modeling Lab 2 – Facial Detection): MIT Lab 2: Detecting and mitigating algorithmic bias in facial recognition using CNNs; ethical implications of generative AI.	
NVIDIA DLI Courses (Primary Reference): NVIDIA DLI: Getting Started with Deep Learning; Generative AI with Diffusion Models (Instructor – Led Workshop) **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1 **MIT 6.S191 Reference:** https://introtodeeplearning.com/	
Module V: Advanced Deep Learning – Parallel Training, AI for Science & Ethical AI (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (Advanced Scalable Deep Learning): Multi-GPU deep learning, Memory optimization techniques, Scaling laws for deep learning, Mixture of Experts (MoE), NVIDIA Jetson and Edge AI, AI for Science, Ethical AI and responsible deployment NVIDIA DLI Final Project: End-to-end deep learning pipeline – dataset preparation, model selection, training with GPU cluster, evaluation, and deployment demonstration. MIT 6.S191 Supplementary (Lecture 6 – New Frontiers; Lecture 7 – AI for Science; Lecture 8 – Massively Parallel Training; Lecture 9 – Three Laws of AI): Case studies in large-scale model training; AI regulation; panel discussions on safe and beneficial deployment of AI systems.	
NVIDIA DLI Courses (Primary Reference): Fundamentals of Deep Learning for Multi-GPUs; Getting Started with AI on Jetson Nano **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1 **MIT 6.S191 Reference:** https://introtodeeplearning.com/	

AI Integration:

1. Implementation of deep learning workflows using TensorFlow and Keras on NVIDIA GPU cloud instances; data preprocessing with NumPy and Pandas; building, training, and evaluating neural network models using the NVIDIA DLI Jupyter notebook environment.
2. Training CNN models for image classification and object detection; applying data augmentation and transfer learning from pre-trained NVIDIA-supported models to achieve high validation accuracy on real-world visual datasets.
3. Implementing RNN and LSTM models for sequence prediction and NLP tasks; fine-tuning transformer-based LLMs using NVIDIA DLI labs; evaluating model performance using BLEU scores and perplexity metrics.
4. Building VAE and GAN architectures for image generation and data augmentation; evaluating generative models using FID scores and visual inspection; exploring RLHF techniques for LLM alignment.
5. Deploying trained DL models on NVIDIA Jetson devices using TensorRT; performing model quantization (INT8) and benchmarking inference throughput; documenting end-to-end pipeline performance.

Authentic Intelligence:

1. Understanding the ethical constraints of training deep learning systems on biased datasets; risks of deploying high-accuracy but poorly interpretable models in safety-critical applications such as medical diagnosis and autonomous driving.
2. Evaluating the societal impact of computer vision systems on privacy; understanding fairness, accountability, and transparency (FAccT) concerns in CNN-based face recognition and surveillance systems.
3. Risks of deploying large language models without adequate alignment; hallucination in LLMs, factuality concerns, and the importance of human oversight in transformer-based generative systems.
4. Ethical implications of generative AI including deepfakes, copyright infringement, and malicious content generation using GANs and diffusion models; responsible use policies and detection mechanisms.
5. Understanding Asimov's Three Laws of AI reframed for modern deep learning; governance challenges in deploying autonomous AI agents; the role of regulation, interpretability, and international AI safety frameworks

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the architecture, components, and training mechanics of deep neural networks including activation functions, forward and backward propagation, and optimization algorithms using GPU-accelerated environments.	**L2**
2	Analyse convolutional neural network architectures, data augmentation strategies, and transfer learning methods for accurate image classification and object detection tasks.	**L3**
3	Apply recurrent networks, LSTMs, attention mechanisms, and transformer models to design sequence models and NLP applications, leveraging pre-trained model fine-tuning.	**L3**
4	Design deep generative models (VAEs, GANs, Diffusion Models) to solve creative and decision-making problems in real-world applications.	**L4**
5	Evaluate advanced DL paradigms including large-scale parallel GPU training, AI for scientific discovery, and ethical implications of deploying AI systems responsibly in society.	**L5**

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	2	-	-	-	-	-	-	3	2
CO2	2	3	-	2	3	-	-	-	-	-	-	3	3
CO3	2	2	2	-	3	-	-	-	-	-	-	3	2
CO4	-	2	3	2	3	-	-	1	-	-	-	1	3
CO5	-	-	-	-	2	3	2	3	-	-	-	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. **Goodfellow, I., Bengio, Y., and Courville, A., 2016.** Deep Learning. MIT Press. [Available free at deeplearningbook.org]
2. **Chollet, F., 2021.** Deep Learning with Python. 2nd Edition. Manning Publications.
3. **Raschka, S. and Mirjalili, V., 2022.** Machine Learning with PyTorch and Scikit-Learn. Packt Publishing

REFERENCE BOOKS:

1. **Bishop, C.M., 2006.** Pattern Recognition and Machine Learning. Springer.
2. **Nielsen, M.A., 2015.** Neural Networks and Deep Learning. Determination Press. [Available free online]
3. **Aggarwal, C.C., 2018.** Neural Networks and Deep Learning: A Textbook. Springer.
4. **Prince, S.J.D., 2023.** Understanding Deep Learning. MIT Press.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	MIT 6.S191: Introduction to Deep Learning https://www.youtube.com/playlist?list=PLtBw6njQRU-rwp5__7C0oIVt26ZgjG9NI	Alexander Amini & Ava Amini	MIT (introtodeeplearning.com)
2	Deep Learning Specialization https://www.coursera.org/search?query=Deep%20Learning%20Specialization	Andrew Ng	Coursera / deeplearning.ai
3	Practical Deep Learning for Coders https://www.fast.ai/posts/2022-07-21-dl-coders-22.html	Jeremy Howard	fast.ai

CONTROL AUTOMATION AND INTELLIGENT MACHINES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. **Understand** the principles of various types of control systems, to derive transfer function and state space models of various physical systems.
2. **Analyse** the behaviour of a control system in time and frequency domains.
3. **Familiarising** different compensation methods.
4. **Analyse** the stability of a control system using time and frequency domain.
5. **Understand** the principles of various instrumentation and measurement systems.
6. **Understand** the applications of intelligent machines in control systems.

Teaching-Learning Process (General Instructions):

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: MATHEMATICAL MODELS OF CONTROL SYSTEMS	**09 Hours**

Concepts of Control Systems- Open Loop and closed-loop control systems, Classification of control systems, Feedback Characteristics-Effects of feedback.

Mathematical models of physical systems –Mechanical, Electrical and electromechanical. Transfer functions- Block diagram representation of systems, Block diagram algebra, Signal flow graph, Mason's gain formula.,

Applications: Mathematical modeling to everyday systems like cruise control and servo motors.

NVIDIA DLI Courses: Accelerating CAE with NVIDIA AI Physics Technology

MODULE – II: TIME DOMAIN ANALYSIS	09 Hours
Time responses of first-order and second-order systems, Time domain specifications, characteristic Equation, the concept of stability, Routh-Hurwitz stability criterion. Root locus concept, Effects of addition of poles and zeros on root locus plot. construction of root loci, Stability analysis using root locus. Applications : Stability analysis to safety-critical systems like ABS brakes and aircraft control.	
NVIDIA DLI Courses: Applications of AI for Predictive Maintenance	
MODULE – III: FREQUENCY DOMAIN STABILITY ANALYSIS	**09 Hours**
Frequency response characteristics, Frequency domain specifications, Bode plot, Transfer function from the Bode plot, Stability Analysis using Bode Plot, Lag compensation, Lead compensation, Lag-Lead compensation using Bode Plot. Applications : Frequency domain tools to practical filter and compensator design.	
MODULE – IV: STATE SPACE ANALYSIS	**09 Hours**
Concepts of state, state-space modeling for continues physical systems, Representation of state space model in different canonical forms, Transfer function. Eigen values, Eigen vectors, State Transition Matrix and its Properties, Solution of state equations, Controllability and Observability. **Applications :** State-space methods to modern multi-variable control in drones, spacecraft, and robots.	
MODULE – V: FOUNDATIONS OF INTELLIGENT MACHINES	**09 Hours**
Evolution from classical automation to intelligent machines; Laws of Robotics and modern AI ethics; Progressive advancements — from teleoperation to embodied AI. Taxonomy of intelligent machines: industrial manipulators, mobile robots, collaborative robots (cobots), service robots, humanoids, and autonomous mobile robots (AMRs). **Applications :** Warehouse AMRs (Amazon Kiva) · Surgical cobots (Da Vinci) · Self-driving cars (embodied AI).	
NVIDIA DLI Courses: A Beginner's Guide to Autonomous Robots Robotics Fundamentals Learning Path	

Artificial Intelligence:

1. Use NVIDIA AI Physics Technology (CAE) or MATLAB to auto-generate and verify transfer functions from physical system parameters, with AI-assisted block-diagram simplification.
2. Deploy an AI anomaly-detection model on a simulated control system to predict stability margins and transient response degradation from sensor data in real time.
3. Use AI-enabled sensor-processing tools to construct Bode plots from frequency-response data and automate compensator design verification.
4. Apply a deep-learning-based state estimator to a simulated multi-variable system and compare predicted states against the analytical solution of the state equations.
5. Run an NVIDIA Isaac Sim demo tracing the perception–planning–control loop for an AMR, documenting how each AI subsystem contributes to embodied intelligence.

Authentic Intelligence:

1. Hand-derive the transfer function of a given mechanical or electrical system, reduce its block diagram algebraically, and verify using Mason's gain formula.
2. Compute time-domain specifications (rise time, settling time, overshoot) for a second-order system by hand, plot the root locus, and verify stability via Routh–Hurwitz criterion.
3. Manually sketch the Bode plot for a given transfer function, determine gain and phase margins, and design a Lag–Lead compensator with analytical verification.
4. Derive the state-space model in controllable canonical form, compute eigenvalues and the State Transition Matrix, and test controllability and observability using Kalman's rank criteria.
5. Classify five real-world robotic systems across autonomy levels, mapping each to its sensing modalities, actuation strategy, and target application — defended in a short viva.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Modelling and Simplification** of any linear control system using block reduction and signal flow graph techniques	L2
2	**Analyze** the time domain, transient and steady state performance parameters of control systems for various error signals.	L4
3	**Evaluate** the stability of a system using time domain and frequency domain techniques and Design different compensators	L5
4	**Examine** the controllability and observability of control systems using the state space method.	L4
5	**Design and integrate** sensors, actuators, and controllers for intelligent machines.	L3

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	1	1	-	-	-	-	-	-	-	1	-
CO2	3	3	2	1	-	-	-	-	-	-	1	1	-
CO3	3	3	3	2	2	1	-	-	-	-	2	1	1
CO4	3	3	2	2	2	1	-	-	1	-	2	1	1
CO5	3	3	3	3	3	-	-	-	2	2	2	1	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. I.J. Nagrath and M. Gopal, "Control Systems Engineering", New Age International (P) Limited, Publishers, 6th edition,2021.
2. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, "Robotics: Modelling, Planning and Control", Springer, 2009.
3. Norman S. Nise, Control Systems Engineering, Wiley, 7th Edition,2024

REFERENCE BOOKS:

1. B. C. Kuo, "Automatic Control Systems", John wiley and sons, 8th edition, 2003.
2. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education, 3rd edition, 2005.
3. Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall of India Pvt. Ltd., 3rd edition,2020,

E-RESOURCES:

Sl no	**NPTEL Course Name**	**Instructor**	**Host Institute**
1	Control Systems Engineering https://nptel.ac.in/courses/107106081	Prof. C.S.Shankar Ram	IIT Madras
2.	Introduction to Robotics https://nptel.ac.in/courses/107106090	Prof. Asokan T	IIT Madras
3.	Robotics Learning Path https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-35+V1		NVIDIA

POWER ELECTRONICS FOR ELECTRIC VEHICLES AND SMART GRIDS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	04
Hours / Week	:	03 Hours	**Total Hours**	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students to

1. To provide a comprehensive understanding of the fundamentals of power electronic converters and devices.
2. To understand electric vehicle architecture and propulsion systems.
3. To analyze the interaction between batteries, power electronics, and electric drives using modeling and simulation by adopting AI tools.
4. To study charging techniques, battery management systems, and energy recovery mechanisms by adopting AI tools for modeling and simulation
5. To familiarize with current trends and challenges in electric vehicle development.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Fundamentals of Power Electronics	**09 Hours**

Power semiconductor devices- Diodes, SCRs, MOSFETs, IGBTs-Characteristics and switching behavior, **PWM techniques** for motor control.

Applications: Device selection for Power converter circuits, comparison of devices and selection for different applications

NVIDIA DLI Courses: Fundamentals of Deep Learning: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3

MODULE – II: PE Converters and their configurations used in Electric Vehicles	10 Hours
AC-DC: Semi-controlled and Fully Controlled Converters**, DC-DC**: Buck, Boost, Buck-Boost, **AC-AC Converters:** On-Off and phase control, cycloconverters, **DC-AC**- Single Phase Inverters, On-board and off-board chargers, charger classification (Level 1,2, DC Fast Charging) **Applications:** Electric Vehicles, SMPS	
MODULE – III: Electric Vehicle Architecture	**09 Hours**
Types of EVs-BEV, HEV, PHEV, FCEV. Vehicle layout: traction motor, inverter, gearbox, Drive cycles and energy consumption. **Applications:** Traction, Power Conversion, Regenerative Braking.	
MODULE – IV: Electric Machines and Drives	**08 Hours**
Motors in EVs: BLDC, PMSM, Induction Motors, Motor characteristics and selection, Inverter-motor interaction, Regenerative braking and torque control **Applications:** Speed Control, Traction Control	
NVIDIA DLI Courses: Computer Vision and Video Analytics Training: https://www.nvidia.com/en-in/training/instructor-led-workshops/deep-learning-for-intelligent-video-analytics/	
MODULE – V: Battery and Energy Management	**09 Hours**
Types of batteries: Li-ion, NiMH, solid-state. Battery modeling and parameters (SoC, DoD, C-rate), Battery Management Systems (BMS), Thermal management and safety, Energy regeneration and Vehicle-to-Grid (V2G), Monitoring, control **Applications:** UPS, Electric Vehicle, Charging System	
NVIDIA DLI Courses: Applications of AI for Anomaly Detection**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1**	

AI Integration:

1. Introduction to Python-based machine learning workflow, data preprocessing and feature engineering techniques, usage of libraries like NumPy, Pandas, and Scikit-learn for building and evaluating models.
2. Implementation of supervised learning algorithms using Scikit-learn, training and evaluating models using real-world datasets.
3. Implementing clustering and dimensionality reduction techniques using Scikit-learn, visualization of clusters using Python tools.
4. Implementation of graphical models and ensemble techniques using Scikit-learn, use of bagging and boosting methods, model evaluation with Out-of-Bag score.
5. Use of Grid Search and Random Search for hyperparameter tuning, implementation of validation techniques and performance metrics, application of optimization algorithms and regularization methods using Scikit-learn.

Authentic Intelligence:

1. Understanding well-posed learning problems and their real-world constraints, challenges in designing efficient learning systems, limitations of deep learning models, risks associated with poor feature selection and sampling bias, ethical considerations and responsible deployment of AI systems.
2. Interpretability of machine learning models, risks of incorrect predictions in automated decision-making systems.
3. Risks of misinterpreting clusters, responsible interpretation of patterns discovered from data.
4. Limitations of graphical and ensemble models, overfitting risks in boosting, interpretability challenges, and importance of responsible model selection.
5. Understanding overfitting and underfitting, bias-variance tradeoff, limitations of optimization methods, and importance of selecting appropriate validation and regularization techniques.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand** the operation and application of power semiconductor devices and converters.	L2
2	**Analyse** inverter and converter circuits used in electric vehicles using theoretical principles, simulation tools, and AI-assisted modelling techniques	L3
3	**Analyse** electric vehicle drivetrain components and energy storage systems using theoretical principles, simulation techniques, and AI-enabled modelling tools for performance prediction and optimization.	L3
4	**Design** and model basic charging systems and battery management systems by leveraging AI tools for monitoring, control, and intelligent decision-making.	L4
5	**Evaluate** and optimize the impact of power electronic converters on electric vehicle performance and energy efficiency using data-driven analysis and AI-assisted diagnostic techniques.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	1	2	1	1	1	2	1	3	-	2
CO2	3	2	1	1	3	2	1	1	2	1	3	-	2
CO3	3	2	2	2	3	2	2	2	2	2	3	-	2
CO4	3	2	3	3	3	2	2	2	2	2	3	-	2
CO5	3	2	3	3	3	2	2	2	3	2	3	-	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Muhammad, H.R., 2014. Power Electronics-Circuits, Devices, and Applications.4th Edition, Upper Saddle River, NJ, Pearson Prentice Hall.
2. Power Electronics, 2022, 3ed: Converters, Applications and Design (An Indian Adaptation) Ned Mohan, Tore M. Undeland, William P. Robbins
3. Larminie, J. and Lowry, J., 2012. Electric vehicle technology explained. 2nd Edition, John Wiley & Sons.
4. Emadi, A. ed., 2017. Handbook of automotive power electronics and motor drives. CRC Press.

REFERENCE BOOKS:

1. Bimal. K. Bose, 2002. Modern Power Electronics and AC Drives, 1st Edition, Pearson.
2. Sandeep Dhameja, 2001.Electric Vehicle Battery Systems, 1st Edition, Elsevier.
3. Ibrahim Dincer, Halil S. Hamut, Nader Javani, 2017. Thermal Management of Electric Vehicle Battery Systems, 1st Edition, Wiley Publishers

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Electric Vehicles and Renewable Energy https://onlinecourses.nptel.ac.in/noc21_ee112/preview	Prof. Ashok Jhunjhunwala, Prof. Kaushal Jha, Prof. L Kannan, Prof. Prabhjot Kaur	IIT Madras
2	Electric Vehicle Technology for Academia https://onlinecourses.swayam2.ac.in/e-learning/preview/ntr25_ed14	Dr. G.A. Rathy, Dr. R. Suja Mani Malar	National Institute of Technical Teachers Training and Research
3	AI in Electrical Technologies https://in.mathworks.com/videos/ai-in-electrical-technologies-1734712030943.html	Mohsen Aleenejad joined	MathWorks
4	AI Workflow for integration for Battery State of Charge https://in.mathworks.com/help/deeplearning/ug/define-requirements-for-battery-state-of-charge-estimation.html		Mathworks

RF AND MICROWAVE ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	04
Hours / Week	:	03 Hours	**Total Hours**	:	45+30 Hours
L–T–P	:	3–0–2			

Course Learning Objectives:

This course enables students to

This Course will enable students to:

1. To familiarize students with the importance of RF, microwave engineering and its applications in modern communication, radar, and satellite systems.
2. To apply the concepts of electromagnetic field theory and transmission line theory to analyze microwave transmission lines, standing waves, and impedance characteristics.
3. To understand microwave network characterization techniques, including scattering matrix (S-matrix), S-parameters, and relationships between different network parameters. And To study microwave passive components and ferrite devices such as directional couplers, T-junctions, isolators, and circulators used in microwave systems.
4. To understand the construction and operation of microwave tubes and semiconductor devices, including klystron, magnetron, TWT, Gunn diode, PIN diode, and Schottky diode.
5. To analyze microwave measurements and planar transmission lines, and explore the application of AI-assisted tools for modeling, parameter prediction, and microwave circuit optimization.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Introduction to Transmission Line Theory	**10 Hours**

Microwave frequencies, Microwave devices and Microwave Systems, RF behavior of resistor, capacitor, inductor. TransmissionLine Equations and Solutions. Reflection Coefficient and Transmission Coefficient, standing wave and standing-wave ratio, Line Impedance and Admittance (Derivations are excluded), Smith Chart and Impedance Matching.

Applications: Measuring VSWR using slotted line setup. Smith chart-based impedance matching in antennas.

MODULE – II: Microwave Network Characterization and Passive Devices	**10 Hours**
The scattering Matrix – Reciprocity Theorem- Lossless networks and unitary conditions- ABCD parameters- Cascaded networks-Relations between S- Y and ABCD parameters (Derivations are excluded).. Properties and s-matrices for typical network such as section of uniform transmission line, 3-port networks (reciprocal and nonreciprocal), T-junctions directional coupler, magic tee, ferrite devices, isolator, circulators. **Applications:** Antenna feed networks: directional couplers and power dividers. Magic tee as microwave mixer.	
MODULE – III: Microwave Tubes and Semiconductor Devices	**09 Hours**
Klystron, Multi-cavity Klystron, Reflex klystron, velocity modulation, transit time, density modulation, beam spreading/ de-bunching, power output and efficiency, Travelling Wave Tube, Magnetron. Gunn diode and its applications, PIN diode, Schottky barrier diodes. (For all the devices: only constructions, operation, definition with explanation and end equations are included. Derivations are excluded). **Applications:** Radar transmitters, Microwave ovens.	
MODULE – IV: Microwave Measurements	**08 Hours**
Introduction, tunable detector, Slotted line carriage, VSWR meter, Spectrum Analyzer, Power Measurements, Insertion loss and attenuation measurements, VSWR Measurements, Return loss measurements by reflectometer, Impedance measurement,frequency measurements. **Applications:** Testing labs: VSWR, return loss measurement, frequency & wavelength. Insertion loss and attenuation measurement.	
MODULE – V: Planar Transmission Lines	**08 Hours**
Planar transmission lines such as strip line, micro-strip line, slot line and coplanar waveguides. Characteristics of planar transmission lines. Losses in Micro-strip Lines- Quality Factor Q of Micro-strip Lines: - Properties of materials (Substrate, Conductor, Dielectric and Resistive). Introduction to MIC's:-Technology of hybrid MICs, monolithicMICs, comparison of both MICs. **Applications:**Analysis of characteristic impedance of planar transmission lines in MATLAB. Predict impedance based on dimensions using ML.	

AI Integration:

1. AI/ML models are used to predict reflection coefficient, VSWR, and impedance matching conditions from transmission line parameters.
2. Machine learning techniques assist in predicting S-parameters for passive microwave networks such as directional couplers and T-junction.
3. AI-based regression models are applied to predict device characteristics such as frequency vs voltage in klystrons and Gunn diodes.
4. AI techniques to measure parameters such as return loss, insertion loss, and VSWR.
5. Machine learning models are applied to predict characteristic impedance based on geometrical and material parameters of microstrip and stripline structures

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Authentic Intelligence:

1. Understanding Data Quality & Limitations: Recognize the importance of accurate experimental data (VSWR, S-parameters, impedance) and understand how noise, measurement errors, and improper preprocessing can affect ML model predictions.
2. Model Selection & Overfitting Awareness: Choose appropriate ML models (regression, curve fitting) for impedance and S-parameter prediction, while avoiding overfitting and ensuring models generalize well to new microwave datasets.
3. Interpretability of AI Predictions: Analyze whether AI-generated outputs (Smith chart matching, impedance prediction) are physically meaningful and consistent with transmission line theory.
4. Bias, Error & Reliability in RF & MW Systems: Understand risks of incorrect predictions in microwave systems (e.g., mismatch losses, incorrect S-parameters) and evaluate model reliability before practical implementation.
5. Ethical & Responsible Use of AI Tools: Ensure responsible use of AI by validating results with theoretical calculations and simulations, avoiding blind dependence on AI for critical design decisions.

Lab Experiments :

S.No	Experiment	AI Tool	Utility
1.	Study of Reflex Klystron Oscillator Mode Characteristics	MATLAB + Python. /Test Bench	Predict oscillation modes, frequency vs voltage characteristics - reduces repeated tuning and improves accuracy
2.	Frequency & Wavelength Measurement using Slotted Line- Direct Method	Test Bench	Wavelength & Frequency Determination
3.	Frequency & Wavelength Measurement using Slotted Line- In Direct Method	Test Bench	Wavelength & Frequency Determination
4.	Characteristics Gunn Diode Characteristics	MATLAB + Python. /Test Bench	Voltage characteristics
5.	Study of isolator (S-Parameter Extraction)	Test Bench + MATLAB RF Toolbox /	Automates S-parameter extraction and predicts insertion loss & isolation performance
6.	Study of circulator (S-Parameter Extraction)	Test Bench + MATLAB RF Toolbox /	Automates S-parameter extraction and predicts insertion loss & isolation performance
7.	Study of E-plane, (Waveguide Tees)	Test Bench + Python	Predicts power division, phase shift & port characteristics
8.	Study of H- (Waveguide Tees)	Test Bench + Python	Predicts power division, phase shift & port characteristics
9.	Study of Magic Tee (Waveguide Tees)	Test Bench + Python	Predicts power division, phase shift & port characteristics
10.	Study of Directional Coupler (S-Parameters)	Python (Scikit-learn) + MATLAB /Test Bench	Predict coupling factor, directivity & isolation - reduces manual calibration errors
11.	Reflection Coefficient Measurement using Smith Chart (Magnitude & Phase)	MATLAB + Python (AI-based impedance matching tool). Test Bench	Computes reflection coefficient and suggests impedance matching solutions
12.	Measurement of Input Impedance using Smith Chart	Python + MATLAB RF Toolbox.	Predicts impedance variation with frequency for faster optimization
13.	Analysis of Characteristic Impedance in Planar Transmission Line	MATLAB RF Toolbox + AI	Predicts characteristic impedance for different geometries
14.	Open ended experiments	Python + MATLAB RF Toolbox.	
15.	Open ended experiments	HFSS	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Analyze microwave frequency spectrum and transmission line theory, including reflection coefficient, standing waves, VSWR, and impedance matching using Smith chart, and utilize AI-based computational tools to evaluate transmission line parameters.	L3
2	Analyze microwave networks using S-parameters and ABCD parameters, and evaluate the performance of passive microwave devices such as directional couplers and magic tee using AI-based data modeling techniques.	L4
3	Explain the construction and operation of microwave tubes and semiconductor devices such as klystron, magnetron, TWT, Gunn diode, PIN diode, and Schottky diode, and apply AI-assisted modeling methods to analyze device characteristics including output power and efficiency.	L3
4	Perform microwave measurements such as VSWR, insertion loss, return loss, impedance, and frequency using microwave instruments and interpret the measured results.	L3
5	Understand & explain planar transmission lines and microwave integrated circuits (MIC and MMIC) used in microwave systems. and use AI-based optimization tools to analyze and improve microwave circuit parameters.	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	–	2	–	–	–	–	–	-	3	1
CO2	3	3	1	1	3	–	–	–	2	–	-	3	2
CO3	3	2	1	–	2	–	–	–	2	–	-	3	2
CO4	2	2	2	3	3	–	–	1	2	–	-	2	3
CO5	3	2	2	–	3	-	–	–	1	–	1	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Samuel Y. Liao - *Microwave devices and Circuits",* Prentice Hall of India, New Delhi,3rd Ed. 2006.
2. Annapurna Das and Sisir K .Das - *Microwave Engineering* – Tata McGraw Hill, New Delhi, 2008

REFERENCE BOOKS:

1. R.E. Collin - *Foundations for Microwave Engineering*. - IEEE Press Second Edition .2002.
2. David M. POZAR - *Microwave Engineering.* - John Wiley & Sons - 2nd Edition 2003.
3. Rizzi P.A, - *Microwave Engineering, Passive Circuits.* Prentice Hall of India.1988.

E-Resources:

Sl no	Course Name	Instructor	Host Institute
1	Microwave Theory and Techniques https://nptel.ac.in/courses/108101112	Prof. Girish Kumar	IIT Bombay
2.	RF and Microwave Networks https://nptel.ac.in/courses/108105189	Prof. Bratin Ghosh	IIT Kharagpur
3.	Microwave Integrated Circuits https://nptel.ac.in/courses/117101119	Prof. Jayanta Mukherjee	IIT Bombay

WIRELESS COMMUNICATION

[As per Choice Based Credit System (CBCS)scheme]

SEMESTER - VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the functioning of various wireless communication systems, their revolution and standards.
2. Analyze one cellular communication system, architecture, functioning, various standards
3. Visualize signal propagation in cellular environment
4. Develop skills on multiple access techniques for Wireless Communication
5. Evaluate the functioning of architecture, protocols, capabilities and application of various wireless communication networks.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note taking, annotating, and role playing.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world***-and when that's possible, it helps improve the students' understanding.

MODULE – I: Fundamentals of Cellular Communication and Wireless Propagation	**10 Hours**

Evolution of mobile radio communication fundamentals 1G, 2G. 2.5G, 3G and beyond), General Model of Wireless Communication Link, Types of Signals, Cellular Infrastructure, Cellular System Components, Antennas for Cellular Systems, Operation of Cellular Systems, Channel Assignment, Channel Assignment strategies, Handoff Strategies Cellular Interferences, Sectorization; Wireless Channel and Radio Communication, Free Space Propagation Model, Channel Noise and Losses, FadinginLandMobileSystems,MultipathFading,FadingEffectsonSignalandFrequency, Shadowing.

Application: Used in modern cellular networks (4G/5G) to provide reliable, high-speed wireless communication services.

MODULE – II: Cellular System Design	**09 Hours**
The cellular fundamentals: cellular communication and frequency reuse, general architecture of a cellular system, channel assignment strategies, hand-off in a cellular system. Interference and cellular system capacity: co-channel interference and adjacent channel interference, power, typical cellular standards (AMPS, GSM, GPRS, WCDMA, LTE, concept of LTE-advanced), 4G features and challenges, 5G vision. **Application:** Applied in modern cellular networks like **LTE** and **5G** to enable efficient spectrum use, seamless mobility, and high-speed, reliable wireless communication for mobile users.	
MODULE – III: Wireless Channel & Propagation	**09 Hours**
Signal propagation in mobile communication: mobile cellular environment, multipath propagation and fading, free space propagation model, propagation path loss, outdoor propagation models (Okumura model & Hata model), indoor propagation models, power delay profile, channel parameters (delay spread, Doppler spread, coherence bandwidth, coherence time). **Application:** Applied in modern wireless systems like **LTE** and **5G** to model real-world channel behavior and design reliable, high-speed mobile communication links under varying environmental conditions.	
MODULE – IV: Wireless Networks	**09 Hours**
Wireless Communication Networks: Wireless Personal Area Networks (Bluetooth, UWB and ZigBee), Wireless Local Area Networks (IEEE 802.11, network architecture, medium access methods, WLAN standards), Wireless Metropolitan Area Networks (WiMAX), Ad-hoc Wireless Networks. **Application:** All these wireless communication network technologies are applied in systems like **IEEE 802.11**, **Bluetooth**, and **WiMAX** to enable short-range, local, and wide-area wireless connectivity for devices, supporting applications such as IoT, home networking, and smart infrastructure.	
MODULE – V: Multiple Access Techniques	**08 Hours**
Multiple access schemes: duplexing schemes, FDMA, TDMA, SDMA, spread spectrum technique and CDMA, OFDMA, ALOHA and CSMA. Survey of Cutting-edge technologies on5G and 6G such as millimeter wave systems. **Application:** All these multiple access and duplexing techniques are applied in modern cellular systems like **5G** and emerging **6G.**	

AI Integration:

1. AI-Based Network simulation and analysis of cellular system capacity and interference **Using MATLAB Copilot.**
2. AI-Based Modulation / Access Scheme Selection-**Using MATLAB Copilot** to generate classification model.
3. AI-Based Simulation and analysis of wireless network protocols and IoT communication-**Using MATLAB Copilot.**

Authentic Intelligence:

1. AI-Based Network Simulation & Analysis (Capacity & Interference)
    - Uses **data-driven models** instead of fixed analytical methods
    - Adapts simulation based on changing network conditions
    - Optimizes performance metrics like throughput and signal quality
    - Provides realistic and dynamic analysis of cellular systems
2. Interpretability of an **adaptive, data-driven decision engine** that dynamically selects the optimal **modulation scheme** (e.g., QPSK, 16-QAM, 64-QAM).
3. AI-Based Simulation & Analysis of Wireless Protocols and IoT
    - Performs **intelligent analysis of protocols** under varying conditions
    - Adapts to IoT constraints like low power and latency
    - Supports scalable and efficient communication
    - Enables context-aware decision-making

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Examine** the functions and services of cellular networks and simulate free space propagation, fading models and analyze signal degradation.	L2
2	**Analyze** a wireless cellular system and design a cellular network model by studying frequency reuse and interference effects.	L3
3	**Develop** indoor and outdoor prorogation models in mobile communication such as Okumura HATA model and implement Okumura-HATA path loss models and plot propagation curves.	L4
4	**Evaluate** different wireless standards and Bluetooth communication and simulate ZigBee / WLAN networks and analyze packet communication	L5
5	**Analyze** multiple access technologies like CDMA,TDMA, FDMA and simulate TDMA/CDMA communication systems.	L5

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	2	-	-	-	-	2	2	2	-	3	-
CO2	3	2	2	2	-	-	-	2	-	2	2	3	2
CO3	3	2	3	2	-	2	2	2	-	2	2	3	2
CO4	3	3	2	3	2	2	2	2	2	2	2	3	3
CO5	3	2	2	3	-	2	2	2	2	2	2	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. **WirelessCommunications:Principles&Practice,**T.S.Rappaport,2ndEd.,Prentice Hall, 2002
2. **Wireless Communications & Networks**, W. Stallings, 2ndEd.,Prentice-Hall,2005.

REFERENCE BOOKS:

1. Vijay K Garg, "Wireless Communications and Networks", Morgan Kaufmann Publishers an Imprint of Elsevier, USA 2009 (Indian reprint)
2. J.Schiller,"MobileCommunication"2/e,PearsonEducation,2012.
3. ItiSahaMisra,"WirelessCommunicationandNetworks:3GandBeyond",2/e,McGrawHil l Education (India) Private Ltd, New Delhi, 2013.
4. Wireless Communications by Andrea Goldsmith Cambridge University press 2005.

E-Resources:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Electronics & Communication Engineering-Wireless Communication 1. NPTEL::Electronics&CommunicationEngineering-WirelessCommunication	Prof. Dr. Ranjan Bose	Indian Institute of Technology, Delhi

PHOTONICS AND OPTICAL COMMUNICATION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To learn the basic of photonics, source and receiver configurations.
2. To understand the fiber optical network components and losses in optical fiber communication link.
3. To learn the optical wireless communication in various medium with Radiative Transfer Equation.
4. SONET/SDH and operational principles WDM.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:

Module 1: Fundamentals of Optics and Photonics	**09 Hours**

Fundamental principles of photonics and light-matter interactions, Quantum Nature of Light Wave phenomena – Interference, Diffraction, Coherence, Photon properties - energy, flux, statistics, Interaction of photons with atoms.

Application: optical sensors, photonic integrated circuits, and quantum information technology

MODULE 2: Optical sources, detector, receiver and optical link design	**09 Hours**
Optical Sources: Light source materials, LED Structures; LED Characteristics; Semiconductor Laser Diode, LASER Characteristics, Photo detectors, Photo detector noise, Response time, double heterojunction structure, Photo diodes, comparison of photo detectors, Optical receiver operation, Receiver design, Receiver Noise; Receiver sensitivity, Eye diagrams, Optical Link Design: Point-to point links, System considerations; Link Power budget. **Application:** optical communication system	
MODULE 3: Optical fiber communication	**09 Hours**
Elements of Optical Fiber communication, applications of optical fiber communication: Ray theory, Total Internal reflection, Skew rays, Overview of Modes: Cut-off wavelength, V number, Fiber types: SI, GI, MM, SM, Special Fibers: Polarization, transmission characteristics of optical fibers Attenuation: Material Absorption, Scattering, bending and core cladding losses, Overview of Signal dispersion in Fibers, its limitations, Intermodal dispersion, Intra-Modal dispersion.	
Relevant NVIDIA DLI Courses: 1. Fundamentals of Accelerated Computing with CUDA Python https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-AC-10+V1	
MODULE 4: Optical wireless communication: Free space and underwater	**09 Hours**
Fundamental principles of OWC, (b) devices and systems, (c) modulation techniques and (d) channel models and system performance analysis, challenges encountered in OWCs as well as o possible solutions and current research trends. **Application:** Design of free space and underwater communication system	
Relevant NVIDIA DLI Courses: 1. Fundamentals of Deep Learning https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2	
MODULE 5: Optical networks	**09 Hours**
Basic networks-SONET/ SDH-wavelength routed networks - Nonlinear effects on network performance, performance of various systems (WDM, DWDM + SOA).	

AI Integration:

1. AI-based optimization of the channel performance of the optical communication system.
2. Machine learning for estimation of BER of communication system

Authentic Intelligence:

1. AI algorithms dynamically select channels and manage interference, improving throughput and reducing bit error rates.
2. Deep learning optimizes geometric constellation diagrams, enabling higher spectral efficiency and secure transmission.
3. Neural networks outperform traditional methods like SVM and k-NN in correcting transmission errors.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand** the basic of photonics and optical source and detector configurations	L2
2	**Examine** the Transmission characteristics of optical fibers by understanding Attenuation, Signal dispersion in Fibers Intermodal dispersion, Intra-Modal dispersion, Nonlinear effects, Fiber alignment and Joint Loss.	L4
3	**Calculate** Link budget of optical wireless communication system by studying the characteristics and properties of optical sources, detectors and receivers	L3
4	**Model** optical networks using SONET/SDH and understand optical transport networks	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	2	-	-	-	-	2	2	1	-
CO2	3	2	-	2	2	-	-	-	-	2	2	1	-
CO3	3	3		2	3	-	-	-	2	2	2	1	-
CO4	3	3		3	3	-	-	-	2	2	3	1	-
CO5	3	3		3	3			-	2	2	3	1	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Optical Communication System, J.Gower, Prentice Hall Of India, second edition, 2001.
2. Optical Networks, Rajiv Ramaswami, Second Edition, Elsevier, 2004.
3. Optical Fiber Communication, Gred Keiser, McGraw Hill Education (India) Private Limited. Fifth Edition, Reprint 2013.

REFERENCE BOOKS:

1. Advanced Optical Wireless Communication Systems, Shlomi Arnon, John Barry, George Karagiannidis, Robert Schober, and Murat Uysal, CAMBRIDGE UNIVERSITY, First edition, 2012.
2. Optical Wireless Communications System and Channel Modelling Z. Ghassemlooy W. Popoola S. Rajbhandari, CRC, second edition,2019.

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Introduction to Photonics nptel.ac.in/courses/108106135	Prof. Balaji Srinivasan	IIT Madras

Department of Electronics and Communication Engineering

DIGITAL IMAGE PROCESSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand fundamentals of digital image representation and processing
2. Apply image enhancement and restoration techniques
3. Analyze image segmentation and feature extraction methods
4. Introduce computer vision concepts and object recognition
5. Explore AI/ML approaches in vision systems.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Discuss how every ***concept can be applied to the real world*** – and when that's possible, it helps improve the students' understanding.
7. **Problem-based learning** (adaptive filter design cases)
8. **GPU-based simulation** demonstrations (NVIDIA tools)
9. Group discussions on **real-world applications** (5G, biomedical signals)
10. **Case studies on AI-enabled signal processing**
11. Encourage **mini-projects** on adaptive filtering applications

MODULE – I: Digital Image Fundamentals	**09 Hours**

Image formation and representation, Sampling and quantization, Intensity transformations
Spatial domain filtering, Histogram processing

Applications:

- Medical imaging (X-ray, MRI enhancement)
- Satellite image preprocessing

NVIDIA DLI Courses:

- Fundamentals of Deep Learning
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3

MODULE – II: Image Enhancement in Frequency Domain	**08 Hours**
Fourier Transform in image processing, Frequency domain filtering (LPF, HPF, Band-pass), Homomorphic filtering, Image smoothing and sharpening **Applications:** • Noise removal in images • Edge sharpening in industrial inspection	
NVIDIA DLI Courses: • Fundamentals of Accelerated Data Science • https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-DS-02+V2	
MODULE – III: Image Restoration & Morphological Processing	**08 Hours**
Image degradation model, Noise models (Gaussian, Salt & Pepper), Restoration techniques (Inverse, Wiener filtering), Morphological operations: Dilation, Erosion, Opening and Closing **Applications:** • Biomedical image cleaning • OCR preprocessing	
NVIDIA DLI Courses: • CUDA Optimization Tools • https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-AC-03+V2	
MODULE – IV: Image Segmentation & Feature Extraction	**10 Hours**
Edge detection (Sobel, Canny, Prewitt), Thresholding techniques, Region-based segmentation, Feature extraction: Shape features,Texture features **Applications:** • Tumor detection • Object boundary detection	
NVIDIA DLI Courses: • AI for Anomaly Detection • https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1	
MODULE – V: Computer Vision & AI Integration	**10 Hours**
Introduction to Computer Vision, Image classification and object detection, Feature descriptors (SIFT, SURF basics), Deep learning for vision: CNN fundamentals, Transfer learning **Applications:** • Autonomous vehicles • Face recognition • Surveillance systems	
NVIDIA DLI Courses: • Deep Learning Learning Path • https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3 • Build High-Performance and AI-Enabled Sensor Processing Applications • https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-30+V1	

AI Integration:

1. CNN-based object detection
2. GPU acceleration for real-time vision
3. Applications in healthcare, robotics, and smart cities

Authentic Intelligence:

1. Combines engineering knowledge with AI
2. Enhances interpretability of adaptive models
3. Supports human-in-the-loop systems
4. Ensures ethical AI deployment

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand** digital image representation, sampling, and processing fundamentals	L2
2	**Apply** image enhancement, restoration, and filtering techniques to improve image quality	L3
3	**Analyze** image segmentation and feature extraction methods for meaningful interpretation	L4
4	**Evaluate** feature extraction and computer vision techniques for real-world applications	L5
5	**Design** AI-based computer vision systems for practical and real-time applications	L6

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	–	–	1	–	–	–	–	–	1	2	–
CO2	3	3	2	2	2	–	–	–	–	–	1	2	1
CO3	3	3	2	2	2	–	–	–	–	–	1	2	1
CO4	3	3	3	3	3	1	–	1	2	1	2	2	2
CO5	3	2	3	2	3	2	1	2	2	2	3	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXTBOOKS:

1. Digital Image Processing using Matlab, Rafeal C. Gonzalez, Richard E. Woods, Steven L. Eddins, Pearson Education, 4th Edition, 2018.
2. Digital Image Processing- Rafeal C. Gonzalez, Richard E. Woods, 3rd Edition, Pearson, 2008.
3. Digital Image Processing- S Jayaraman, S. Essakkirajan, T. Veerakumar-TMH,2010.

REFERENCE BOOKS:

1. Fundamentals of Digital Image Processing-A.K. Jain,PHI,1989.
2. Digital Image Processing using Matlab, Rafeal C. Gonzalez, Richard E. Woods, Steven L. Eddins, Pearson Education. 2003
3. Digital Image Processing with MATLAB & Labview - Vipula Singh Elsevier.2019
4. Sandipen Dey, "Hands on Image Processing with Python", Packt Publishing Ltd, 2023.

E-Resources:

Sl no	Course Name	Instructor	Host Institute
1	Computer Vision And Image Processing https://onlinecourses.nptel.ac.in/noc26_ee31/preview	Prof. M.K. Bhuyan	IIT Guwahati
2.	Digital image Processing IIT https://www.iitmandi.ac.in/pdf/senate_courses/EE608.pdf https://www.cse.iitd.ac.in/~pkalra/col783/		NPTEL
3.	Image Processing Using Python https://onlinecourses.swayam2.ac.in/nou23_cs15/preview	Mrs. Bharati Pate	SWAYAM
4.	Digital Image Processing https://nptel.ac.in/courses/117105135	Prof. Prabir Kumar Biswas	IIT Kharagpur

DIGITAL IC DESIGN

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To understand the basic concepts of digital IC design.
2. To understand different implementation strategies of ICs.
3. To understand the concept of fast adders and their performances
4. To understand the concept of fast multipliers and their performances
5. To analyze different kinds of timing issues that occur in digital ICs.
6. To know different techniques for memory design and their performances.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Implementation Strategies for Digital ICs	**09 Hours**

Introduction, From Custom to Semi-custom and Structured Array Design Approaches, Custom Circuit Design, Cell-Based Design Methodology, Standard Cell, Compiled Cells, Microcells, Mega cells and Intellectual Property, Semi-Custom Design Flow, Array-Based Implementation Approaches, Pre-diffused (or Mask-Programmable) Arrays, Pre-wired Arrays.

Applications: ASIC design flow, System-on-Chip (SoC) development

MODULE – II: Timing Issues in Digital Circuits	**09 Hours**
Introduction, Timing Classification of Digital Systems, Synchronous Interconnect, Mesochronous interconnect, Plesiochronous Interconnect, Asynchronous Interconnect, Synchronous Design-An In-depth Perspective, Synchronous Timing Basics, Sources of Skew and Jitter, Clock-Distribution Techniques, Latch-Based Clocking, Self-Timed Circuit Design, Self-Timed Logic - An Asynchronous Technique, Completion-Signal Generation, Self-Timed Signaling, Practical Examples of Self-Timed Logic, Synchronizers and Arbiters, Synchronizers-Concept and Implementation, Arbiters. **Applications:** High-speed processor design, Chip-to-chip communication.	
MODULE – III: Design of Fast Adders	**10 Hours**
Introduction, Data-paths in Digital Processor Architectures, Analysis of Ripple carry adders, carry look-ahead, conditional sum adder, prefix adders: Brent-kung and Kogge-stone adder, carry select adders, carry skip adders, carry-save adders, Binary Shifter, Barrel Shifter, Logarithmic Shifter **Applications:** Arithmetic Logic Unit (ALU) design, Digital Signal Processors (DSPs)	
MODULE – IV: Design of Fast Multipliers	**07 Hours**
Array multiplier design, Fast multipliers: Reducing partial products, Booth's multiplier, implementing bigger multipliers using smaller ones, accumulation of partial products using carry save adders, 4:2 compressor implementation, Wallace tree multipliers. **Applications:** Digital Signal Processing (FIR filters), Machine Learning accelerators.	
MODULE – V: Designing Memory and Array Structures	**10 Hours**
Introduction, Memory Classification, Memory Architectures and Building Blocks, The Memory Core, Read-Only Memories, Nonvolatile Read-Write Memories, Read-Write Memories (RAM), Contents-Addressable or Associative Memory (CAM), Memory Peripheral Circuitry, The Address Decoders, Sense Amplifiers, Voltage References Drivers/Buffers, Timing and Control, Memory Reliability and Yield, Signal-To-Noise Ratio, Memory yield. **Applications:** Processor caches, Embedded memory systems, High-performance computing.	

AI Integration:

(Python + SPICE parametric sweep + ML regression for design optimization)
Sample workflow:

1. Synthesize adder variants (Ripple, CLA, Kogge-Stone) with different bit-widths
2. Extract timing/power/area reports from synthesis tool (or estimate via gate counts)
3. In Python:
    - Build a dataset: {architecture, bit-width, tech node} → {delay, power, area}
    - Train a decision tree to recommend architecture for given constraints
    - Visualize Pareto fronts (speed vs. power)
4. Students critique AI recommendations against hand analysis

Authentic Intelligence:

1. AI-Assisted Design Space Exploration
2. Cadence Simulations v/s AI Predicted parameters

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Analyze** digital IC implementation strategies	L4
2	**Analyze** timing challenges in synchronous/ asynchronous systems and **apply** clock distribution/self-timed techniques.	L4
3	**Design** and **analyze** the performance of fast adders and compare their design performance and also design high-speed shifters	L4
4	**Analyze** and **implement** fast multipliers	L4
5	**Design** memory subsystems with peripheral circuits and **assess** reliability/yield factors	L3

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	3	1	-	-	-	-	-	-	-	-	2	-
CO2	2	3	1	-	-	-	-	-	-	-	-	2	-
CO3	1	3	3	-	-	-	-	-	-	-	-	2	-
CO4	2	3	3	-	-	-	-	-	-	-	-	2	-
CO5	1	2	3	-	-	-	-	-	-	-	-	2	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Jan M Rabaey, Digital Integrated Circuites – A design perspective', 2nd Edition 2016.

REFERENCE BOOKS:

1. Neil H.E. Weste, David Money Harris, Ayan Banerjee CMOS VLSI Design: ACircuits and Systems Perspective, 4th edition 2015.
2. Israel Koren, Computer arithmetic algorithms, 2nd Edition 2018, A K Peters, Natick, Massachusetts

E-Resources:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Digital IC Design (https://nptel.ac.in/courses/108106158)	Prof. Janakiraman	IIT Madras

APPLIED MODEL BASED DESIGN

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:	26EC3611	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. To understand the lifecycle of Model Based Design and appropriate tool chains and togain fundamental Knowledge of MATLAB Programming.
2. To apply the basic modelling techniques to design Systems, model Equations and Debug using Simulink tool.
3. To create models for various physical domains such as electrical, mechanical, and hydraulic using Simscape tool.
4. To create models based upon transitions between states using Stateflow tool.
5. To generate codes automatically for developed models and implement on physical processors or controllers.
6. To test the models, software, and hardwire in line with the MATLAB/SIMULINK tool

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning*** which thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding

MODULE – 1: Fundamentals of Model-Based Design	**08 Hours**

Fundamentals of Model-Based Design (Definition and principles, Advantages of MBD over traditional design methods Tools and Platforms for MBD, Overview of tools like MATLAB/Simulink, LabVIEW, Introduction to toolchains and integration), MBD Workflow (Requirements gathering, Model creation and simulation, Code generation and deployment), Applications of MBD in Various Industries (Automotive, aerospace, and robotics, Case studies and examples), and Introduction to System Modelling (Types of models: physical, mathematical, and simulation models, Levels of modelling: system-level, component-level, and detailed modelling).

Applications: Role in every product development cycle in industry.
MODULE – 2: Introduction to Applied Modeling **07 Hours**
Modelling of Ordinary Differential equations, Modelling the Difference equations, Modelling Flow Charts according to the requirements of the system, Modelling State Machines based on the Input and transition conditions, State flow Modelling of System, Introduction to Plant Modelling, and Introduction to Data-Driven Modelling. **Applications:** Role in every product development cycle in industry.
MODULE – 3: MATLAB Programming **11 Hours**
Working with the MATLAB User Interface (Exploring MATLAB working environment, Reading data from files, Saving and loading variables, Plotting data, Customizing plots, Variables and Commands, Entering commands, Creating numeric and character variables, Making and annotating plots, Getting help, Creating and running live scripts), Analysis and Visualization with Vectors (Creating and manipulating matrices, Performing calculations with matrices, Calculating statistics with matrix data, Matrix Indexing Techniques, Visualizing matrix data), Tables of Data (Storing data as a table, Operating on tables, Extracting data from tables, Modifying tables), Conditional Data Selection (Logical operations and variables, Finding and counting, Logical indexing), **Applications:** Role in modelling of any systems in MATLAB in Industry.
MODULE – 4: Simulink Modelling **10 Hours**
Creating and Simulating a Model (Introduction to the Simulink interface, Potentiometer system, System inputs and outputs, Simulation and analysis), Modeling Programming Constructs, Comparisons and decision statements, Vector signals, PWM conversion system, Zero crossing, MATLAB Function block), Developing Model Hierarchy (Subsystems, Bus signals, Masks), Solver Selection (Solver behavior, System dynamics, Discontinuities, Algebraic loops), and Debugging of Models. **Applications:** Role in modelling of any systems in MATLAB in Industry.
NVIDIA DLI Courses: No DLI course is suitable for this module.
MODULE – 5: Stateflow and Simscape **09 Hours**
State flow Modeling Flow Charts (Stateflow overview, States, actions, and execution, Types of states, Transitions and action, Data in a Stateflow chart, Flow chart behaviour, Stateflow interface, Conditions and condition actions, Chart data), Introduction to Simscape (Differences between Simulink and Simscape, Building and simulating a model in Simscape, Guidelines for Simscape modelling), Working with the various Simscape Components (Describing Simscape component fundamentals, Using the Simscape Foundation Library, Setting initial conditions and logging physical variables), Combining Simscape Models and Simulink Models (Connecting physical signals and Simulink signals, Performing operations on physical signals, Controlling physical models, Solving models with Simscape and Simulink blocks), Modeling Conditionally Executed Algorithms (Conditionally executed subsystems, Enabled subsystems, Triggered subsystems, Input validation model, Common patterns) **Applications:** Role in modelling of any systems in MATLAB in Industry.

AI Integration: Applied Model-Based Design using MATLAB/Simulink

1. Introduction to Model-Based Design (MBD) with AI context: fundamentals of system modeling, simulation, and verification using MATLAB and Simulink; representation of dynamic systems, control logic, and signal flow; role of AI in enhancing model accuracy, automation, and predictive capabilities.
2. Integration of AI algorithms within Simulink models: implementation of machine learning models (regression, classification) using MATLAB toolboxes; incorporation of trained AI models into Simulink for tasks such as system identification, fault detection, and predictive maintenance in engineering systems.
3. Application of deep learning in model-based systems: deployment of neural networks (CNNs, LSTMs) using MATLAB Deep Learning Toolbox; integration with Simulink for real-time applications such as autonomous systems, control optimization, and signal-based decision-making.
4. Co-simulation and hybrid system design: combining physics-based models with AI-driven components; use of Simulink blocks for integrating traditional control systems (PID, state-space models) with AI models for adaptive and intelligent system behavior.
5. Optimization, code generation, and deployment: model optimization using parameter tuning and AI-assisted design space exploration; automatic C/C++ code generation using Simulink Coder for embedded systems; deployment on real-time hardware platforms with considerations for latency, resource constraints, and system reliability.

Authentic Intelligence: Applied Model-Based Design using MATLAB/Simulink

1. **Understanding well-posed Model-Based Design (MBD) problems and real-world constraints:** challenges in accurately modeling dynamic systems with uncertainties, noise, delays, and nonlinearities; limitations of ideal assumptions in simulation versus real-world deployment; risks due to incorrect system modeling, parameter estimation, or discretization; and ethical considerations in safety-critical domains such as automotive, aerospace, and healthcare systems using MATLAB and Simulink.
2. **Interpretability of models and simulation results:** importance of understanding system behavior from block diagrams, state-space representations, and simulation outputs; risks of incorrect conclusions due to improper visualization, scaling, or solver selection; need for validation of models against real-world data to ensure reliability in control and embedded applications.
3. **Risks of misinterpretation in co-simulation and hybrid systems:** challenges in integrating physical models with data-driven (AI/ML) components; potential errors due to synchronization issues, solver mismatches, or incorrect interfacing between subsystems; avoiding misleading conclusions caused by simulation artifacts, numerical instability, or insufficient test scenarios.
4. **Limitations of control strategies and adaptive systems:** trade-offs between classical controllers (PID, state-space) and adaptive or AI-based controllers; stability concerns, robustness issues, and risks of overfitting in data-driven models embedded within Simulink; importance of proper tuning, constraint handling, and model selection for dependable system performance.

5. **Understanding trade-offs and validation in MBD workflows:** balancing model fidelity vs computational efficiency, simulation speed vs accuracy, and generalization vs specificity in system design; limitations of optimization and auto-tuning methods; importance of rigorous verification, validation (V&V), hardware-in-the-loop (HIL) testing, and code generation checks to ensure robust and safe deployment.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand** the fundamental concepts, definitions, and principles of Model-Based Design and **apply** them to practical engineering scenarios when all requirements are clearly supplied.	L3
2	**Explain** the concepts and techniques of modelling ordinary differentia equations, difference equations, flow charts, and state machines, and **apply** them to practical system scenarios using plant and data-driven modelling approaches.	L3
3	**Apply** MATLAB programming to explore, analyze, and visualize complex datasets, perform matrix and table operations, use logical indexing for conditional data selection, create automated live scripts, and **develop** MATLAB GUI for practical engineering applications.	L3
4	**Develop, simulate, and analyze** complex system models in Simulink, including the use of programming constructs, hierarchical subsystems, solver selection, and debugging techniques, to **design** and **evaluate** practical engineering systems.	L3
5	**Apply** Stateflow and Simscape tool including state-based modeling conditional execution, and integration of physical and Simulink models to **design, simulate, and analyze** complex system behaviors.	L2

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	3	3	3	-	-	-	-	-	1	3	2
CO2	2	2	3	2	3	-	-	-	-	-	-	3	2
CO3	1	2	2	2	3	-	-	-	-	-	2	3	2
CO4	1	2	2	3	3	-	-	-	2	2	2	3	2
CO5	1	2	2	3	3	-	-	-	2	2	2	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Embedded Control System Design: A Model Based Approach, 2012, Alexandru Forrai, Springer Science & Business Media, ISBN 3642285953, 9783642285950.
2. Real-Time Simulation Technologies: Principles, Methodologies, and Applications, Katalin Popovici, MathWorks, CRC Press, Inc., 2013, ISBN: 978-1-4398-4665-0.
3. Model-Based Design and Evaluation of Interactive Applications., Paterno, F. (2012) United Kingdom: Springer London.

YouTube Links

1. **How to design a simple Casino Game in MATLAB using App Designer with Gauge and Spinner? – MATLAB GUI Development.**
2. **MATLAB TUTORIAL | STATEFLOW TUTORIAL | HOW TO IMPLEMENT A SIMULINK FUNCTION IN STATEFLOW? – MATLAB, SIMULINK, STATEFLOW, GUI.**

E.Resources:

Alternative NPTEL/SWAYAM Course			
S. No.	**NPTEL Course Name**	**Instructor**	**Host Institute**
1	Advanced Linear Continuous Control Systems: Applications with MATLAB Programming and Simulink https://nptel.ac.in/courses/108107115	Prof. M. L. Dewal	IIT Roorkee

SPEECH & AUDIO SIGNAL PROCESSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

1. To understand the fundamentals of digital speech processing and production of speech.
2. To analyze time domain models for speech signals and to analyze speech signals in frequency domain.
3. To analyze linear predictive coding techniques.
4. To illustrate the homomorphic speech processing.
5. To analyze the speech enhancement techniques and application of speech signal processing.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning*** which thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Fundamentals of Digital Speech Processing	**08 Hours**

Anatomy and Physiology of Speech Organs, The process of Speech Production, Acoustic Phonetics, Articulatory Phonetics, The Acoustic Theory of Speech Production- Uniform lossless tube model, effect of losses in vocal tract, effect of radiation at lips, Digital models for speech signals.

Applications: Role in processing speech and audio signals by Audio instruments.

MODULE – II: Short-Time Analysis of Speech	**07 Hours**
Short-Time Analysis of Speech, Short-Time Energy and Zero-Crossing Rate, Short-Time Autocorrelation Function (STACF), Short-Time Fourier Transform (STFT), Sampling the STFT in Time and Frequency, The Speech Spectrogram, Relation of STFT to STACF, Short-Time Fourier Synthesis. Applications: Role in processing speech and audio signals by Audio instruments.	
MODULE – III: Linear Predictive Coding (LPC) Analysis	**11 Hours**
Basic principles of Linear Predictive Analysis: The Autocorrelation Method, The Covariance Method, Solution of LPC Equations: Cholesky Decomposition Solution for Covariance Method, Durbin's Recursive Solution for the Autocorrelation Equations, Comparison between the Methods of Solution of the LPC Analysis Equations, Applications of LPC Parameters: Pitch Detection using LPC Parameters, Formant Analysis using LPC Parameters. **Applications:** Role in processing speech and audio signals by Audio instruments.	
MODULE – IV: Homomorphic Speech Processing	**10 Hours**
Introduction, Homomorphic Systems for Convolution: Properties of the Complex Cepstrum, Computational Considerations, The Complex Cepstrum of Speech, Pitch Detection, Formant Estimation, The Homomorphic Vocoder. **Applications:** Role in processing speech and audio signals by Audio instruments.	
NVIDIA DLI Courses: Introduction to Transformer-Based Natural Language Processing. nvidia-learning-training-course-catalog.pdf	
MODULE – V: Speech Enhancement	**09 Hours**
Nature of interfering sounds, Speech enhancement techniques: Single Microphone Approach: spectral subtraction, Enhancement by re-synthesis, Comb filter, Wiener filter, Multi microphone Approach. **Applications of Speech Processing:** Speech recognition systems, Text-to-Speech system and Speaker recognition systems: speaker verification systems, speaker identification systems. **Applications:** Role in processing speech and audio signals by Audio instruments.	
NVIDIA DLI Courses: Fundamentals of Deep Learning nvidia-learning-training-course-catalog.pdf	

AI Integration:

1. **Introduction to Speech & Audio Signal Processing with AI context:**
   Fundamentals of speech and audio signals, including time-domain and frequency-domain representations; characteristics of human speech production and perception; preprocessing techniques such as sampling, framing, windowing, and noise reduction; role of AI in enhancing signal analysis, feature extraction, and intelligent interpretation of audio data.

2. **Feature extraction and classical audio processing techniques:**
   Extraction of key features such as MFCCs, spectrograms, pitch, and formants; traditional DSP-based methods for speech enhancement, filtering, and compression; limitations of conventional approaches and the need for AI-based models to handle variability, noise, and real-world audio complexities.

3. **Integration of machine learning in speech and audio systems:**
   Application of machine learning algorithms (classification, regression, clustering) for tasks such as speech recognition, speaker identification, emotion detection, and audio classification; use of MATLAB/Python-based toolboxes to train and evaluate models; embedding trained models into signal processing pipelines.

4. **Deep learning for speech and audio applications:**
   Use of deep neural networks such as CNNs, RNNs, and LSTMs for advanced tasks like automatic speech recognition (ASR), speech synthesis, keyword spotting, and audio event detection; end-to-end learning approaches and comparison with traditional pipelines; deployment considerations for real-time audio processing systems.

5. **Real-time implementation, optimization, and deployment:**
   Integration of AI-based audio models into real-time systems; optimization techniques for latency, memory, and computational efficiency; deployment on embedded platforms and edge devices; considerations for robustness, scalability, and ethical issues such as bias, privacy, and misuse in speech technologies.

Authentic Intelligence:

1. **Understanding well-posed speech and audio processing problems and real-world constraints:**
   Challenges in processing real-world audio signals affected by noise, reverberation, channel distortions, and variability in speakers and environments; limitations of ideal assumptions such as clean signals and perfect segmentation; risks due to improper sampling, aliasing, filtering, or feature extraction; and ethical considerations in applications like speech surveillance, biometric identification, and assistive technologies.

2. **Interpretability of speech and audio features and system outputs:**
   Importance of understanding features such as spectrograms, MFCCs, pitch, and formants in representing speech characteristics; challenges in interpreting model outputs in tasks like speech recognition, speaker identification, and emotion detection; risks of incorrect conclusions due to poor feature selection, inadequate preprocessing, or biased datasets; need for validating system outputs against perceptual and ground-truth benchmarks.

3. **Risks of misinterpretation in AI-driven audio systems:**
   Challenges in integrating traditional DSP methods with machine learning or deep learning models; potential errors due to overfitting, dataset bias, or mismatch between training and real-world conditions; risks of misleading results caused by noise sensitivity, adversarial inputs, or insufficient testing across diverse audio scenarios.

4. **Limitations of speech and audio processing models:**
   Trade-offs between classical signal processing approaches and AI-based models for tasks such as speech enhancement, recognition, and synthesis; issues related to robustness, generalization, and computational complexity; limitations of deep learning models in handling low-resource languages, unseen speakers, or noisy environments; importance of proper model design, tuning, and evaluation.

5. **Understanding trade-offs and validation in speech and audio systems:**
   Balancing accuracy vs latency, model complexity vs resource constraints, and real-time processing vs performance; limitations of optimization techniques and automated model selection; importance of rigorous testing, cross-validation, dataset diversity, and real-time evaluation to ensure reliable and fair deployment; considerations for privacy, security, and ethical use of speech data.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Explain** the fundamental concepts of production of speech signal and digital speech signal processing.	L2
2	**Apply** short time Fourier transform (STFT) and short time autocorrelation function (STAF) to analyze speech signals.	L3
3	**Analyze** the digital speech signals by applying linear predictive coding (LPC) technique or homomorphic speech processing techniques.	L4
4	**Apply** speech enhancement techniques like spectral subtraction, filtering techniques etc. to improve the quality of speech signal.	L3
5	Given a speech signal, **develop** a software program using Python or Matlab to acquire, analyze, and to enhance it.	L5

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	1	1	1	-	-	-	-	1	-	1	1	-
CO2	3	1	1	1	1	-	-	-	1	-	1	2	-
CO3	1	3	1	1	1	-	-	-	1	-	1	2	-
CO4	3	1	1	1	1	-	-	-	2	1	1	2	-
CO5	2	2	3	2	3	-	-	1	2	2	2	3	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

2. L.R. Rabiner and S. W. Schafer, Digital Processing of Speech Signals, Pearson Education, 2008.
3. Human & Machine, Douglas O'Shaughnessy, Speech Communications, 2nd Edition., Wiley India, 2000

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Digital Speech Processing https://nptel.ac.in/courses/117105145	Prof. Shyamal Kumar Das Mandal	IIT Kharagpur

COMPUTER VISON AND VIDEO ANALYTICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the fundamental principles of image formation, digital image processing, and convolutional neural network-based feature extraction for computer vision tasks using NVIDIA GPU-accelerated frameworks.
2. Analyse deep learning architectures for object detection, image segmentation, and classification using NVIDIA DLI hands-on pipelines with TensorFlow, Keras, and the TAO Toolkit.
3. Apply intelligent video analytics pipelines using NVIDIA DeepStream SDK for multi-stream real-time processing, object tracking, and metadata extraction on edge devices.
4. Design end-to-end hardware-accelerated industrial inspection systems leveraging NVIDIA TAO Toolkit, TensorRT, and Triton Inference Server for automated defect detection and visual quality control.
5. Evaluate and deploy edge AI computer vision applications on NVIDIA Jetson platforms using DeepStream, TensorRT, and AI-enabled sensor processing techniques for smart city, healthcare, and manufacturing use cases.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. **Interactive Teaching:** Adopt Active Learning that includes brainstorming, group work, and notetaking using NVIDIA DLI GPU-accelerated Jupyter notebooks for hands-on model training in computer vision and video analytics tasks.
2. **Video/Animation Films:** Show NVIDIA DLI tutorial recordings and DeepStream pipeline demonstrations to explain CNN inference, object tracking, multi-stream analytics, and edge AI deployment workflows.
3. **Collaborative (Group) Learning:** Encourage team projects using NVIDIA Jetson Nano and DeepStream SDK to build real-time video analytics applications for smart city, retail, and industrial inspection scenarios.
4. **Critical Thinking:** Ask Higher Order Thinking questions on trade-offs between accuracy and latency in embedded vision systems, ethical concerns in surveillance AI, and challenges in industrial defect detection pipelines.
5. **Problem Based Learning:** Adopt real-world NVIDIA DLI assessment challenges—training defect classifiers from manufacturing datasets, building DeepStream pipelines, and deploying models to Jetson edge devices—to foster analytical and design skills.

MODULE – I: Foundations of Computer Vision & Deep Learning for Image (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Fundamentals of Deep Learning – S-FX-01 & Getting Started with Image Segmentation – T-FX-01): Introduction to computer vision, Image pre-processing pipeline, Convolutional Neural Networks for image classification, CNN architectures for computer vision, Transfer learning and fine-tuning NVIDIA DLI Hands-on (S-FX-01): Training your first CNN on a visual dataset; applying data augmentation; evaluating model performance with accuracy and confusion matrices. Image segmentation fundamentals (T-FX-01): semantic segmentation vs. instance segmentation; pixel-wise classification; U-Net architecture; DICE loss and IoU metrics. NVIDIA DLI Lab (T-FX-01): Cardiac MRI segmentation pipeline — TFRecord preparation, U-Net model build and training, evaluation with DICE coefficient, and TensorBoard visualisation. Applications: Medical image analysis, autonomous driving perception, satellite imagery segmentation, and robotics scene understanding.	
NVIDIA DLI Courses (Relevant to this Module): **Getting Started with Deep Learning / Fundamentals of Deep Learning (S-FX-01, 8 hrs) –** CNN training, transfer learning, data augmentation, pre-trained models. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1 **Getting Started with Image Segmentation (T-FX-01) –** Semantic segmentation, U-Net, DICE loss, cardiac MRI lab. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+T-FX-01+V1	
MODULE – II: Object Detection, Tracking & NVIDIA TAO Toolkit (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Custom Object Detection with TAO Toolkit – C-TC-01 & Fundamentals of Deep Learning – S-FX-01): Object detection paradigms, NVIDIA TAO Toolkit overview, TAO Toolkit model zoo, Dataset preparation for object detection, Object tracking algorithms, NVIDIA NvDCF and NvDeepSORT trackers in DeepStream, configuring tracker plugins; handling track lifecycle (birth, active, lost, re-identification), Model optimization with NVIDIA TensorRT. NVIDIA DLI Hands-on Lab (C-TC-01): Fine-tuning a TAO DetectNet model on a custom object detection dataset; configuring training specs, evaluating mAP, and exporting the trained model. Applications: pedestrian and vehicle detection, automated retail self-checkout, drone-based surveillance, smart manufacturing line monitoring.	
NVIDIA DLI Courses (Primary References for this Module): **Custom Object Detection with NVIDIA TAO Toolkit (C-TC-01) –** TAO Toolkit, fine-tuning DetectNet/YOLO, dataset prep, TensorRT export. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1 **Fundamentals of Deep Learning – Pre-trained Models Module (S-FX-01) –** Transfer learning, model evaluation, object classification assessment. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1	

MODULE – III: Intelligent Video Analytics with NVIDIA DeepStream SDK (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Building Video AI Applications at the Edge – S-ES-01 & Build High-Performance AI-Enabled Sensor Processing – S-FX-30): NVIDIA DeepStream SDK architecture, DeepStream pipeline componentsBuilding an end-to-end, DeepStream application, Multi-stream processing, DeepStream metadata API, AI-enabled sensor processing (S-FX-30), DeepStream cloud messaging. NVIDIA DLI Hands-on Lab (S-ES-01): Setting up DeepStream on NVIDIA Jetson Nano; creating a video analytics pipeline to process webcam/RTSP streams; configuring object detection with SSD-MobileNet; annotating video output with bounding boxes, labels, and metadata. Applications: smart city traffic monitoring, crowd density estimation, retail heat-map analytics, hospital patient monitoring, and industrial conveyor surveillance.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course: **Building Video AI Applications at the Edge on Jetson Nano (S-ES-01, 8 hrs) –** DeepStream pipelines, Jetson Nano setup, multi-stream RTSP, object tracking. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-ES-01+V1 **Build High-Performance and AI-Enabled Sensor Processing Applications (S-FX-30, 3 hrs) –** GPU-accelerated sensor fusion, real-time multi-modal AI processing. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-30+V1	
MODULE – IV: Industrial Computer Vision – Inspection, Defect Detection & Deployment (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Computer Vision for Industrial Inspection – S-IV-01, C-MF-01 & Deep Learning for Industrial Inspection – C-MF-02): Industrial inspection problem formulation, Data handling challenges in industrial inspection, NVIDIA DALI for industrial data pipelines, Transfer learning for industrial vision, Model optimization for industrial deployment, NVIDIA Triton Inference Server, Common pitfalls in industrial CV NVIDIA DLI Hands-on Lab (S-IV-01 / C-MF-01): Building an end-to-end defect detection classifier using NVIDIA's production semiconductor inspection dataset; model training, validation, and threshold tuning. NVIDIA DLI Hands-on Lab (C-MF-02): Designing, training, and deploying building blocks of a full hardware-accelerated industrial inspection pipeline; measuring throughput and optimising inference performance. Applications: semiconductor fab defect detection, PCB solder joint inspection, food and beverage quality sorting, automotive paint scratch detection, and pharmaceutical tablet inspection	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course **Computer Vision for Industrial Inspection – Workshop (S-IV-01, 8 hrs) –** End-to-end inspection pipeline: DALI, TAO Toolkit, TensorRT, Triton. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-IV-01+V1 **Deep Learning for Industrial Inspection (C-MF-02) –** Defect classification, data curation, transfer learning, deployment. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-02+V1 **Computer Vision for Industrial Inspection – Self-Paced (C-MF-01) –** Hardware-accelerated inspection pipeline, performance assessment. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2	

MODULE – V: Edge AI Deployment – Jetson Nano, TensorRT, DeepStream & Advanced Applications (NVIDIA DLI Primary)	**09 Hours**
Core NVIDIA DLI Topics (from Getting Started with AI on Jetson Nano – S-RX-02, Building Video AI Applications at the Edge – S-ES-01 & Custom Object Detection with TAO Toolkit – C-TC-01 & C-FX-07): NVIDIA Jetson platform overview, Setting up Jetson Nano for AI (S-RX-02), Image regression on Jetson Nano (S-RX-02), TensorRT optimisation for Jetson, Advanced DeepStream on Jetson (S-ES-01), TAO Toolkit to Jetson deployment workflow, Advanced Ethical and regulatory considerations in video analytics NVIDIA DLI Hands-on Lab (S-RX-02): Collecting image data on Jetson Nano; training a CNN-based image classification model (ResNet-18) using PyTorch; deploying for real-time inference on live camera feed. NVIDIA DLI Hands-on (C-FX-07): Deploying classification and detection models for time-series and video data analytics; configuring inference pipelines with TensorRT and DeepStream for advanced video understanding. Applications:license plate recognition (LPR) with TAO LPRNet, re-identification with TAO Re-ID models, retail foot-traffic analytics, real-time PPE (Personal Protective Equipment) compliance detection, smart traffic signal control.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course **Getting Started with AI on Jetson Nano (S-RX-02, 8 hrs, FREE) –** Jetson setup, CNN classification, regression, live camera inference. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2 **Building Video AI Applications at the Edge (S-ES-01, 8 hrs) –** Multi-camera DeepStream pipelines, object tracking, Jetson deployment. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-ES-01+V1 **Custom Object Detection with TAO Toolkit (C-TC-01) –** End-to-end TAO → TensorRT → DeepStream Jetson pipeline. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1 **Advanced Inference Pipeline / Video Analytics (C-FX-07) –** TensorRT + DeepStream for advanced video understanding tasks. Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-07+V1	

AI Integration :

1. Implementation of image preprocessing and CNN training workflows using TensorFlow/Keras on NVIDIA GPU cloud; applying NVIDIA DALI for high-throughput data loading; evaluating model accuracy on benchmark datasets (ImageNet, COCO).
2. Fine-tuning NVIDIA TAO Toolkit pre-trained detection models (DetectNet, YOLO-v4) on custom datasets; performing mAP evaluation; exporting trained models to ONNX and TensorRT engine formats for downstream deployment.
3. Building and configuring end-to-end NVIDIA DeepStream pipelines on Jetson Nano; integrating TensorRT-optimised detectors; processing multiple RTSP video streams simultaneously; extracting and logging per-frame metadata.
4. Constructing a complete industrial inspection pipeline: dataset curation using Pandas, GPU-accelerated training with TAO Toolkit, TensorRT INT8 quantisation, and inference performance benchmarking with Triton Inference Server.
5. Deploying trained CV models on NVIDIA Jetson Nano for real-time edge inference; building TAO-to-Jetson workflows using TensorRT and DeepStream; evaluating end-to-end latency, throughput (FPS), and GPU memory utilisation.

Authentic Intelligence:

1. Understanding ethical constraints in deploying CV models: surveillance privacy, consent, and GDPR compliance; risks of biased training data in defect detection causing manufacturing over-rejection or safety escapes.
2. Evaluating the societal impact of object detection systems in public spaces; understanding fairness and accountability (FAccT) concerns in AI-based pedestrian detection and access control applications.
3. Risks of deploying real-time video analytics without adequate safeguards; hallucination of object detectors in edge cases; importance of human-in-the-loop verification for safety-critical industrial inspection.
4. Ethical implications of industrial AI: job displacement in quality inspection roles; responsible automation; transparency in AI-assisted decision-making; interpretability of defect classification decisions.
5. Governance challenges of edge AI deployment: data sovereignty on Jetson devices, model version control, over-the-air update security, and compliance with industrial safety standards (ISO 9001, IEC 62443).

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the principles of digital image representation, convolutional neural network architectures, and GPU-accelerated image classification and segmentation pipelines using NVIDIA DLI frameworks.	**L2**
2	Analyse object detection architectures (YOLO, SSD, Faster R-CNN), evaluate mAP performance, and apply NVIDIA TAO Toolkit for fine-tuning custom detection models with transfer learning.	**L3**
3	Apply NVIDIA DeepStream SDK to design and implement intelligent video analytics pipelines supporting multi-stream real-time object detection, tracking, and edge-cloud metadata streaming.	**L3**
4	Design end-to-end hardware-accelerated industrial inspection systems using NVIDIA TAO, TensorRT, and Triton Inference Server for high-throughput defect detection and quality control automation.	**L4**
5	Evaluate and deploy computer vision models on NVIDIA Jetson edge platforms using TensorRT optimisation and DeepStream for real-time inference in smart city, healthcare, and industrial applications.	**L5**

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	2	-	-	-	-	-	-	3	2
CO2	2	3	-	3	3	-	-	-	-	-	-	3	3
CO3	-	-	3	2	3	2	-	-	-	-	-	2	3
CO4	2	-	3	2	3	2	1	-	-	-	-	3	3
CO5	-	-	2	-	3	3	2	2	-	-	-	2	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. **Szeliski, R., 2022.** Computer Vision: Algorithms and Applications. 2nd Edition. Springer.
2. **Goodfellow, I., Bengio, Y., and Courville, A., 2016.** Deep Learning. MIT Press.
3. **Chollet, F., 2021.** Deep Learning with Python. 2nd Edition. Manning Publications.

REFERENCE BOOKS:

1. **Gonzalez, R.C. and Woods, R.E., 2018.** Digital Image Processing. 4th Edition. Pearson.
2. **Prince, S.J.D., 2023.** Understanding Deep Learning. MIT Press.
3. **Bewley, A. et al., 2016.** Simple Online and Realtime Tracking (SORT). IEEE ICIP. [NVIDIA DeepStream tracker foundation]
4. **NVIDIA Corporation, 2024.** DeepStream SDK Developer Guide. NVIDIA Documentation.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Fundamentals of Deep Learning (S-FX-01, 8 hrs)	NVIDIA DLI Team	NVIDIA Deep Learning Institute
2	Getting Started with Image Segmentation (T-FX-01)	NVIDIA DLI Team	NVIDIA Deep Learning Institute
3	Building Video AI Applications at the Edge (S-ES-01, 8 hrs)	NVIDIA DLI Team	NVIDIA Deep Learning Institute
4	Computer Vision for Industrial Inspection (S-IV-01, 8 hrs)	NVIDIA DLI Team	NVIDIA Deep Learning Institute
5	Getting Started with AI on Jetson Nano (S-RX-02, FREE)	NVIDIA DLI Team	NVIDIA Deep Learning Institute
6	CS231n: Deep Learning for Computer Vision	Prof. Fei-Fei Li et al.	Stanford University (YouTube)
7	Computer Vision (OpenCV & Deep Learning)	Adrian Rosebrock	PyImageSearch / YouTube

Department of Electronics and Communication Engineering

ENERGY STORAGE TECHNOLOGIES (BATTERIES AND BMS)

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Understand what energy storage is, why it matters, and how batteries fit into the broader picture of clean energy and modern technology.
2. Learn how different types of batteries work, what they are made of, and where each type is best suited — explained in simple, everyday terms.
3. Appreciate the role of a Battery Management System (BMS) in keeping batteries safe, healthy, and performing at their best.
4. Explore how AI and data analytics are being used to monitor, predict, and optimise battery performance in real-world applications.
5. Develop awareness of the environmental impact of batteries, recycling challenges, safety considerations, and India's emerging battery industry.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. Use simple analogies throughout: compare a battery to a water tank (capacity = tank size, voltage = water pressure, current = flow rate) so students from any engineering background can immediately relate.
2. Show video demonstrations: animations of how a lithium-ion cell charges and discharges, real-world battery teardowns (18650 cell, EV battery pack, phone battery), and thermal runaway videos with safety lessons.
3. Encourage Interactive Discussion: pose questions like 'Why does your phone battery degrade over two years?' or 'Why did the Boeing 787 Dreamliner have battery fires?' to trigger curiosity and critical thinking.
4. Use Collaborative (Group) Learning: assign student groups to research and present one battery application (EV, drone, satellite, grid storage, smartphone) covering its battery type, capacity, and key challenges.
5. Apply Problem-Based Learning: scenarios such as 'Select a battery chemistry for a solar-powered rural health clinic that needs 48 hours of backup' or 'Why did the Ola S1 battery catch fire and what BMS feature could have prevented it?'
6. Invite Industry Speakers: arrange sessions from battery companies like Exide Industries, Amara Raja, Ola Electric, ISRO's SAC battery division, or researchers from IISc's energy storage group.
7. Connect every concept to the real world: discuss India's PLI scheme for battery manufacturing, the Gigafactory concept, second-life battery use in home energy storage, and the global race for solid-state batteries.

COURSE CONTENT:	
Module 1: Energy Storage — Fundamentals	**09 Hrs**
Challenges in Energy Storage, Strategies to address energy storage, Design considerations in Energy Storage, Conversion of Energy for Storage. The mismatch problem., Applications-energy storage: phone batteries, power banks, UPS systems, electric vehicle packs, and grid-scale storage farms, Mechanical storage, Thermal storage, Chemical storage, Capacitors and supercapacitors **Applications:** Solar home systems in rural India, grid-scale lithium-ion storage farms, uninterruptible power supplies (UPS) in hospitals, and drone battery packs.	
NVIDIA DLI Courses (Relevant to this Module): ◗ **Generative AI Explained**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-07+V1	
Module 2: Batteries: Construction and Working	**09 Hrs**
Inside a Battery, Types of Batteries-Lead-Acid batteries, Nickel-Metal Hydride (NiMH), Lithium-Ion (Li-ion), Lithium Iron Phosphate (LFP), Sodium-Ion batteries, Solid-State batteries, Key Battery Parameters **Applications:** 18650 Li-ion cells in laptops, LFP packs in electric buses, lead-acid banks in rural solar home systems, NiMH packs in hybrid cars, lithium polymer (LiPo) in drones and model aircraft. Applications: 18650 Li-ion cells in laptops, LFP packs in electric buses, lead-acid banks in rural solar home systems, NiMH packs in hybrid cars,	
Module 3: Battery Pack Design and Thermal Management	**09 Hrs**
Cell to Pack — Building a Battery System **Applications:** Tata Nexon EV liquid-cooled battery pack, Ather 450X air-cooled pack, ISRO satellite battery design, drone LiPo pack assembly, grid-scale containerised battery storage units.	
NVIDIA DLI Courses (Relevant to this Module): ◗ **Fundamentals of Accelerated Computing with CUDA C/C++**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-01+V2	
Module 4: Battery Management System (BMS)	**09 Hrs**
Significance and Implementation of BMS, Core Functions of a BMS, How AI Is Transforming BMS, BMS Communication and Integration **Applications:** Ola Electric BMS, Tata Nexon EV battery controller, ISRO satellite power regulation unit, aircraft Auxiliary Power Unit (APU) battery management, and industrial UPS battery systems.	
NVIDIA DLI Courses (Relevant to this Module): ◗ **Applications of AI for Anomaly Detection:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1 ◗ **Accelerating End-to-End Data Science Workflows:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-DS-01+V2	

Module 5: Applications, Safety, Environment, and Future of Batteries	**09 Hrs**
Real-World Battery Applications Across Engineering Domains, Battery Safety, Environmental Impact and Battery Recycling, Future of Battery Technology **Applications:** Hornsdale grid battery (Australia), Ola Electric Gigafactory (Krishnapur), ISRO spacecraft battery qualification, Boeing 787 APU battery redesign case study, and second-life battery home storage systems.	
NVIDIA DLI Courses (Relevant to this Module): ◗ **Deploying and Optimizing AI Inference at Scale**: https://www.nvidia.com/gtc/session-catalog/sessions/gtc26-dliw82274/ ◗ **Agentic AI Explained**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-39+V1	

AI Integration

(Guided activity-based learning — free tools used throughout; no advanced coding required)

1. Use Google's Teachable Machine (free, browser-based) to train a simple classifier to distinguish 'healthy' from 'degraded' battery voltage curves represented as images; evaluate classification accuracy and discuss limitations.
2. Simulate State of Charge estimation: given a battery's starting voltage, capacity, and a recorded current profile (provided as a spreadsheet), calculate cumulative charge delivered using the coulomb-counting method and compare against a 'true' reference.
3. Using MATLAB tool sets for Battery Management Systems

Authentic Intelligence

(Critical thinking and ethical awareness indicators)

1. Is lithium-ion always the best choice? Argue: for each of the following applications (rural solar home, electric bus, drone, implantable medical device), identify whether Li-ion is truly the best option or whether another chemistry would be more appropriate and why.
2. The cobalt dilemma: cobalt is essential for many Li-ion batteries but is mined in conditions involving child labour in the DRC. As an engineer specifying a battery system, what ethical responsibility do you have? What actions can the industry take?
3. The recycling gap: only about 5% of lithium-ion batteries globally are recycled effectively. Discuss the engineering, economic, and policy barriers to better recycling in India, and propose one realistic solution that a startup or the government could implement.
4. Second-life or new life? A battery retired from an EV at 80% capacity still has years of useful life for stationary storage. Evaluate the business case, safety considerations, and technical challenges of repurposing used EV batteries for a solar microgrid in a rural Indian village.

Course Outcomes		
CO	**Description**	**Bloom's Taxonomy Level**
CO1	Describe the need for energy storage, different forms of storage technology, and fundamental electrical quantities relevant to battery systems, using everyday language and analogies.	L2
CO2	Explain how different battery chemistries (lead-acid, Li-ion, LFP, solid-state) work, their key parameters, and the trade-offs between performance, cost, safety, and life.	L2
CO3	Identify how battery cells are assembled into packs, explain the principles of thermal management, and recognise the safety features required in a well-designed battery system.	L4
CO4	Explain the core functions of a Battery Management System, describe how AI is used for SOC/SOH estimation and fault detection, and evaluate the role of BMS in ensuring battery safety and longevity.	L5
CO5	Assess the real-world applications, environmental impact, safety standards, and future direction of battery technology, and reflect critically on the ethical and sustainability challenges of the battery industry.	L5

COs	**Programme Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	1	-	-	-	2	1	1	1	-	1	1	1
CO2	2	2	1	-	1	2	1	1	1	-	2	1	2
CO3	2	2	2	2	2	2	1	1	1	-	2	2	2
CO4	2	3	3	2	3	2	1	1	1	1	3	2	3
CO5	1	2	2	2	2	3	2	2	1	1	3	2	3

TEXT BOOKS:

1. Pistoia, G. (Ed.) (2014). Lithium-Ion Batteries: Advances and Applications. Elsevier.
2. Rand, D.A.J., Woods, R. and Dell, R.M. (1998). Batteries for Electric Vehicles. Research Studies Press. (Introductory concepts remain highly relevant.)
3. Plett, G.L. (2015). Battery Management Systems, Volume I: Battery Modeling. Artech House.

REFERENCES:

1. Blomgren, G.E. (2017). The development and future of lithium-ion batteries. Journal of The Electrochemical Society, 164(1), A5019–A5025.
2. IEA. (2024). Global EV Outlook 2024. International Energy Agency. Available at: https://www.iea.org/reports/global-ev-outlook-2024
3. NITI Aayog and Rocky Mountain Institute. (2023). India's Energy Storage Mission: A Make-in-India Opportunity for Globally Competitive Battery Manufacturing. Government of India.
4. IEEE Std 1188-2005: IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.
5. NVIDIA Developer. (2024). NVIDIA DLI Course Catalogue. Available at: https://learn.nvidia.com

Alternative NPTEL / SWAYAM Courses			
S.No.	**NPTEL Course Name**	**Instructor**	**Host Institute**
1	Electrochemical Energy Storage https://onlinecourses.nptel.ac.in/noc21_mm34/preview	Prof. Subhasish Basu Majumder	IIT Kharagpur
2	Battery Pack Design and Development: Fundamentals https://elearn.nptel.ac.in/shop/completed-courses/execedu-closed/battery-pack-design-and-development-cohort-2/?v=13b5bfe96f3e	Prof. Atriya Biswas	IIT Madras
3	Sustainable Energy Technology https://iith.ac.in/mae/sayakb/	Prof. Sayak Banerjee	IIT Hyderabad
4	Energy Materials and Devices https://onlinecourses.nptel.ac.in/noc25_ph56/preview	Prof. Santanu Ghosh	IIT Delhi
5	Machine Learning for Engineering and science applications https://nptel.ac.in/courses/106106198	Prof. Balaji Srinivasan Prof. Ganapathy Krishnamurthi	IIT Madras

ELECTRONIC MATERIALS, DEVICES AND PROCESSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

1. Understand the fundamental properties of electronic materials, including crystal structures, energy band theory, and carrier transport mechanisms.
2. Explain and analyze the operation of semiconductor devices such as PN junction diodes, BJTs, MOSFETs, and optoelectronic devices.
3. Describe the semiconductor fabrication processes, including crystal growth, oxidation, diffusion, lithography, and thin-film deposition.
4. Apply characterization techniques (I–V, C–V, SEM, XRD) to evaluate material and device performance.
5. Utilize modern simulation tools (Simscape, TCAD, MATLAB) to model and analyze electronic devices.
6. Explore emerging technologies such as nanoelectronics, flexible electronics, and AI applications in semiconductor design and processing.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

MODULE – I: Electronic Materials & Crystal Structure	**09 Hours**

Crystal structure- SC, BCC, FCC, Atomic bonding in solids, Energy band theory of solids, Intrinsic and extrinsic semiconductors, Carrier concentration and mobility, Fermi level and carrier statistics

Applications: Electronic Material Property Prediction - Predict bandgap, mobility, or conductivity using supervised learning on material vs bandgap dataset.

NVIDIA DLI Courses: Getting Started with Deep Learning - Introduction to neural networks and supervised learning - directly applicable to material property regression tasks.

DLI Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1

MODULE – II: Semiconductor Devices	**09 Hours**
PN junction diode - operation and characteristics, Zener and Schottky diodes, Bipolar Junction Transistor (BJT), Field Effect Transistors (JFET, MOSFET), Basic optoelectronic devices (LED, photodiode) **Applications**: Simulate PN junction diode / MOSFET characteristics and use AI tools to analyze behavior using tools MATLAB Simulink + Simscape Electrical	
NVIDIA DLI Courses: Fundamentals of Deep Learning - Covers CNN and regression models with hands-on exercises - applicable to training models on diode I-V characteristic data **DLI Link**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3	
MODULE – III: Semiconductor Fabrication Technology	**09 Hours**
Crystal growth - Czochralski method, Wafer preparation and cleaning, Oxidation (dry and wet), Diffusion and ion implantation, Lithography techniques, Thin film deposition (CVD, PVD, epitaxy) **Applications**: AI-Based Defect Detection in Semiconductor Wafers using CNN	
MODULE – IV: Characterization & Modeling	**09 Hours**
Electrical characterization I–V and C–V analysis, Material characterization: SEM, XRD, FTIR, Thickness and resistivity measurement, Device modeling basics, Introduction to TCAD tools. **Applications**: SEM Image Feature Extraction — Use a pre-trained CV model to identify grain boundaries or features from SEM images	
NVIDIA DLI Courses: Getting Started with Image Segmentation - Teaches U-Net and segmentation architectures for categorizing image regions - directly applicable to identifying grain boundaries in SEM images **DLI Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+L-FX-04+V2	
MODULE – V: Advanced & Emerging Topics	**09 Hours**
Nanoelectronics and scaling issues, Organic and flexible electronics, Optoelectronic and photonic devices, Introduction to MEMS/NEMS, Role of AI in semiconductor design and fabrication. **Applications**: Generative AI for Nano-material Design — Explore tools like MatBERT or GNoME (Google DeepMind) to understand AI-driven materials discovery.	
NVIDIA DLI Courses: Generative AI Explained - No-code introduction to how generative AI works - perfect conceptual grounding before exploring MatBERT and GNoME for nano-material design. **DLI Link**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-07+V1	

AI Integration:

1. Use supervised learning (sklearn regression) on material datasets to predict electronic properties like bandgap and conductivity, making abstract theory tangible.
2. Simulate PN junction diode and MOSFET characteristics using MATLAB Simulink + Simscape Electrical, then feed I-V data to AI to extract ideality factor and series resistance.
3. Apply pre-trained convolutional neural networks to classify defects from SEM images of semiconductor wafers, replicating real-world fab quality control pipelines.
4. Use pre-trained CV models to extract grain boundaries and surface features from SEM images, supplemented by TCAD simulation for device modeling and characterization.
5. Explore tools like MatBERT and Google DeepMind's GNoME to understand how AI accelerates materials discovery, and use AI-assisted coding to simulate dopant diffusion profiles.

Authentic Intelligence:

1. Conceptual Reasoning from First Principles - Students derive energy band diagrams, Fermi level positions, and carrier statistics from physical reasoning rather than relying on simulation outputs — building deep theoretical intuition.
2. Critical Interpretation of Device Characteristics - Manually analyze BJT, MOSFET, and diode I-V curves to identify operating regions, breakdown mechanisms, and non-ideal behavior — a skill that grounds AI tool outputs in physical reality.
3. Process Trade-off Decision Making - Debate the engineering trade-offs between CVD vs PVD deposition, wet vs dry oxidation, and ion implantation vs diffusion — developing judgment that no AI can substitute in process design.
4. Hands-On Characterization & Data Interpretation - Perform and interpret I-V, C-V, XRD, and FTIR measurements directly, developing the experimental literacy needed to critically evaluate AI-generated analyses and flag anomalies.
5. Ethical Reflection on AI in Semiconductor Design - Critically evaluate the societal, economic, and environmental implications of AI-driven semiconductor fabrication, MEMS/NEMS scaling, and flexible electronics — forming responsible engineering perspectives.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Explain** properties of electronic materials and band theory	L2
2	**Analyze** semiconductor devices (diodes, BJT, MOSFET)	L3
3	**Describe** fabrication processes like oxidation, lithography	L3
4	**Interpret** characterization techniques (I–V, C–V, SEM, XRD)	L4
5	**Discuss** emerging technologies (nanoelectronics, flexible electronics, AI)	L3

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	1	1	1	-	-	-	-	-	2	3	1
CO2	3	3	2	2	2	-	-	-	-	-	2	3	2
CO3	3	2	3	2	2	2	-	-	-	-	2	3	3
CO4	3	3	2	3	3	1	-	-	-	-	2	2	3
CO5	2	2	2	2	3	2	2	1	1	1	3	2	3

3: Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

TEXT BOOKS:

1. S.O. Kasap – *Principles of Electronic Materials and Devices*, McGraw-Hill, 4th Editon, 2020.
2. Ben G. Streetman & Sanjay Banerjee – *Solid State Electronic Devices*, Pearson, 7th Edition, 2014
3. S. M. Sze & Kwok K. Ng – *Physics of Semiconductor Devices*, Wiley, 3rd Edition, 2006

REFERENCE BOOKS:

1. Donald A. Neamen – *Semiconductor Physics and Devices*, McGraw-Hill, 4th Editon, 2021.
2. Plummer, Deal & Griffin – *Silicon VLSI Technology*, Pearson, 1st Edition, 2009.
3. Campbell – *Fabrication Engineering at the Micro and Nanoscale*, Oxford, 4th Editon, 2020.
4. Tyagi – *Introduction to Semiconductor Materials and Devices*, Wiley, 1st Edition, 1991.
5. William D. Callister – *Materials Science and Engineering*, Wiley, 10th Editon, 2020.

Alternative NPTEL/SWAYAM Course:

Sl. No.	**Course /Resource Name**	**Instructor**	**Host Institute**
1	Semiconductor Devices and Circuits https://nptel.ac.in/courses/108108112	Prof.Sanjiv Sambandan	IISc, Bangalore
2	Introduction to Materials Science and Engineering https://nptel.ac.in/courses/113106032	Dr. Ranjit Bauri	IIT Madras

SMART CITIES AND SMART GRIDS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To provide a comprehensive understanding of the fundamentals of power electronic converters and devices.
2. To understand electric vehicle architecture and propulsion systems.
3. To analyze the interaction between batteries, power electronics, and electric drives using modeling and simulation by adopting AI tools.
4. To study charging techniques, battery management systems, and energy recovery mechanisms by adopting AI tools for modeling and simulation
5. To familiarize with current trends and challenges in electric vehicle development.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:	
Module 1: Smart Cities-Introduction	**09 Hrs**
Concept and Need for Smart Cities, Key Elements of Smart Cities- Mobility, Energy, Environment, Infrastructure, Urbanization Trends and Challenges Applications: Role of ICT in Smart Cities, Global Smart City Initiatives and Case Studies	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course **For reference:** 1. **AI for All: From Basics to Gen AI Practice**: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1	
MODULE 2: Smart City Infrastructure and Technologies	**09 Hrs**
Urban Infrastructure Planning in Smart Cities: Sensors, Networks, and Platforms Applications: Smart Transportation and Mobility, Smart Water and Waste Management, Smart Governance and Citizen Engagement	
NVIDIA DLI Courses (Relevant to this Module): **Agentic AI Explained:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-39+V1	
MODULE 3: Introduction to Smart Grids	**09 Hrs**
Evolution of the Electrical Grid to Smart Grid, Smart Grid Architecture and Components, Advanced Metering Infrastructure (AMI), Demand Response and Load Management Applications: Grid Automation and Monitoring Systems	
NVIDIA DLI Courses (Relevant to this Module): **Getting Started with Accelerated Computing in Modern CUDA C++:** **https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-AC-04+V2**	
MODULE 4: Communication and Information Technologies in Smart Grids	**09 Hrs**
Communication Protocols: Zigbee, Wi-Fi, cellular networks, Ethernet, OpenADR, SCADA, IoT Integration to smart grids. Applications: Cybersecurity in Smart Grids	
NVIDIA DLI Courses (Relevant to this Module): **Applications of AI for Anomaly Detection :** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1	
MODULE 5: Sustainability, Challenges, and Policy Framework	**09 Hrs**
Integration of Renewable Energy Sources, Energy Storage Systems and Microgrids, Economic, Social, and Environmental Impact, Standards, Policies, and Regulatory Issues Applications: Future Trends and Innovations in Smart Cities and Grids	

AI Integration:

1. Introduction to Python-based machine learning workflow, data preprocessing and feature engineering techniques, usage of libraries like NumPy, Pandas, and Scikit-learn for building and evaluating models.
2. Implementation of supervised learning algorithms using Scikit-learn, training and evaluating models using real-world datasets
3. Implementing clustering and dimensionality reduction techniques using Scikit-learn, visualization of clusters using Python tools.
4. Implementation of graphical models and ensemble techniques using Scikit-learn, use of bagging and boosting methods, model evaluation with Out-of-Bag score.
5. Use of Grid Search and Random Search for hyperparameter tuning, implementation of validation techniques and performance metrics, application of optimization algorithms and regularization methods using Scikit-learn.

Authentic Intelligence:

1. Understanding well-posed learning problems and their real-world constraints, challenges in designing efficient learning systems, limitations of deep learning models, risks associated with poor feature selection and sampling bias, ethical considerations and responsible deployment of AI systems.
2. Interpretability of machine learning models, risks of incorrect predictions in automated decision-making systems
3. Risks of misinterpreting clusters, responsible interpretation of patterns discovered from data.
4. Limitations of graphical and ensemble models, overfitting risks in boosting, interpretability challenges, and importance of responsible model selection.
5. Understanding overfitting and underfitting, bias-variance tradeoff, limitations of optimization methods, and importance of selecting appropriate validation and regularization techniques.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Analyze the characteristics and operation of **power semiconductor devices and converters** used in modern energy and electric vehicle systems.	L3
2	Apply the **architecture and working principle of electric vehicles**, including propulsion systems, drive trains, and associated components	L3
3	Model and analyze the **interaction between batteries, power electronics, and electric drives** using simulation tools integrated with AI techniques	L4
4	Evaluate **charging methods, battery management systems (BMS), and energy recovery mechanisms** using AI-based modeling and optimization approaches	L4
5	Assess **current trends, challenges, and emerging technologies** in electric vehicles and their integration with smart grids and sustainable urban energy systems	L4

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	-	2	1	1	1	-	2	2	2
CO2	3	2	2	-	3	2	1	1	1	-	2	2	2
CO3	3	3	2	2	2	2	1	1	1	-	3	2	2
CO4	2	3	3	3	3	2	1	1	1	-	3	2	2
CO5	2	3	3	2	2	3	2	1	1	1	3	2	2

3: Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

TEXT BOOKS:

1. Angelakis, V., Tragos, E., Pöhls, H., Kapovits, A. and Bassi, A., 2017. Designing, Developing, and Facilitating Smart Cities. Springer International Pu.
2. S. Borlase, 2013. Smart Grids, Infrastructure, Technology and Solutions, CRC Press, 1st Edition.
3. Krishna Kumar, Gaurav Saini, Duc Manh Nguyen, Narendra Kumar, Rachna Shah, 2022. Smart Cities Concepts, Practices and Applications, CRC Press, 1st Edition

REFERENCE BOOKS:

1. Ekanayake, J.B., Jenkins, N., Liyanage, K.M., Wu, J. and Yokoyama, A., 2012. Smart grid: technology and applications. John Wiley & Sons.
2. Sato, T., Kammen, D.M., Duan, B., Macuha, M., Zhou, Z., Wu, J., Tariq, M. and Asfaw, S.A., 2015. Smart grid standards: specifications, requirements, and technologies. John Wiley & Sons.
3. Song, H., Srinivasan, R., Sookoor, T. and Jeschke, S., 2017. Smart cities: foundations, principles, and applications. John Wiley & Sons.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Smart Grid: Basics to Advanced Technologies https://onlinecourses.nptel.ac.in/noc26_ee84/preview	Prof. N.P. Padhy, Prof. Premalata Jena	IIT Roorkee
2	Integrated Waste Management for a Smart City https://nptel.ac.in/courses/105105160	Prof. Brajesh Kumar Dubey	IIT Kharagpur
3	Introduction to Machine Learning https://nptel.ac.in/courses/106106139	By Prof. Balaraman Ravindran	IIT Madras

Entrepreneurial Finance & AI-Driven Deep-Tech Start-ups

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hrs
L–T–P-J	:	3–0–0-0			

Prerequisites: - Basics of Economics, AI/ML Fundamentals, Data Science

Course Learning Objectives:

This Course will enable students to:

1. Understand fundamentals of entrepreneurial finance and start-up ecosystems.
2. Analyse valuation methods and funding strategies for AI-driven start-ups.
3. Apply AI tools for financial modelling, forecasting, and market analysis.
4. Develop skills to design, pitch, and scale deep-tech ventures.
5. Evaluate ethical, regulatory, and societal implications of AI entrepreneurship.

Course Description

Entrepreneurial Finance & AI-Driven Deep-Tech Start-ups is an interdisciplinary course that integrates financial literacy, entrepreneurship, and advanced technology domains such as Artificial Intelligence and deep-tech innovation. The course equips students with the knowledge and skills required to build, evaluate, and scale start-ups in emerging technology sectors. Students will explore start-up ecosystems, financial planning, valuation techniques, and funding mechanisms including venture capital, angel investment, and government grants. The course emphasizes AI-driven decision-making for market analysis, forecasting, and business strategy development. It also introduces business models tailored for AI and deep-tech domains such as robotics, IoT, and quantum technologies. Learners will engage in hands-on activities including financial modelling, pitch deck creation, and start-up simulations using modern tools like Excel, Power BI, and AI platforms. Ethical considerations, legal frameworks, intellectual property rights, and sustainability in AI-driven entrepreneurship are integral components of the course. By the end of the course, students will be capable of conceptualizing, validating, and presenting scalable and responsible deep-tech start-up ideas.

UNIT – I	**09 Hours**

Foundations of Entrepreneurial Finance

Start-up ecosystem overview, types of start-ups (SaaS, AI, Deep-Tech), financial statements (Profit & Loss, Balance Sheet, Cash Flow), unit economics (Customer Acquisition Cost, Lifetime Value), break-even analysis.

UNIT – II	**09 Hours**

Start- Valuation & Funding Strategies

Start-up valuation methods (DCF, Comparable, Scorecard), capitalization tables, equity vs debt financing, funding stages (Seed, Series A/B/C), venture capital, angel investors, government funding schemes.

UNIT – III	**09 Hours**
AI-Driven Business Models & Deep-Tech Ventures AI business models (platform, API-based, subscription), deep-tech domains (AI, robotics, IoT, quantum computing), product-market fit, competitive analysis, monetization strategies	
UNIT – IV	**09 Hours**
Financial Planning, Forecasting & Scaling Financial projections, burn rate, runway, scenario planning, scaling strategies, growth metrics, exit strategies (IPO, M&A).	
UNIT – V	**09 Hours**
Legal, Ethical & Future of AI Entrepreneurship Start-up legal frameworks, intellectual property (patents, copyrights), AI regulations, data privacy laws, ESG principles, future trends in AI entrepreneurship	

I Integration & Authentic Intelligence Reflection (AI² Pedagogy)

- **AI-Augmented Financial Analysis:** Use AI tools for financial dashboards, forecasting, and
- automated analysis.
- **AI-Assisted Start-up Ideation:** Leverage generative AI for idea validation, market research, and MVP design.
- **Human vs AI Decision Making:** Compare human intuition vs AI-driven insights in financial and strategic decisions.
- **Data-Driven Entrepreneurship:** Use AI tools for market intelligence and predictive analytics.
- **Ethical AI Entrepreneurship:** Address bias, fairness, and responsible innovation in start-up ecosystems.
- **Experiential Learning:** Build real-world AI start-up projects with AI-assisted tools.

Applications:

1. AI-based start-up financial planning
2. Venture capital investment analysis
3. Deep-tech innovation ecosystems
4. FinTech and AI-driven business models
5. Start-up valuation and fundraising
6. Smart city and healthcare start-up solutions

Mini Project Component

Industry-Driven Projects

Project 1 – AI Startup Financial Model

- Problem: Build financial projections for an AI-based startup.
- Concepts: Unit economics, forecasting, valuation
- Industry relevance: Startup financial planning

Project 2 – Deep-Tech Startup Pitch

- Problem: Develop and pitch a scalable AI startup idea
- Concepts: Business model, funding strategy, AI integration
- Industry relevance: Venture capital ecosystem

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Apply financial concepts such as cash flow and valuation	L3
CO2	Design AI-driven business models for deep-tech ventures	L3
CO3	Analyze startup funding strategies	L4
CO4	Develop financial projections and pitch decks	L6
CO5	Build scalable and ethical AI startups	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											Program Specific Outcomes (PSOs)	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO 1	PSO 2
CO1	3	2	2	2	2	-	-	-	3	3	3	3	2
CO2	3	3	2	2	3	2	-	-	3	3	3	3	2
CO3	3	3	2	3	3	2	-	-	-	3	3	3	2
CO4	2	3	2	3	3	2	-	-	3	3	3	3	2
CO5	2	3	2	3	3	2	-	-	3	3	3	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Suggested Tools

- Excel, Power BI, Tableau
- Python, SQL
- AI Tools (ChatGPT, AutoML, forecasting tools)
- Startup tools (Pitch deck, Cap table tools)

TEXT BOOKS

1. Brad Feld & Jason Mendelson – *Venture Deals*
2. Eric Ries – *The Lean Start-up*

REFERENCE BOOKS

1. Ash Maurya – *Running Lean*
2. Scott Kupor – *Secrets of Sand Hill Road*
3. Harvard Business Review – Entrepreneurship Articles
4. NASSCOM & Start-up India Reports

E-Resources

1. Coursera – Entrepreneurship & Finance
2. edX – Start-up & Innovation Courses
3. NPTEL – Entrepreneurship

Activity-Based Learning (Suggested Activities in Class)

1. Start-up Pitch Simulation
2. Financial Modelling Workshop
3. Case Study Discussions (AI Start-ups)
4. Ethical AI Entrepreneurship Debate

WIRELESS SENSOR NETWORKS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

The broad objective of the course is to provide students with the following.

1. To understand the fundamentals of wireless sensor networks and their application to critical real-time scenarios.
2. To study the protocols at various layers and their differences with traditional protocols.
3. To understand the issues of sensor networks.
4. To learn the challenges involved in managing a sensor network.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teachers can use to accelerate the attainment of the various course outcomes.

1. ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note taking, annotating, and role playing.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding

MODULE – I : OVERVIEW OF WIRELESS SENSOR NETWORKS	**07 Hours**

Introduction, Sensor network applications – Advantages of sensor networks. Challenges for Wireless Sensor Networks, Enabling Technologies for Wireless Sensor Networks.

Applications: Habitat Monitoring – Tracking chemical plumes – Smart transportation.

MODULE – II : WIRELESS SENSOR ARCHITECTURES:	08 Hours
Single-Node Architecture - Hardware Components, Energy Consumption of Sensor Nodes, Operating Systems and Execution Environments, Network Architecture - Sensor Network Scenarios, Optimization Goals and Figures of Merit, Gateway Concepts. **Applications**: Energy efficiency and consumption estimation for a WSN application.	
MODULE- III : NETWORKING SENSORS	**10 Hours**
Physical Layer and Transceiver Design Considerations, MAC Protocols for Wireless Sensor Networks, Low Duty Cycle Protocols, and Wakeup Concepts - S-MAC, The Mediation Device Protocol, Wakeup Radio Concepts, Address and Name Management, Assignment of MAC Addresses, Routing Protocols- Energy-Efficient Routing, Geographic Routing. **Applications:** Simulation of S-MAC protocol /Wake-up protocol in a Wireless Sensor Network.	
MODULE – IV : INFRASTRUCTURE ESTABLISHMENT	**9 Hours**
Topology Control, Clustering, Time Synchronization, Localization and Positioning, Sensor Tasking and Control. Implementation of Clustering algorithms for WSN. **Applications:** Simulation of the LEACH protocol in a Wireless Sensor Network**,** Estimation of the position of an unknown sensor node**.**	
MODULE – V: SENSOR NETWORK PLATFORMS AND TOOLS	**11 Hours**
Sensor Node Hardware – Berkeley Motes, Programming Challenges, Node-level software Platforms, Node-level Simulators, State-centric programming, **Applications**: WSN Network Performance Analysis.	
NVIDIA DLI Free Courses (Relevant to this Module): *1.* **Getting Started with AI on NVIDIA Jetson Nano** (8 hrs) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2 2. **Build High-Performance and AI-Enabled Sensor Processing Applications. (3 Hrs)** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-30+V1	

AI Integration:

1. Implementation of Energy consumption prediction models for sensor nodes in MATLAB Copilot.
2. Integrate MATLAB / simulation tools with AI models for performance analysis and optimization of WSN scenarios.
3. Use AI for adaptive sleep–wake scheduling to extend network lifetime.

Authentic Intelligence:

1. Recognize privacy, security, and societal implications of sensor data collection and ensure responsible use of AI-enabled WSN solutions in real-world scenarios.
2. Ensure that decisions made by AI-enabled WSN systems, like routing decisions and fault detection are interpretable and explainable.
3. Promote responsible interpretation of sensed data patterns before making system-level decisions.

Course Outcomes	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Understand the architecture, characteristics, and application domains of Wireless Sensor Networks (WSNs).	L2
CO2	Illustrate and apply single-node and network architectures, energy consumption models, operating systems, and gateway concepts in WSN design.	L3
CO3	Analyze physical layer considerations, MAC protocols, wake-up concepts, address management, and energy-efficient routing protocols used in WSNs.	L4
CO4	Apply topology control, clustering, localization, time synchronization, and sensor tasking techniques for establishing efficient WSN infrastructure.	L3

COs	POs											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	**3**	-	-	-	-	-	-	-	-	-	**3**	**3**	-
CO2	**3**	**2**	-	-	-	-	-	-	-	-	**3**	**3**	-
CO3	**2**	**3**	**3**	**3**	**3**	-	**2**	**2**	**2**	**2**	**3**	**3**	**3**
CO4	**2**	**3**	**3**	**3**	**3**	-	**2**	**2**	**2**	**2**	**3**	**3**	**3**
CO5	**2**	**3**	**3**	**3**	**3**	-	**2**	**2**	**2**	**2**	**3**	**3**	**3**

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Holger Karl and Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley, 2005, ISBN: 0-470-09510-5.
2. Feng Zhao and Leonidas J. Guibas, "Wireless Sensor Networks- An Information Processing Approach", Elsevier, 2007.

REFERENCE BOOKS:

1. Kazem Sohraby, Daniel Minoli, and Taieb Znati, "Wireless Sensor Networks - Technology, Protocols and Applications", Second Edition, John Wiley, 2011.
2. Anna Hac, "Wireless Sensor Network Designs", John Wiley, 2010.

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Wireless Adhoc and Sensor Networks https://onlinecourses.nptel.ac.in/noc25_cs74/preview	Prof. Sudip Misra	IIT Kharagpur

Activity-Based Learning (Suggested Activities in Class)

1. Use simulation software and tools to solve real-time issues and scenarios in WSNs

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SATELLITE REMOTE SENSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To understand satellite orbital laws, parameters and launching procedure.
2. To explain physical principles of remote sensing including atmospheric and thermal effects.
3. To understand the sensor system in satellite required for remote sensing.
4. To analyze and represent the images captured by earth observation satellites

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. **The lecture method** means it includes not only the traditional lecture method, but also different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

MODULE – 1: SATELLITE ORBITS	**09 Hours**

Kepler's Laws, Newton's law, orbital parameters, orbital perturbations, station keeping, geo stationary and non-Geo-stationary orbits – Look Angle Determination- Limits of visibility – eclipse-Sub satellite point –Sun transit outage-Launching Procedures - launch vehicles and propulsion.

MODULE – 2: PHYSICAL PRINCIPLES OF REMOTE SENSING	**09 Hours**

Fundamentals of Remote Sensing Signals, Electromagnetic Radiation Laws, Spectral Signatures in the Solar Spectrum, Brief introduction of Vegetation Reflectance, Soil Reflectance Properties, Water in the Solar spectrum ,The Thermal Infrared Domain, Characteristics of EM Radiation in the Thermal Infrared, Thermal Properties of Vegetation, Soils in the Thermal Domain, Thermal Signature of Water and Snow, The Microwave Region ,Characteristics of Electromagnetic Radiation in the, Atmospheric Interactions Atmospheric Absorption, Atmospheric Scattering, Atmospheric Emission

MODULE – 3: SENSORS AND REMOTE SENSING SATELLITES	09 Hours
Resolution of a Sensor System and types, Passive and active sensors: Photographic Cameras, Across- Track Scanners, Along-Track (Push-Broom) Scanners, Video Cameras, Microwave Radiometers, RADAR, LIDAR Satellite remote sensing mission: The Landsat Program, The SPOT Satellites.	
MODULE – 4: BASIS FOR ANALYZING EO SATELLITE IMAGES	**09 Hours**
Constraints in Using Remote Sensing Data, Costs of Data Acquisition, End-User Requirements, Types of Interpretation, Thematic Classification, Generation of Biophysical Variables, Change Detection, Spatial Patterns, Organization of Remote Sensing Project, Description of Objectives, Scale and Resolution, Classification Typology, Selection of Imagery, Image Formats and Media.	
Relevant NVIDIA DLI Courses: 1. Fundamentals of Deep Learning https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2	
MODULE – 5: VISUAL ANALYSIS OF SATELLITE IMAGES	**09 Hours**
Geometric Characteristics of a Satellite Image, Effect of Spatial and spectral Resolution in Visual Analysis, Effect of Spectral Resolution in Visual Analysis, Digital Image Processing Systems,Image Statistics and Histograms, Satellite image collection by Sentinel Hub, Hyperspectral imaging and feature extraction using Machine Learning, Command And Data acquisition Station(CDAS), ocean color remote sensing using ML.	
Relevant NVIDIA DLI Courses: 1. Fundamentals of Accelerated Computing with CUDA Python https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-AC-10+V1	

AI Integration:

- Satellite image processing by **Command and Data acquisition Station (CDAS),**

Authentic Intelligence:

1. Image classification and object detection using CNN
2. Analyzing time-series satellite data RNN
3. Adaptive decision-making in dynamic environments using Reinforcement learning
4. Ethical Reflection on AI in Semiconductor Design - Critically evaluate the societal, economic, and environmental implications of AI-driven semiconductor fabrication, MEMS/NEMS scaling, and flexible electronics — forming responsible engineering perspectives.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Illustrate satellite launching procedure by understanding orbital laws and parameters.	L3
2	Apply physical principles of energy transmission and image acquisition; optical, thermal, and microwave radiant energy interactions on the Earth's surface to aid remote sensing.	L3
3	Employ principal characteristics of sensors to understand Satellite observation systems	L3
4	Analyze earth observation satellite images by considering the constraint in remote sensing.	L4
5	Implement image processing on the satellite image by performing acquisition, feature identification, organization.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	3	4	5	6	7	8	9	10	11		1
CO2	3	3	1		2		-	2	-	-	3		3
CO3	3	2	1		2		-	2	-	-	3		3
CO4	3	2	2		2	-	-	2	-	-	3		3
CO5	3	2	2		1	3	-	2	-	-	3		3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Satellite Communications- Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003, John Wiley & Sons.
2. Satellite Communication Engineering- Wilbur L. Pritchand, Robert A Nelson and Henri G.Suyderhoud, 2nd Edition, Pearson Publications.

REFERENCE BOOKS:

1. Remote Sensing Systems—Platforms and Sensors-Shudharsan. N.K, 2nd Edition, 2024.

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Remote Sensing Essentials nptel.ac.in/courses/105107201	Prof. A. K. Sara	IIT Roorkee

LOW POWER VLSI DESIGN

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Understand the concept of power dissipation in CMOS devices
2. Learn the basic principles of low power design and power optimization
3. Propose and formulate computer arithmetic techniques for low power system
4. Develop and simulate low-power VLSI circuits using industry-standard tools such as Cadence Virtuoso and MATLAB.
5. Analyze and optimize energy-efficient VLSI systems using AI-assisted techniques and high-performance computing platforms such as NVIDIA for accelerated design exploration.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. **The lecture method** includes not only the traditional lecture method, but also different types of teaching methods may be adopted to effectively achieve the course outcomes.
2. **Interactive Teaching**: Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying
3. Use **video or animation**-based content to explain the functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To promote **critical thinking**, ask at least three higher-order thinking questions during the class.
6. Adopt **Problem-Based Learning** which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Demonstrate **different approaches to solving** the same problem and encourage students to develop their own creative solutions.
8. Discuss how each **concept can be applied in real-world scenarios**, as this helps improve students' understanding

MODULE 1: Sources of Power Dissipation	**08 Hrs**

Introduction, Sources of power dissipation, designing for low power. Physics of power dissipation in MOSFET devices – MIS Structure, Long channel and sub-micron MOSFET, Gate induced Drain leakage.

Applications: Low Power Semiconductor Chip Design and Battery-Powered & Standby Electronic Systems.

MODULE 2: Power Dissipation in CMOS	**09 Hrs**
Power dissipation in CMOS – Short circuit dissipation, dynamic dissipation, Load capacitance. Low power design limits - Principles of low power design, Hierarchy of limits, fundamental limits, Material, device, circuit, and system limits. **Applications:** Energy-Efficient CMOS Circuit Design and Battery-Operated High-Performance Electronic Systems.	
MODULE 3: Synthesis for Low Power	**10 Hrs**
Behavioral, Logic and Circuit level approaches, Algorithm level transforms, Power-constrained Least squares optimization for adaptive and non-adaptive filters, Circuit activity driven architectural transformations, voltage scaling, operation reduction and substitution. **Applications:** Low Power Digital Signal Processing Systems and Energy-Efficient VLSI Architecture Design	
MODULE 4: Low Energy Computing	**09 Hrs**
Energy dissipation in transistor channel, Energy recovery circuit design, designs with reversible and partially reversible logic, energy recovery in adiabatic logic and SRAM core, Design of peripheral circuits – address decoder, level shifter, supply clock generation. **Applications:** Adiabatic Low Power Memory and Energy-Recovery VLSI Circuit Design.	
MODULE 5: Design and Test of Low-Voltage CMOS Circuits	**09 Hrs**
Design style, Leakage current in Deep sub-micron transistors, device design issues, minimizing short channel effect, Low voltage design techniques using reverse Vgs, steep sub-threshold swing and multiple threshold voltages. **Applications:** Ultra-Low Power Deep Sub-Micron CMOS Design and Leakage-Aware Portable Electronic Systems	

AI Integration:

1. Use Cadence Virtuoso to simulate MOSFET characteristics and leakage currents, and MATLAB-based AI models to predict power dissipation trends for different device dimensions.
2. Use Cadence Virtuoso to analyze CMOS switching power and MATLAB AI/ML models to estimate dynamic and short-circuit power under varying load capacitances
3. Implement least squares optimization and low-power filter design in MATLAB and accelerate AI-based optimization tasks using NVIDIA GPU computing support
4. Perform circuit design and validation in Cadence Virtuoso and use MATLAB AI techniques for optimization and energy analysis of reversible logic circuits with NVIDIA GPU acceleration
5. Simulate low-voltage CMOS circuits in Cadence Virtuoso and apply MATLAB AI-based predictive analysis to evaluate leakage reduction techniques

Authentic Intelligence:

1. Understanding the limitations of AI models in predicting MOSFET characteristics and power dissipation, including dependence on accurate simulation data, device parameter variations, and model generalization issues.
2. Recognizing risks of incorrect AI-based estimation of CMOS dynamic, leakage, and short-circuit power, and the importance of validating predictions with Cadence simulation results.
3. Evaluating ethical and practical considerations of AI-driven circuit optimization, including reliability, transparency, and avoiding overdependence on automated design decisions.
4. Understanding overfitting, underfitting, and bias in AI models used for low-power filter design, reversible logic optimization, and energy-efficient circuit architectures.
5. Appreciating the importance of responsible model selection, validation, and interpretability when applying AI techniques for leakage reduction and low-voltage deep sub-micron CMOS design

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course, the student will be able to:		
CO1	Identify and analyze the sources of power dissipation in MOSFET devices.	L4
CO2	Determine short circuit and dynamic power dissipation in CMOS and interpret low power design limits across devices.	L2
CO3	Apply behavioral, logic, and circuit-level synthesis techniques to develop low-power architectures using voltage scaling and power- constrained optimization.	L3
CO4	Design energy-efficient memory and peripheral circuits, SRAM, decoders, level shifters, and clock generators, including leakage and short-channel effects in deep sub-micron technologies.	L5
CO5	Analyze low-voltage CMOS circuits considering leakage currents and short-channel effects.	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)												PSOs
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	1	-	-	3	-	-	-	3	3	-
CO2	3	3	3	1	-	-	3	-	2	-	3	3	-
CO3	3	2	3	-	-	-	3	-	2	-	3	3	-
CO4	3	2	3	1	3	-	3	-	2	-	3	3	3
CO5	3	2	3	1	3	-	3	-	2	-	3	3	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Kaushik Roy and S.C.Prasad, “Low power CMOS VLSI circuit design” Wiley January 2009.
2. J.Rabaey, “Low Power Design Essentials (Integrated Circuits and Systems)”, Springer,2009.
3. J.B.Kulo and J.H Lou, “Low voltage CMOS VLSI Circuits”, Wiley 1999.
4. Christian Piguet, “Low Power CMOS Circuits – Technology, Logic Design and CAD Tools”, CRC Press, 2006.

REFERENCES:

1. A.P.Chandrasekaran and R.W.Broadersen, “Low power digital CMOS design”, Kluwer,October 2012.
2. Gary Yeap, “Practical low power digital VLSI design”, Kluwer, October 2012.
3. Abdelatif Belaouar, Mohamed.I.Elmasry, “Low power digital VLSI design”, Kluwer, September 2012.
4. James B.Kulo, Shih-Chia Lin, “Low voltage SOI CMOS VLSI devices and Circuits”, John Wiley and sons,inc. 2001.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	Low Power VLSI Circuit and Systems https://nptel.ac.in/courses/106105034	Prof. Ajith Pal	IIT Kharagpur
2	Low Voltage CMOS Circuit Operation https://nptel.ac.in/courses/117107485	Prof. Anand Bulusu	IIT Roorkee

EDGEAI

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students

1. To understand the fundamental concepts, hardware platforms, and ecosystem of Edge AI and TinyML.
2. To apply model compression techniques — pruning, quantization, knowledge distillation — for on-device inference.
3. To design and deploy neural network models using TensorFlow Lite Micro, Edge Impulse.
4. To implement and benchmark real-time inference pipelines for keyword spotting, image classification, and anomaly detection at the edge.
5. To evaluate responsible AI practices, energy efficiency, and privacy-preserving constraints unique to edge deployments

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where the teacher can use to accelerate the attainment of the various course outcomes.

1. **Interactive Teaching:** Adopt Active Learning that includes brainstorming, discussing, group work, and formulating questions around edge hardware constraints.
2. **Hands-on Labs:** Each module includes a mandatory embedded hardware lab using Arduino Nano 33 BLE Sense, Raspberry Pi, or NVIDIA Jetson Nano.
3. **Video/Demonstration:** Show real-time demos of keyword spotting and gesture recognition running entirely on microcontrollers.
4. **Problem-Based Learning:** Assign open-ended projects where students must fit a neural network within a 256 KB flash constraint.
5. **Collaborative Learning:** Group edge AI deployment challenges using Edge Impulse Studio and shared datasets.

Module - I: Introduction to Edge AI and TinyML Ecosystem	**06 Hours**

What is Edge AI? Cloud vs. Edge inference trade-offs; latency, bandwidth, power, privacy. The TinyML stack: sensors → MCU → model → actuator. Edge AI hardware landscape: microcontrollers (Arduino Nano 33 BLE Sense, STM32), SBCs (Raspberry Pi 4), accelerators (NVIDIA Jetson Nano, Google Coral). ML at the edge: key metrics — FLOPS, memory footprint, energy per inference. Introduction to TensorFlow Lite (TFLite), TFLite Micro, Edge Impulse, and ONNX Runtime Mobile. Overview of edge AI applications: keyword spotting, wake-word detection, gesture recognition, predictive maintenance, anomaly detection.

NVIDIA DLI Courses (Relevant to this Module):

For reference:

1. **Getting Started with the Edge AI and Robotics Teaching Kit**
   https://www.nvidia.com/en-us/on-demand/session/gtcfall21-a31535/

Module - II: Model Compression and Optimization for Edge	**07 Hours**
PN junction diode - operation and characteristics, Zener and Schottky diodes, Bipolar Junction Transistor (BJT), Field Effect Transistors (JFET, MOSFET), Basic optoelectronic devices (LED, photodiode) Applications: Simulate PN junction diode / MOSFET characteristics and use AI tools to analyze behavior using tools MATLAB Simulink + Simscape Electrical	
NVIDIA DLI Courses: Fundamentals of Deep Learning - Covers CNN and regression models with hands-on exercises - applicable to training models on diode I-V characteristic data	
Module - III: Semiconductor Fabrication Technology	**09 Hours**
Why model compression? Memory and compute constraints on MCUs. Quantization: float32 → int8/int16 post-training quantization (PTQ) and quantization-aware training (QAT). Pruning: weight pruning, structured vs. unstructured pruning. Knowledge Distillation: teacher-student paradigm. Weight clustering and Huffman encoding. Neural Architecture Search (NAS) for edge: MobileNet, EfficientNet, SqueezeNet. Benchmarking tools: TFLite benchmark tool, MLPerf Tiny. Energy and latency profiling on microcontrollers.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course **For reference:** 1. **Getting Started with the Edge AI and Robotics Teaching Kit** https://www.nvidia.com/en-us/on-demand/session/gtcfall21-a31535/	
Module - IV: On-Device Learning and TinyML Deployment	**06 Hours**
TensorFlow Lite Micro (TFLM) architecture: interpreter, operator resolver, tensor arena. Edge Impulse Studio: data ingestion, signal processing DSP blocks, model training, deployment to firmware. Arduino Uno Q/STM32 peripherals: IMU (LSM9DS1), microphone (MP34DT05), colour sensor. Keyword spotting pipeline: MFCC feature extraction → CNN/RNN → on-device inference. Image classification on camera modules attached to Arduino UNO Q. Gesture/motion recognition using accelerometer data. Anomaly detection on time-series sensor data with autoencoders and Z-score methods. Transfer learning on edge: fine-tuning MobileNet with small domain datasets.	
Module - V: Edge AI Hardware Acceleration and Real-Time Inference	**06 Hours**
Hardware accelerators for edge AI: DSP, GPU, NPU, dedicated silicon (Google Coral TPU, Hailo-8, STM32 Cube.AI). NVIDIA Jetson Nano / Orin NX for edge vision: CUDA, TensorRT optimisation, DeepStream SDK. OpenCV on embedded Linux for pre/post-processing. ONNX export and runtime for cross-platform deployment. Real-time object detection: MobileNet-SSD, YOLOv5-Nano on Jetson. Edge video analytics pipeline: camera → ISP → inference → overlay → HDMI/RTSP stream. Power management: duty cycling, sleep modes, dynamic voltage and frequency scaling (DVFS). Memory management: static allocation, arena sizing for TFLM.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course **For reference:** 1. **Getting Started with AI on Jetson Nano** (8 hrs) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2	

Module - VI: Responsible Edge AI, Privacy, and End-to-End Deployment	06 Hours
Federated learning for privacy-preserving on-device training: concepts, FedAvg algorithm, communication efficiency. On-device continual/incremental learning. Data privacy at the edge: GDPR implications, local differential privacy. Security threats: adversarial examples, model inversion, firmware attacks; defence strategies. Edge-to-cloud pipelines: MQTT, CoAP, LoRaWAN for telemetry; AWS Greengrass, Azure IoT Edge, Google Cloud IoT. MLOps at the edge: OTA model updates, A/B testing firmware, monitoring inference drift. Responsible AI: fairness, accountability, explainability (LIME/SHAP adapted for tiny models). Capstone project design: problem framing → dataset → model → compression → deployment → evaluation.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course **For reference:** 1. **Advanced Federated Learning with NVIDIA FLARE** (8 hrs) https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-38+V1&ncid=so-link-911670	

AI Integration:

1. Use Edge Impulse Studio (no-code ML platform) to acquire sensor data and auto-generate embedded firmware; use serial plotter for real-time sensor visualization.
2. Apply TensorFlow Model Optimization Toolkit for PTQ and QAT; use TFLite benchmark CLI to profile latency and memory footprint across hardware targets.
3. Deploy TFLM models on Arduino via Edge Impulse Arduino library; use MFCC and spectral features computed on-device for keyword spotting.
4. Use TensorRT for Jetson Nano acceleration; profile with jtop and NVIDIA Nsight Systems; integrate OpenCV pipelines for vision pre-processing.
5. Implement a lightweight MQTT publisher on MCU; test OTA model update workflow on Jetson using Azure IoT Hub; evaluate model fairness using LIME.

Authentic Intelligence:

1. Understanding fundamental trade-offs between model accuracy and hardware constraints; limitations of tiny models in safety-critical applications.
2. Awareness of quantization errors, approximations introduced during compression, and their impact on real-world edge inference reliability.
3. Critical evaluation of on-device data collection biases; responsible handling of user audio/video captured by always-on edge sensors.
4. Ethical concerns with edge surveillance (CCTV AI, emotion recognition); GDPR compliance in IoT deployments; transparency in model decisions.
5. Accountability in deploying life-critical edge AI (medical wearables, autonomous systems); importance of explainability even with resource constraints.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the Edge AI and TinyML ecosystem including hardware platforms, software stacks, and application domains.	L2
2	Apply model compression techniques — quantization, pruning, and knowledge distillation — to deploy neural networks within microcontroller resource constraints.	L3
3	Implement and evaluate end-to-end on-device inference pipelines for keyword spotting, image classification, and anomaly detection using TFLite Micro and Edge Impulse.	L3
4	Analyse hardware accelerators (Coral TPU, Jetson Nano, TensorRT) and design optimised edge inference pipelines for real-time vision and audio applications.	L4
5	Evaluate responsible edge AI design including privacy, security, federated learning, and ethical deployment, and build a complete capstone edge AI system.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	2	3	2	2	1	2	1	3	2	2
CO2	3	3	3	2	3	2	2	2	2	2	3	2	2
CO3	3	3	3	3	3	2	2	2	2	2	3	2	3
CO4	3	2	3	3	3	2	2	2	2	2	3	3	3
CO5	3	2	3	3	3	3	3	2	3	2	3	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Warden, P. and Situnayake, D., 2019. **TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers.** O'Reilly Media.
2. Shafique, M. and Murmann, B. (Eds.), 2022. **TinyML: Efficient Deep Learning for IoT.** Springer.
3. Reddi, V.J. et al., 2022. **MLCommons TinyML Benchmark Suite (MLPerf Tiny).** Open-access proceedings.
4. Howard, J. and Gugger, S., 2020. **Deep Learning for Coders with fastai and PyTorch.** O'Reilly Media.

REFERENCE BOOKS:

1. Langer, E., 2022. **AI at the Edge (Full Book).** O'Reilly. Available: https://6371311.fs1.hubspotusercontentna1.net/hubfs/6371311/Content%20and%20Docs/AI%20at%20the%20Edge%20-%20full%20book%20-%20compressed.pdf
2. Reddi, V.J. et al., 2023. **Machine Learning Systems (mlsysbook.ai).** MIT / Open access. Available: https://mlsysbook.ai/book/

RESOURCES:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Edge Impulse Documentation & Tutorials	Edge Impulse Inc.	https://docs.edgeimpulse.com/
2	TinyML and Efficient Deep Learning (MIT 6.5940)	Prof. Song Han	https://hanlab.mit.edu/courses/2024-fall-65940
3	UNIFEI IESTI05 – Edge AI Course (GitHub)	Prof. M. Rovai	https://github.com/Mjrovai/UNIFEI-IESTI05-EDGE_AI
4	Embedded Deep Learning & TinyML (CMU ECE)	Prof. Ziad Youssfi	https://z4ziad.github.io/mbed_dl_bak/mbed_dl/
5	Edge AI Course CP330 (IISc)	Prof. Pandarasamy Arjunan	https://www.samy101.com/edge-ai-25/
6	Machine Learning Systems Book (mlsysbook.ai)	V.J. Reddi et al.	https://mlsysbook.ai/book/
7	TensorFlow Lite for Microcontrollers	Google / TF Team	https://www.tensorflow.org/lite/microcontrollers

INDUSTRIAL IOT

[As per Choice Based Credit System (CBCS) scheme]
SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To understand the principles of sensing and actuation
2. To understand industrial internet and associated technologies.
3. To study various analytics used in analysing industrial data.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher Order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

Module – I : Introduction	**09 Hours**

Sensing & actuation, Communication Protocols, Networking Protocols, Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems.
Application: Smart Factories

Relevant NVIDIA DLI Courses:

1. Getting Started with AI on Jetson Nano
   Applicable for IIoT Physical Layers & Sensing Learn to collect image data, train models, and run inference on edge hardware
   https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2

Module – II : Industrial Internet Technologies	**09 Hours**
Cyber Physical Systems and Next Generation Sensors and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data, Cybersecurity in Industry 4.0. **Application:** Predictive maintenance on EV assembly lines.	
Relevant NVIDIA DLI Courses: 1. Accelerate Data Analytics on GPUs with the RAPIDS accelerator Big data , data acquisition https://www.nvidia.com/en-us/on-demand/session/gtc25-dlit71528/	
Module – III : IIoT-Business Models	**09 Hours**
Introduction of Business Model, Reference Architecture, Business models of IIOT: Business opportunity, categorization, Reference architecture of IIOT, IIRA frame works, study of key performance indicators. **Application:** Monitoring KPI of an business model	
Relevant NVIDIA DLI Courses: 1. Data Science Teaching Kit Business KPIs, Analytics https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-DS-04+V1	
Module – IV : Analytics for Industy 4.0	**09 Hours**
Introduction, Machine Learning and Data Science in Industrial IoT: Big Data Analytics and Software Defined Networks: IIoT Machine Learning and Data Science Data Management with Hadoop Data Center, Industrial IoT Security and Fog Computing - Fog Computing in IIoT. **Application: Anomaly Detection in Battery Packs, Edge AI for Motor Control**	
Relevant NVIDIA DLI Courses: 1. Fundamentals of Deep Learning https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2	
Module – V : Case Studies: Industrial IoT- Application Domains	**09 Hours**
Healthcare, Power Plants, Industrial IoT- Application Domains: Oil, chemical and pharmaceutical industry, Applications of UAVs in Industries. **Application:** Create a digital twin and Manufacturing industries.	
Relevant NVIDIA DLI Courses: 1. Introduction to Omniverse and OpenUSD for creating digital twins of manufacturing plants. https://docs.nvidia.com/learning/physical-ai/assembling-digital-twins/latest/index.html	

AI Integration:

1. AI-based predictive maintenance in industrial systems
2. Machine learning for fault detection and condition monitoring
3. AI-driven sensor data filtering and pattern recognition
4. Digital Twin development using AI-assisted simulation tools
5. AI-supported optimization of process control parameters

Authentic Intelligence:

1. Human-in-the-loop approach for AI-based automation decisions
2. Verification and validation of AI outputs using real-time data
3. Ethical and responsible use of AI in industrial applications
4. Industry-based case studies and problem-solving using AI tools
5. Critical thinking and engineering judgment in AI-assisted systems

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand** the basic concept of sensing and actuation and Networking and communication protocol, introduction to basic concepts of industry 4.0	L2
2	**Understand** key technologies applied like Cyber Physical Systems, AR,VR, AI, Big data , Cybersecurity, Cloud computing , Data Transmission, Data Acquisition in Industry 4.0	L2
3	**Apply** the Knowledge of IIoT in designing a Business Models in industrial system	L3
4	**Implement** analytics technologies like ML, DS, Big data, SDN, Data Management Fog Computing.	L3
5	**Apply** various Industry 4.0 technologies to different engineering domains.	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
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CO2	3	2	-	2	2	-	-	-	-	2	2	1	-
CO3	3	3	2	2	3	-	-	-	2	2	2	1	-
CO4	3	3	2	3	3	-	-	-	2	2	3	1	-
CO5	3	3	3	3	3	2	2	-	2	2	3	1	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Introduction to industrial internet of things and industry 4.0 by Sudip Misra, Chandan roy, Anandarup Mukarjee, 1st edition , CRC Press publisher,2021, ISBN 9781003020905

REFERENCE BOOKS:

1. Industry 4.0 the industrial Internet of Things , Alasdair Gilchrist, 1st edition, Apress Publisher,2017, ISBN-13: 978-1-4842-2046-7
2. Honbo Zhou, "The Internet of Things in the Cloud: A Middleware Perspective" -CRC Press-2012.
3. Designing the Industry - Internet of things connecting the physical, digital and virtual worlds, OvidiuVermesan and Peer Friess,1st edition, Rivers Publishers, 2016, ISBN 978-87-93379-81-7

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Introduction to Industry 4.0 and Industrial Internet of Things – https://onlinecourses.nptel.ac.in/noc26_cs38/preview	By Prof. Sudip Misra	IIT Kharagpur
2	https://www.coursera.org/learn/industrial-internet-of-things	M.S Krishnan	University of Michigan

GENERATIVE AI AND LARGE LANGUAGE MODELS (LLMs)

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the foundational concepts of Generative AI, LLMs, Transformer architecture, and NLP preprocessing techniques.
2. Analyse Prompt Engineering strategies and apply LLM orchestration frameworks for building intelligent language-driven applications.
3. Apply Retrieval-Augmented Generation (RAG) pipelines and vector database integration techniques for knowledge-enhanced LLM systems.
4. Design fine-tuning workflows using PEFT/LoRA methods and diffusion model customization for domain-specific and multimodal generative tasks.
5. Evaluate production-scale LLM deployment strategies, distributed training techniques, safety guardrails, and responsible AI governance frameworks.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. **Interactive Teaching:** Adopt Active Learning that includes brainstorming, Socratic questioning, and think-pair-share activities around GenAI concepts and ethical dilemmas.
2. **Video & Demonstration:** Show NVIDIA DLI course demo videos, Jupyter Notebook walkthroughs, and live LLM inference demonstrations using HuggingFace and NVIDIA NIM APIs.
3. **Collaborative (Group Learning):** Conduct hands-on lab sessions and mini-projects on building RAG systems, fine-tuning LLMs, and deploying AI services using NVIDIA tools.
4. **Critical Thinking:** Ask Higher Order Thinking (HOT) questions on model bias, hallucination, ethical AI, and limitations of current generative systems in each class.
5. **Problem-Based Learning:** Present real-world GenAI challenges — legal document summarization, medical QA, code generation — and guide students through systematic solutions using NVIDIA platforms.
6. **Real-World Application:** Map every concept to an industry use case — healthcare, finance, EdTech, or manufacturing — to strengthen student understanding and motivation.

MODULE – I: Introduction to Generative AI and Large Language Models	09 Hours
Overview of Artificial Intelligence, Machine Learning, and Deep Learning paradigms. Introduction to Generative AI, Evolution from rule-based systems to neural generative models, Core components of a Generative AI system, Fundamental concepts of Natural Language Processing (NLP), Introduction to the Transformer architecture, Overview of prominent LLM families, Ethical dimensions of Generative AI, NVIDIA GPU ecosystem and its role in accelerating GenAI workloads: CUDA, TensorRT, and NVIDIA NIM.	
NVIDIA DLI Courses (Relevant to this Module): 1. ***Generative AI Explained*** Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-07+V1 2. ***Building Transformer-Based Natural Language Processing Applications*** Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-03+V3 3. ***Fundamentals of Deep Learning*** Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-06+V2	
MODULE – II: Transformer Architecture, Prompt Engineering, and NLP Applications	**09 Hours**
Deep dive into Transformer architecture, Pre-training vs. fine-tuning paradigms, Word embeddings and contextual representations, Prompt Engineering fundamentals, Advanced prompting techniques, Practical NLP applications using LLMs, LLM orchestration frameworks, Using NVIDIA APIs and NIM microservices for rapid deployment of LLM-based applications. Evaluation metrics for NLP tasks: BLEU, ROUGE, BERTScore, and Perplexity.	
NVIDIA DLI Courses (Primary References for this Module): 1. ***Introduction to Transformer-Based Natural Language Processing*** Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-12+V2 2. ***Prompt Engineering with Llama 2*** Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-26+V1 3. ***Rapid Application Development Using Large Language Models*** Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-17+V1	
MODULE – III: Retrieval-Augmented Generation (RAG) and Knowledge-Enhanced LLMs	**09 Hours**
Limitations of standalone LLMs, Introduction to Retrieval-Augmented Generation (RAG), Vector databases and semantic search, Embedding models for document retrieval, Document ingestion pipelines, Advanced RAG techniques, Building production RAG agents with LLMs, Agentic AI frameworks, Deploying RAG pipelines at production scale using NVIDIA NIM and Triton Inference Server, Synthetic data generation using Transformers for augmenting training datasets.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course: 1. ***Augment Your LLM Using Retrieval-Augmented Generation*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-16+V1 2. ***Building RAG Agents with LLMs*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-15+V1 3. ***Deploying RAG Pipelines for Production at Scale*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-32+V1 4. ***Techniques for Improving the Effectiveness of RAG Systems*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-20+V1 5. ***Synthetic Tabular Data Generation Using Transformers*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-27+V1	

MODULE – IV: LLM Fine-Tuning, Customization, and Diffusion Models	**09 Hours**
Understanding LLM fine-tuning, Parameter-Efficient Fine-Tuning (PEFT) methods, Dataset preparation for fine-tuning, Domain adaptation strategies, Evaluation of fine-tuned models, Introduction to Diffusion Models, Score-based generative models, DDIM sampling, and classifier-free guidance. Practical diffusion architectures: Stable Diffusion, DALL-E, and Imagen. Multimodal LLMs: CLIP, BLIP, LLaVA, and visual question answering. Fine-tuning diffusion models: DreamBooth, textual inversion, and ControlNet.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course 1. ***Efficient Large Language Model Customization (PEFT & Fine-Tuning)*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-33+V1 2. ***Generative AI with Diffusion Models*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-34+V1 3. ***Building RAG Agents for LLMs (Instructor-Led)*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-26+V1 4. ***Efficient Large Language Model Customizations (Workshop)*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-07+V1	
MODULE – V: LLM Deployment, Distributed Training, and Production-Scale AI	**09 Hours**
Distributed training strategies, Multi-GPU training frameworks, LLM inference optimization, Deploying LLMs at production scale, Containerized AI deployment, LLM monitoring and observability, Safety and alignment, Responsible AI and governance frameworks, Emerging trends: Mixture-of-Experts (MoE) models, small language models (SLMs), agentic AI systems, and on-device AI. Applications: AI-powered code generation (GitHub Copilot, CodeLLaMA), intelligent document processing, conversational AI, and drug discovery.	
NVIDIA DLI Courses (Relevant to this Module): If Applicable for this course 1. ***Model Parallelism: Building and Deploying Large Neural Networks*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-23+V1 2. ***Data Parallelism: How to Train Deep Learning Models on Multiple GPUs*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-18+V1 3. ***Deploying a Model for Inference at Production Scale*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-19+V1 4. ***Rapid Application Development Using LLMs (Advanced Workshop)*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-18+V1 5. ***Generative AI with Diffusion Models (Instructor-Led)*** **Link:** https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-25+V1	

AI Integration :

1. Hands-on implementation of a Generative AI pipeline using HuggingFace Transformers and NVIDIA NeMo: building a text generation application, tokenization, and inference using pre-trained LLMs (GPT-2, LLaMA). Introduction to Python-based prompt engineering workflows using LangChain and NVIDIA NIM APIs.
2. Implementation of Retrieval-Augmented Generation (RAG) systems using LangChain, FAISS/ChromaDB vector store, and sentence-transformers for embedding. Building a domain-specific QA bot over a custom knowledge base with evaluation using RAGAS metrics.
3. Fine-tuning a pre-trained LLM using Parameter-Efficient Fine-Tuning (PEFT/LoRA) techniques with the HuggingFace PEFT library and supervised instruction datasets. Evaluating fine-tuned models against baseline using ROUGE and BERTScore metrics.
4. Building and evaluating a multi-agent AI system using LangChain Agents and NVIDIA NIM tool-augmented LLMs: implementing function calling, tool selection, and ReAct reasoning loops. Visualizing agent reasoning traces using LangSmith.
5. Deployment of a fine-tuned LLM using NVIDIA Triton Inference Server with TensorRT-LLM optimization; benchmarking latency and throughput; integrating NeMo Guardrails for safety filtering; monitoring model outputs using Prometheus and Grafana dashboards.

Authentic Intelligence:

1. Critical analysis of hallucination and factual accuracy risks in LLM-generated content; understanding the limitations of training data biases in generative models; ethical responsibilities of AI practitioners in deploying content-generating systems; regulatory landscape (EU AI Act, DPDP) and responsible disclosure practices.
2. Evaluating trade-offs in prompt engineering strategies: over-reliance on LLM reasoning vs. structured pipelines; risks of prompt injection attacks; interpretability challenges in chain-of-thought prompting; responsible use of LLMs for sensitive NLP tasks such as medical and legal text processing.
3. Responsible deployment of RAG systems: data provenance and attribution of retrieved content; risks of exposing confidential enterprise data through retrieval pipelines; understanding limitations of semantic search and embedding drift; avoiding confirmation bias in agentic AI retrieval loops.
4. Ethical dimensions of fine-tuning LLMs: risks of catastrophic forgetting, mode collapse, and reward hacking in RLHF; bias amplification through instruction tuning on unvetted datasets; responsible use of synthetic data; limitations of automated evaluation benchmarks in capturing real-world performance.
5. Governance and accountability in production AI systems: risks of over-relying on black-box LLM decisions in high-stakes applications; importance of human-in-the-loop frameworks; interpretability limitations of distributed multi-GPU systems; long-term societal impact of large-scale LLM deployment on employment and information ecosystems.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the foundational concepts of Generative AI, Large Language Models, and Transformer architecture, including their evolution, components, and real-world applications.	**L2**
2	Analyse and apply Prompt Engineering strategies, NLP pipelines, and LLM orchestration frameworks to build intelligent language applications using NVIDIA tools and open-source libraries.	**L3**
3	Apply Retrieval-Augmented Generation (RAG) techniques and vector database integration to build knowledge-enhanced, production-ready LLM applications with advanced agentic reasoning.	**L3**
4	Design and implement fine-tuning workflows using PEFT/LoRA and diffusion model customization techniques to adapt pre-trained models for domain-specific and multimodal tasks.	**L4**
5	Evaluate and optimise LLM deployment pipelines using distributed training, inference acceleration, safety guardrails, and responsible AI governance frameworks for scalable production systems.	**L5**

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	1	1	-	-	-	-	-	2	1
CO2	2	3	-	2	3	-	-	-	-	-	-	2	2
CO3	-	2	3	2	3	2	-	-	-	-	-	1	2
CO4	2	2	3	3	3	-	-	1	-	-	-	2	2
CO5	-	-	2	-	3	3	2	3	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. **Goodfellow, I., Bengio, Y., and Courville, A., 2016.** Deep Learning. MIT Press.
2. **Tunstall, L., von Werra, L., and Wolf, T., 2022.** Natural Language Processing with Transformers. O'Reilly Media.
3. **Rothman, D., 2022.** Transformers for Natural Language Processing. 2nd Edition, Packt Publishing.

REFERENCE BOOKS:

1. **Alammar, J. and Grootendorst, M., 2023.** Hands-On Large Language Models. O'Reilly Media.
2. **Liu, P., et al., 2023.** Pre-train, Prompt, and Predict: A Systematic Survey of Prompting Methods in NLP. ACM Computing Surveys.
3. **Lewis, P., et al., 2020.** Retrieval-Augmented Generation for Knowledge-Intensive NLP Tasks. NeurIPS Proceedings.
4. **Hu, E.J., et al., 2022.** LoRA: Low-Rank Adaptation of Large Language Models. ICLR 2022 Proceedings.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Generative AI Explained	NVIDIA Deep Learning Institute	https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-07+V1
2	Introduction to Transformer-Based NLP	NVIDIA Deep Learning Institute	https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-12+V2
3	Building RAG Agents with LLMs	NVIDIA Deep Learning Institute	https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-15+V1
4	Efficient LLM Customization (PEFT/LoRA)	NVIDIA Deep Learning Institute	https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-33+V1
5	CS224N: NLP with Deep Learning	Prof. Chris Manning	Stanford University (YouTube)
6	Generative AI for Everyone	Andrew Ng	Coursera / DeepLearning.AI
7	LangChain & Vector Databases in Production	Activeloop	Activeloop.ai (Free Course)

Department of Electronics and Communication Engineering

5G AND MOBILE COMMUNICATION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Provide a comprehensive understanding of 5G radio spectrum and channel modeling concepts, efficient spectrum management and enhanced wireless communication performance.
2. Apply 5G architecture options to implement physical layer procedures like MIMO, power control, link adaptation and beamforming
3. Examine access design principles and analyze multi-carrier techniques and non-orthogonal schemes for efficient 5G communication.
4. Analyze 5G network slicing concepts including E2E, SDN, and NFV, and explore vehicular communication technologies from V2V to V2X, with the integration of AI for intelligent network management and enhanced communication efficiency.
5. Enable students to critically evaluate mobility and handoff management in 5G, including network deployment, interference management, and dynamic reconfiguration, as well as analyze various 5G use cases, with the application of AI for intelligent optimization and decision-making.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:	
Module 1: 5G Radio Spectrum, Channel Model and System Concept	**09 Hrs**
5G RADIO SPECTRUM: 5G spectrum landscape and requirements, Spectrum access modes and sharing scenarios, 5G spectrum technologies. **5G CHANNEL MODEL:** 5G wireless Propagation Channels, Channel modeling requirements, propagation scenarios and challenges in the 5G modeling. **SYSTEM CONCEPT:** 5G system concept	
MODULE 2: Radio Interface Architecture And 5G Physical Layer	**09 Hrs**
5G architecture options, core network architecture, RAN architecture,Physical channels and signals, 5G frame structure, physical layer procedures (MIMO, Power control, link adaptation, beam forming).	
MODULE 3: 5G Radio-Access Technologies	**09 Hrs**
Access design principles for multi-user communications, multi-carrier with filtering: a new waveform, non-orthogonal schemes for efficient multiple access.	
MODULE 4: Introduction to 5G Network Slicing and Vehicular Communications	**09 Hrs**
Network Slicing, E2E Slicing, SDN and NFV Slicing, From V2V to V2X, key standards, VC architectures, V2X Use cases.	
MODULE 5: Mobility and Handoff Management in 5G and 5G Use Cases	**09 Hrs**
Mobility and Handoff Management in 5G: Network deployment types, Interference management in 5G, Mobility management in 5G, Dynamic network reconfiguration in 5G **5G USE CASES:** Use cases and requirements, Generate AI model for different 5G use cases.	

AI Integration:

1. Optimize network slicing, manage resources in SDN/NFV environments, and enhance V2X communication performance through intelligent decision-making using AI.
2. Enhance mobility and handoff decisions, enable dynamic network reconfiguration, and develop intelligent models for diverse 5G use cases by integration.

Authentic Intelligence:

1. Understanding real-world spectrum requirements, propagation challenges, and channel behaviour while analyzing modeling limitations and system design considerations.
   Analyzing architectural and physical layer design choices while understanding implementation challenges, trade-offs and deployment constraints.
2. Understanding multi-user access and waveform design challenges while analyzing interference, limitations and efficiency considerations.
3. Critically evaluating network slicing and vehicular communication systems while considering scalability, reliability and real-world constraints.
4. Analyzing mobility and handoff challenges while understanding interference, reconfiguration and practical deployment issues in 5G systems.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	**Understand** 5G spectrum requirement and channel model	L2
2	**Apply** 5G architecture options and implement physical layer procedures such as MIMO, power control, link adaptation, and beamforming in practical scenarios	L3
3	**Examine** the multi-carrier techniques and non-orthogonal schemes for 5G communication	L4
4	**Analyze** 5G network slicing concepts and vehicular communication technologies from V2V to V2X, with the integration of AI for intelligent network management and enhanced communication efficiency.	L4
5	**Evaluate** and justify mobility, handoff, interference management, and dynamic reconfiguration strategies in 5G networks, and assess AI-based models for optimizing diverse 5G use cases	L5

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	-	3	-	-	-	-	2	2	-
CO2	3	3	3	3	3	-	-	3	3	-	3	3	2
CO3	3	3	3	3	3	-	-	2	2	-	3	3	2
CO4	3	3	3	3	3	2	2	-	-	-	3	3	3
CO5	3	3	2	2	-	-		-	-	-	2	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Afif Osseiran, Jose F Monserrat, Patrick Marsch, "5G Mobile and Wireless Communications Technology", Cambridge University Press, 2016
2. Saad Z. Asif, "5G Mobile Communications Concepts and Technologies", CRC Press, Taylor & Francis Group, First Edition, 2018
3. Harri Holma, Antti Toskala, Takehiro Nakamura, "5G Technology 3GPP NEW RADIO", John Wiley & Sons First Edition,2020

REFERENCE BOOKS:

1. Gordon L. Stuber, "Principles of Mobile Communication", KLUWER ACADEMIC PUBLISHERS, 2nd Edition, 2002
2. Joseph C. Liberti, Theodore S. Rappaport, "Smart Antennas for Wireless Communications", Prentice Hall PTR, 1999 76
3. Ying Zhang, "Network Function Virtualization Concepts and Applicability in 5G Networks", John Wiley & Sons, 2018
4. A. Chockalingam, B. Sundar Rajan, "Large MIMO Systems", Cambridge University Press, 2014

E.Resources: NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	https://nptel.ac.in/courses/108105134	Prof. Suvra Sekhar Das	IIT Kharagpur

SEISMIC SIGNAL PROCESSING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To understand the principles of seismic wave theory
2. To understand concepts of 2D and 3D seismic data Processing technique.
3. Knowledge on 2D and 3D seismic data Interpretation

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. **The lecture method** means it includes not only the traditional lecture method, but also different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

MODULE – 1: Seismic wave theory	**09 Hours**

Seismic wave theory

Fundamentals to seismic wave theory: Propagation of Seismic Waves in Linear and Nonlinear medium, Waveforms and their characteristics, N Layered case, continuous increase of velocity. Seismic attenuation, reflection and transmission coefficients, Knott and Zoeppritz equations.

MODULE – 2: Sampling Theory	**09 Hours**

Sampling Theorem and Analysis of Seismic signals, Convolution, Correlation Techniques and Inverse Filtering of Seismic Data, Seismic Inversion, Determination of Average Seismic Velocities**.**	
MODULE – 3: Seismic Methods/Analysis	**09 Hours**
Seismic energy sources, Seismic noises and Noise Profile Analysis, Source and receiver arrays, Directional shooting, Shooting geometry. Instrumentation in refraction & reflection surveys. Digital seismic data recording.	
Relevant NVIDIA DLI Courses: 1. Fundamentals of Deep Learning https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2	
MODULE – 4: Seismic Signal Processing	**09 Hours**
Introduction to seismic data processing. Processing sequences- preparation of processing geometry, quality checks, true amplitude recovery, deconvolution, filtering, velocity analysis, Statics Corrections, NMO corrections, Stacking; Complex trace analysis; Hilbert transform (instantaneous frequency; instantaneous phase); noise elimination through multichannel filtering, parameter optimization for generation final stacked section. Discrete time sequence; Z-transform, Linear system; Filtering system, Frequency alias; Nyquist frequency; Interpolating; Low-pass, high-pass, band-pass filters; Notch, Moving average; Gibbs effect; Spectral analysis, Zero Phase; Linear phase shift, DMO and migration AVO and attribute analysis. Anisotropy processing: HTI, VTI Mode. Converted Wave Processing.	
MODULE – 5: Seismic data interpretation	**09 Hours**
Introduction to seismic data interpretation: Overview of Seismic Stratigraphy. Seismic data interpretation Wavelet analysis for seismic stratigraphic interpretation. Seismic sequence analysis and seismic facies analysis. Overview of Seismic Stratigraphy. Study of seismic section and other geological aspects of prospecting, structural interpretation, construction of isochron and isopach maps, thin bed resolution and pitfalls, LRLC interpretation, AVO and attribute analysis, Prospect evaluation & Ranking, Basis of seismic interpretation in workstation environment using standard packages.	

AI Integration:

- seismic interpretation software KINGDOM / OpendTect

Authentic Intelligence:

- Deep learning algorithms can automatically identify earthquakes, micro seismic events, or subsurface anomalies with high accuracy.
- Neural networks enhance precision in identifying seismic wave arrivals, crucial for earthquake monitoring and exploration.
- AI enables denoising and event detection in DAS data, which uses fiber optic cables as seismic sensors.
- Machine learning accelerates geological model building, automating horizon picking, fault delineation, and facies classification.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to		
1	**Analysis of** Various seismic analysis methods and their limitations and potential for creating models of the subsurface	L2
2	**Apply** Fourier, wavelet, and spectral analysis techniques to seismic signals for noise reduction and feature extraction.	L3
3	**Implement** preprocessing workflows including filtering, deconvolution, and phase picking for seismic datasets.	L4
4	**Infer** subsurface structures, faults, and horizons for exploration and monitoring using processed seismic signals.	L4
5	**Employ** machine learning and deep learning models for automated seismic signal analysis and interpretation.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	2	-	-	-	-	2	2	1	-
CO2	3	2	-	2	2	-	-	-	-	2	2	1	-
CO3	3	3	2	2	3	-	-	-	2	2	2	1	-
CO4	3	3	2	3	3	-	-	-	2	2	3	1	-
CO5	3	3	3	3	3	2	2	-	2	2	3	1	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Dobrin, M. B., and Savit, C. H., 1988, Introduction to Geophysical Prospecting (Fourth Edition), Tata McGraw Hill.
2. Telford, W. M., Geldart, L. P., Sheriff, R. E., and Keys, D. A., 1988, Applied Geophysics.

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REFERENCE BOOKS:

1. Parasnis, D. S., 1997, Principles of Applied Geophysics (Fifth Edition), Chapman and Hall.
2. Grifith, and King, Applied Geophysics for Engineers and Geologists, 2013.
3. Kearey, P., Brooks, M., and Hill, I., 2002, Introduction to Geophysical Exploration: BlackWell
4. Scientific Publications.
5. Parasnis, D. S., 1997, Principles of Applied Geophysics (Fifth Edition), Chapman and Hall.
6. Evans, B., Field Geophysics: SEG Publications, 1980.

E-Resources:

S. No.	Course /Resource Name	Instructor	Host Institute
1	Introduction to Engineering Seismology nptel.ac.in/courses/105108204	Prof. P. Anbazhagan	IISc Bangalore

SEMICONDUCTOR DEVICE MODELING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To introduce the fundamental concepts of carrier transport and energy band theory in semiconductors.
2. To develop understanding of transport equations and drift-diffusion modelling for semiconductor devices.
3. To analyze semiconductor devices using energy band diagrams and characteristic physical parameters.
4. To familiarize students with device modelling methodology and approximation techniques used in practical modelling.
5. To provide an understanding of MOSFET operation and its qualitative modelling approaches.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:	
Module 1: Fundamentals of Carrier Transport and Energy Bands	**09 Hrs**
Introduction to device modelling, role of approximations and modelling in IC design, understanding of carrier transport, scattering mechanisms, effective mass and carrier temperature, concept of semi-classical transport, energy band diagrams (ε–k and ε–x), equilibrium and non-equilibrium band diagrams, Understanding of carrier motion and transport phenomena **Applications:** Understanding current flow in semiconductor devices and basic operation of diodes and transistors. Provides a foundation for analyzing device performance and further modeling concepts.	
MODULE 2: Transport Equations and Drift-Diffusion Model	**09 Hrs**
Concept of electromagnetic forces on carriers, transport equations, conservation principles in carrier transport, introduction to Boltzmann Transport Equation, derivation of drift-diffusion model, current density equations, mobility models, generation and recombination mechanisms, boundary conditions. **Applications:** Estimation of current in semiconductor devices and understanding carrier behavior under electric fields. Forms the basis for modelling real devices and electronic circuits.	
MODULE 3: Device Physics through Band Diagrams and Characteristic Scales	**09 Hrs**
Energy band diagrams of semiconductor devices under equilibrium and bias, band diagrams of PN junction and heterojunctions, exponential current behavior from band diagrams, concept of characteristic times and lengths, carrier lifetime, transit time, dielectric relaxation time, Analysis of carrier distribution and current flow using spatial plots. **Applications:** Visualization of device operation using band diagrams and understanding switching speed of devices. Useful for analyzing diode and transistor behavior	
MODULE 4: Device Modelling Methodology and Approximation Techniques	**10 Hrs**
Steps involved in deriving a device model (SQEBASTIP concept), role of approximations in modelling, identification of variables and parameters, normalization of equations, classification of device models based on application, frequency and signal level, interpretation of different modelling approaches and simplifications. **Applications:** Development of simplified models for complex semiconductor devices. Helps in understanding how models are used in circuit design and simulation.	
MODULE 5: MOSFET Modelling	**08 Hrs**
MOSFET structure and operation, Modelling of MOSFET characteristics, role of surface potential, concept of threshold voltage, basic idea of current transport in MOSFET, introduction to modelling approaches (surface potential and threshold-based), limitations of models and need for improvement. **Applications:** Understanding MOSFET operation in VLSI circuits and predicting device behavior. Forms the basis for designing and analyzing CMOS circuits	

AI Integration:

1. Use of MATLAB for plotting and analyzing semiconductor device characteristics such as current–voltage (I–V) behavior and carrier variation, enabling visualization and interpretation of modelling results.
2. Application of curve fitting and regression techniques using MATLAB to perform parameter extraction (such as threshold voltage and mobility) from device characteristics and compare analytical models with numerical results.
3. Introduction to simple data-driven modeling approaches using MATLAB or Python to study the relationship between input parameters and device behaviour.

Authentic Intelligence:

1. Understanding the limitations of modelling and data-driven approaches, including assumptions and approximations used in semiconductor device models.
2. Interpretation of modelling results to ensure physically meaningful behaviour and identification of unrealistic or non-physical outputs.
3. Awareness of errors in parameter extraction and curve fitting, including overfitting and incorrect model assumptions affecting accuracy.

Course Outcome	**Description**	**Bloom's Taxonomy Level**
At the end of the course the student will be able to:		
1	Explain the principles of carrier transport, energy band structures, and semi-classical concepts in semiconductors.	2
2	Apply the concepts of transport equations and drift-diffusion model to describe carrier behaviour in semiconductor devices.	3
3	Analyze semiconductor devices using energy band diagrams and characteristic time and length scales.	4
4	Examine and interpret device modelling methodologies, approximations, and classification of models used in semiconductor device analysis.	4
5	Apply the concepts of MOSFET operation and qualitative modeling to understand device characteristics and behaviour.	3

COs	POs											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	-	-	-	-	-	-	2	3	-
CO2	3	3	2	2	-	-	-	-	-	-	2	3	2
CO3	3	3	-	2	-	-	-	-	-	-	2	3	-
CO4	2	3	2	3	-	-	-	-	-	-	3	2	2
CO5	3	2	2	-	1	-	-	-	-	-	3	3	3

TEXT BOOKS:

1. Lundstrom, M., 2000. Fundamentals of Carrier Transport. Cambridge University Press.
2. Snowden, C.M., 1986. Introduction to Semiconductor Device Modeling. World Scientific Publishing.
3. Tsividis, Y. and McAndrew, C., 2011. Operation and Modeling of the MOS Transistor. Oxford University Press, 3rd Edition.

REFERENCES:

1. Neamen, D.A., 2012. Semiconductor Physics and Devices: Basic Principles. McGraw-Hill Education, 4th Edition.
2. Streetman, B.G. and Banerjee, S., 2015. Solid State Electronic Devices. Pearson Education, 7th Editio.

Alternative NPTEL/SWAYAM Course:

Sl. No.	NPTEL Course Name	Instructor	Host Institute	Link
1	Semiconductor Device Modeling	Prof. Shreepad Karmalkar	IIT Madras	http://kcl.digimat.in/nptel/courses/video/117106033/L01.html
2	Semiconductor device modeling and Simulation,	Prof. Vivek Dixit	IIT Kharagpur	https://nptel.ac.in/courses/108105188

IN-VEHICLE NETWORKING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives: This Course will enable students to:

1. **Explain** the evolution, architecture, and emerging trends in modern automotive E/E systems, inclu Software Defined, Connected, Autonomous, Shared, and Electric vehicles.
2. **Describe and interpret** in-vehicle communication protocols such as CAN, CAN-FD, and Autom Ethernet, including their architecture, frame structures, and standards.
3. **Analyze** data communication mechanisms, arbitration, error handling, diagnostics, and networ principles used in automotive systems.
4. **Apply** automotive diagnostic protocols (e.g., UDS services) and networking concepts to configure, troubleshoot, and validate ECU communication.
5. **Develop and integrate** simulation and testing solutions using CANoe and CAPL scripts for automated network validation and analysis.

Teaching-Learning Process (General Instructions)

1. **Lecture with Concept Mapping:** Introduce each unit through structured lectures supplemented with concept maps illustrating the relationships between E/E architecture components, protocols, and automotive systems to reinforce knowledge retention.
2. **Industry Case Studies:** Present real-world automotive case studies (e.g., CAN bus failures, OTA update architectures in EVs) to bridge the gap between theoretical protocol knowledge and practical automotive engineering challenges.
3. **Flipped Classroom for Protocol Analysis:** Assign pre-recorded or reference video content on CAN/CAN-FD frame structures for self-study, then use class time for problem-solving, frame decoding exercises, and peer discussions.
4. **Hands-On Lab Sessions with CANoe:** Conduct structured laboratory sessions where students configure network nodes, simulate CAN bus traffic, and execute CAPL scripts in CANoe to reinforce simulation and testing concepts.
5. **Protocol Comparison Activity:** Use structured group activities where students compare CAN, CAN-FD, and Automotive Ethernet across parameters like speed, topology, and error handling — developing analytical and communication skills.

6 **Diagnostic Scenario-Based Learning:** Present students with faulty ECU communication scenarios and have them apply UDS service sequences (e.g., DTC reading, Security Access) to diagnose and resolve issues — promoting applied problem-solving.

COURSE CONTENT:	
Module 1: Introduction to Modern E/E Architecture	**09 Hrs**
Key Trends in E/E Architecture. Current Trends in In-Vehicle Networking: Evolution of E/E architecture, Software Defined Vehicles, Connected Cars, Autonomous Cars, Shared Cars, Electrification. Case Studies and Real-World Applications, Future Directions. **Applications:** AI-Driven E/E Architecture Evolution.	
MODULE 2: CAN Protocol Basics	**09 Hrs**
Overview of Controller Area Network (CAN), Basic Concepts, Types of CAN, OSI Layers. Frame Types and Structure, Message Arbitration, Introduction to CAN-FD. Data Transmission and Reception, Error Handling and Fault Tolerance. CAN Bus Wiring and Configuration. **Applications:** AI-Based Anomaly Detection on CAN Bus.	
MODULE 3: Automotive Ethernet	**09 Hrs**
Comparison of Automotive Networks with Ethernet, Basics of Automotive Ethernet Physical Layer, IEEE 802.3 Standard, Overview, Ethernet PHY and Transceivers, Topology, MAC, User Datagram Protocol, Automotive Ethernet Applications, Diagnostics Over IP (DoIP). **Applications:** AI for Automotive Ethernet Traffic Management.	
MODULE 4: Automotive Diagnostics	**09 Hrs**
Need for diagnostics in automotive, Diagnostic Protocols and Standards, UDS Protocol Basics, Key UDS Services Diagnostic Session Control (0x10), ECU Reset (0x11), Clear Diagnostic Information (0x14), Read DTC Information (0x19), Security Access (0x27), Write Data by Identifier (0x2E), UDS Communication and Data Handling, Diagnostic Procedures and Techniques, Practical Application and Case Studies. **Applications:** AI-Augmented Diagnostics and Predictive Maintenance.	
MODULE 5: Introduction to CANoe	**09 Hrs**
CANoe Environment, Basic CANoe Usage and Configuration: Adding and configuring network nodes and communication protocols, setting up network simulations and configuring network traffic. Basics of CAPL, Creating and executing basic CAPL scripts to automate network behaviour and testing tasks, event handling, timers, and message manipulation. Integrating CAPL scripts with CANoe simulations for enhanced functionality. Hands-On Practice: Practical exercises to create and run CAPL scripts within CANoe. Simulating network scenarios and analysing results using CAPL. **Applications:** AI-Assisted Test Automation and CAPL Script Generation	

AI Integration:

1. **Intelligent ECU Clustering:** Apply k-means / hierarchical clustering to group ECUs by function, power domain, and communication frequency — simulating domain/zonal architecture optimization.
2. **CAN Frame Classification:** Train supervised ML classifiers (Random Forest, SVM, LSTM) on CAN bus datasets to distinguish normal frame sequences from malicious injection or fault conditions
3. **Ethernet Traffic Classification:** Train CNN + time-series deep learning models to classify and prioritize Automotive Ethernet traffic types (audio, video, diagnostic, control) for intelligent routing.
4. **DTC Trend Analysis:** Apply time-series ML (LSTM / GRU) to sequences of Diagnostic Trouble Codes from UDS service 0x19 to predict future faults before vehicle breakdown.
5. **LLM-Based CAPL Script Generation:** Use Large Language Models via API integration to automatically generate CAPL scripts from natural language test case descriptions — automating test design for CANoe simulations.

Authentic Intelligence:

1. **Transparency in Architectural Decisions:** Assess when AI-generated architecture recommendations should be trusted vs. reviewed by experts — explainability is paramount in safety-critical vehicle systems.
2. **Accountability in Intrusion Detection:** False positives in AI anomaly detection can disable legitimate ECU communications — understand the life-safety implications of deploying unvalidated ML models in vehicle networks.
3. **Privacy in AI Traffic Analysis:** Automotive Ethernet carries sensitive sensor streams (camera, microphone, radar) — AI traffic classifiers must anonymize and protect passenger data per privacy regulations.
4. **AI Misdiagnosis and Liability:** Assess who bears liability when an AI diagnostic advisor recommends an incorrect repair — OEM, software provider, or technician — and what safeguards prevent over-reliance.
5. **Validation of AI-Generated Scripts:** LLM-generated CAPL scripts must undergo rigorous peer review — blind trust in auto-generated test code can introduce logical errors that compromise coverage and vehicle safety.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	**Summarize** and **differentiate** modern automotive E/E architectures and emerging mobility paradigms. (Understand/Analyze)	L2
CO2	**Illustrate and evaluate** the operation of CAN, CAN-FD, and Automotive Ethernet protocols within automotive communication systems. *(Analyze/Evaluate)*	L3
CO3	**Diagnose and troubleshoot** communication and diagnostic issues using appropriate protocols, standards, and UDS services. *(Analyze/Evaluate)*	L3
CO4	**Configure and implement** automotive network simulations and diagnostic workflows using industry-standard tools. *(Apply)*	L4
CO5	**Design and automate** testing scenarios by creating CAPL scripts integrated with CANoe for validation of automotive communication systems. *(Create)*	L4

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO 1	2	2	1	1	1	1	1			2		2	1
CO 2	3	3	2	2	2	1	1			1		3	2
CO 3	2	3	2	3	2	2	1	1	1	1	1	3	2
CO 4	2	2	3	2	3	1	1		2	1	1	2	3
CO 5	2	2	3	2	3	1	1	1	2	2	2	2	3

3: Substantial (High) 2: Moderate (Medium) 1: Poor (Low)

TEXT BOOKS:

1. Automotive Ethernet, Matheus K, Königseder T. 3rd ed. Cambridge University Press; 2021.
2. Automotive In–vehicle Networks, Wiley–Blackwell (7 October 2008, ISBN-10 : 0470032324 ISBN-13 : 978-0470032329.

REFERENCE BOOKS:

1. Automotive Embedded Systems Handbook (Industrial Information Technology), 20 December 2008, by Francoise Simonot-Lion (Editor), Nicolas Navet (Editor).

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	Self-Driving Cars Specialization https://www.coursera.org/specializations/self-driving-cars	Dr. Steven Wasslander & Jonathan Kelly	Coursera / University of Toronto
2	Evolution of Automotive E/E Architecture https://academy.vector.com/in/en/courses#product=all&applications=&standards=&certification=false	Vector Informatik Team	Vector Academy / YouTube
3	Introduction to In-Vehicle Networking (CAN, LIN, FlexRay) https://academy.vector.com/de/en/courses/detail/3358/digital-communication-in-vehicles	Vector Informatik Team	Vector Academy / YouTube
4	Unified Diagnostic Services (UDS) – Deep Dive https://www.vector.com/int/en/products/solutions/diagnostic-standards/uds-unified-diagnostic-services-iso14229/	Vector Informatik	Vector Academy
5	CANoe Getting Started – Official Tutorial Series https://www.vector.com/int/en/products/products-a-z/software/canoe/canoe-guideme/	Vector Informatik	Vector Academy

6	Introduction to CAPL Programming https://academy.vector.com/cn/en/courses/detail/10329/capl-test-training-intro	Vector Informatik	Vector Academy / YouTube
7	Automotive Ethernet: From the Basics to the Future https://www.keysight.com/in/en/assets/7018-06381/white-papers/5992-3430.pdf	Keysight Technologies	Keysight / YouTube
8	OPEN Alliance SIG – Automotive Ethernet Standards & Specifications https://opensig.org/automotive-ethernet-specifications/	OPEN Alliance SIG	OPEN Alliance

SOFTWARE DEFINED RADIO

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

By the end of the course, students will be proficient in:

1. Understanding how SDRs work and applying machine learning for spectrum sensing and signal classification.
2. Making changes to hardware design of SDRs and modifying the host-side software and design AI-based cognitive radio system.
3. Transmitting and receiving wireless signals using SDRs and Implementing SDR using GNU Radio and Python.
4. Wireless networking physical layer techniques and analyzing signals using deep learning.
5. Wireless networking MAC, link, and network layer techniques.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:

Module 1: INTRODUCTION	**09 Hrs**

The requirement for software defined radio, the benefits of multi-standard terminals, operational requirements, business models for software defined radio, new base station and network architectures, smart antenna systems.

Applications: 4G/5G/6G Base Stations, Multi-standard Mobile Devices, Cognitive Radio Systems, Smart Antenna Systems (Beamforming), Military Communication Systems

NVIDIA DLI Courses:

1. Generative AI Explained (2 hrs)
   https://www.nvidia.com/en-us/training/online/generative-ai-explained/
2. Building a Brain in 10 Minutes (10 hrs)

https://www.nvidia.com/en-us/training/online/building-a-brain-in-10-minutes/

MODULE 2: BASIC ARCHITECTURE OF A SOFTWARE DEFINED RADIO	**09 Hrs**

Concept of electromagnetic forces on carriers, transport equations, conservation principles in carrier transport, introduction to Boltzmann Transport Equation, derivation of drift-diffusion model, current density equations, mobility models, generation and recombination mechanisms, boundary conditions.

Applications:

Estimation of current in semiconductor devices and understanding carrier behaviour under electric fields. Forms the basis for modelling real devices and electronic circuits.

NVIDIA DLI Course:

Getting Started with AI on Jetson Nano (8 hrs)

https://www.nvidia.com/en-us/training/online/getting-started-with-ai-on-jetson-nano/

MODULE 3: FLEXIBLE RF RECEIVER ARCHITECTURES	**09 Hrs**

Receiver architecture options, implementation of a digital receiver: frequency up conversion using undersampling, achieving processing gain using oversampling, Noise figure, Receiver sensitivity, ADC spurious signals.

Applications: FM/AM/TV Signal Receivers (RTL-SDR), Spectrum Monitoring Systems, Radar and Surveillance Systems, Wireless Signal Intelligence (SIGINT).

NVIDIA DLI Course:

1. Applications of AI for Anomaly Detection (8 hrs)

https://www.nvidia.com/en-us/training/online/ai-for-anomaly-detection/

MODULE 4: MULTI-BAND AND GENERAL COVERAGE SYSTEMS	**09 Hrs**

Multiband Flexible receiver design, the problem of the Diplexer, Achieving Image rejection, Dynamic range enhancement, feedback and feed-forward techniques.

Applications: Wideband Spectrum Scanners, Satellite and Space Communication, Emergency Communication Systems, 5G Carrier Aggregation.

NVIDIA DLI Course: 1. Disaster Risk Monitoring Using Satellite Imagery (8 hrs) https://www.nvidia.com/en-us/training/online/disaster-risk-monitoring-satellite-imagery/

MODULE 5: FLEXIBLE TRANSMITTERS AND POWER AMPLIFIERS	**09 Hrs**
Analog quadrature up conversion, quadrature up conversion with interpolation, Interpolated band passup conversion, PLL based transmitters, Active All-pass filter, Use of high pass and low pass filters, Polyphase filtering. **Applications:** Wireless Communication Transmitters (WiFi, LTE, 5G), Broadcast Systems (TV/Radio), Drone and UAV Communication Systems, Satellite Uplink Systems, Digital Predistortion (DPD) Systems.	
NVIDIA DLI Course: 1. Applications of AI for Predictive Maintenance (8 hrs) https://www.nvidia.com/en-us/training/online/predictive-maintenance/	

AI Integration:

1. Cognitive radio, AI in wireless systems, GNU Radio basics.
2. AI Accelerated SDR, Role of Edge AI in SDR.
3. ML-based signal detection, modulation recognition.
4. Dynamic Spectrum Access, Wideband Spectrum Sensing.
5. AI-based adaptive transmission, AI-based digital predistortion in Power Amplifiers.

Authentic Intelligence:

1. Demonstrate a basic SDR receiver (FM/ADS-B) and explain one cognitive radio use case with required AI capability.
2. Benchmark SDR processing (FFT/FIR) on CPU vs GPU and deploy a simple edge-AI model with measured latency.
3. Implement a digital receiver and train a CNN model for modulation classification with accuracy vs SNR analysis.
4. Capture wideband spectrum data and build a system to detect occupied vs vacant channels within real-time latency.
5. Simulate a transmit chain and implement AI-based digital predistortion showing measurable ACPR improve.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the fundamentals, architecture, and operational requirements of Software Defined Radio (SDR) and its role in modern wireless communication systems.	L2
2	Apply SDR architecture concepts and tools (GNU Radio, Python) to design and implement basic wireless communication systems.	L3
3	Analyze RF receiver and transmitter architectures, including multi-band systems, sampling techniques, and performance parameters.	L4
4	Evaluate and apply AI/ML techniques for spectrum sensing, modulation classification, and cognitive radio applications in SDR.	L4
5	Design and develop AI-enabled SDR systems including adaptive transmission and digital predistortion for real-world wireless applications.	L6

COs	PO											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	-	-	-	2	1	1	1	-	2	2	2
CO2	3	2	2	-	3	2	1	1	1	-	2	2	2
CO3	3	3	2	2	2	2	1	1	1	-	3	2	2
CO4	2	3	3	3	3	2	1	1	1	-	3	2	2
CO5	2	3	3	2	2	3	2	1	1	1	3	2	2

3 Substantial (High) **2: Moderate (Medium)** **1: Poor (Low**

TEXT BOOKS:

1. P Kenington, “RF and Baseband Techniques for Software Defined Radio”, Artec House,2005.
2. Ekram Hossain, Dusit Niyato, Zhu Han “Cognitive Radio Networks: Architectures, Protocols and Standards” CRC Press, 2009.

REFENCES:

1. Jouko Vanakka, “Digital Synthesizers and Transmitter for Software Radio”, Springer,2005

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2. Wally H. W. Tuttlebee, “Software Defined Radio: Baseband Technologies for 3G Handsets and Base stations”, John Wiley & sons, 2003

E-RESOURCES:	
1	https://en.wikipedia.org/wiki/Software-defined_radio
2	https://www.wiley.com/en
3	us/Software+Defined+Radio%3A+Architectures%2C+Systems+and+Functions-p9780470851647
4	https://nptel.ac.in/courses/108107107

INDUSTRIAL DIGITAL TWINS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P		3–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the fundamental concepts, architecture, and types of industrial digital twins using NVIDIA Omniverse and OpenUSD frameworks.
2. Analyse the NVIDIA Omniverse platform architecture, its extensions system, and the role of Universal Scene Description (OpenUSD) in building collaborative 3D digital environments.
3. Apply OpenUSD-based techniques for scene composition, asset management, real-time data integration, and physics-based simulation to construct industrial-scale digital twins.
4. Design and develop custom Omniverse Kit-based applications, extensions, and UI tools for facility-scale industrial digital twin workflows.
5. Evaluate AI-driven simulation, synthetic data generation, and physical AI integration strategies for intelligent industrial digital twin solutions using NVIDIA Omniverse.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. **Interactive Teaching:** Adopt Active Learning using brainstorming, group work, focused listening, and roleplaying around Digital Twin concepts and NVIDIA Omniverse demonstrations.
2. **Video/Animation Films:** Show NVIDIA DLI tutorial videos and Omniverse demonstrations to explain digital twin construction, USD workflows, and AI simulation pipelines.
3. **Collaborative (Group Learning):** Encourage hands-on Omniverse lab sessions, mini-projects on facility-scale digital twin assembly, and team-based USD scene composition exercises.
4. **Critical Thinking:** Ask Higher Order Thinking questions such as: "How does OpenUSD differ from conventional 3D formats?" or "What are the trade-offs between real-time and offline simulation?"

   Problem Based Learning: Foster analytical skills by tasking students with solving industrial scenarios — e.g., building a factory digital twin that integrates live sensor data using Omniverse.

MODULE – I: Introduction to Industrial Digital Twins & NVIDIA Omniverse	**09 Hours**

Definition and evolution of Digital Twins, Types of Digital Twins, Key drivers and value proposition, NVIDIA Omniverse Platform Overview, Virtual Facility Integration (VFI), Omniverse ecosystem Overview of OpenUSD (Universal Scene Description), Industrial Digital Twin use cases, Introduction to NVIDIA Omniverse Cloud.

NVIDIA DLI Courses:

1. ***NVIDIA Digital Twin Overview (Glossary & Concepts) (Self-Study)***
   Link: https://www.nvidia.com/en-us/glossary/digital-twin/
2. ***Develop, Customize, and Publish in NVIDIA Omniverse With Extensions (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-02+V1
3. ***Learn OpenUSD – NVIDIA Documentation (Self-paced)***
   Link: https://docs.nvidia.com/learn-openusd/latest/index.html#start-learning

MODULE – II: NVIDIA Omniverse Architecture & OpenUSD Fundamentals	**09 Hours**

NVIDIA Omniverse Kit, Omniverse Nucleus, OpenUSD Architecture, USD Composition Arcs, USD Layer Stack and Layer Composition, USD Paths and Scene Graph, USD Schemas, SimReady assets, Omniverse. Connectors

NVIDIA Hands-on:

Composing a factory scene in USD, adding references, variants, and layers using Python USD API.

NVIDIA DLI Courses:

1. ***Develop, Customize, and Publish in NVIDIA Omniverse With Extensions (~8 hrs)***
   Link: **https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-02+V1**
2. ***Learn OpenUSD – NVIDIA Official Documentation (Self-paced)***
   Link: **https://docs.nvidia.com/learn-openusd/latest/index.html#start-learning**
3. ***Developing an Omniverse Kit-Based Application (~8 hrs)***
   Link: **https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-11+V1**
4. ***Build Beautiful, Custom UI for 3D Tools on NVIDIA Omniverse (~8 hrs)***
   Link: **https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-16+V1**

MODULE – III: Scene Assembly, Simulation & Real-Time Data Integration for Industrial Digital Twins	**09 Hours**

Assembling industrial digital twin scenes, Scene composition workflows, Physics simulation in Omniverse, Isaac Sim for robotics simulation, Real-time data integration, Operational Digital Twins, USD data optimization, Material Definition Language (MDL), Collaborative workflows.

NVIDIA Hands-on:

Assembling a manufacturing floor digital twin using USD Composer, adding physics, and linking sensor data streams.

NVIDIA DLI Courses:

1. ***How to Build OpenUSD Applications for Industrial Digital Twins (~8 hrs)***
   Link:https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-13+V1
2. ***Easily Develop Advanced 3D Layout Tools on NVIDIA Omniverse (~8 hrs)***
   Link:https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-49+V1
3. ***Introduction to Robotic Simulations in NVIDIA Isaac Sim (~8 hrs)***
   Link:https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-25+V1
4. ***Learn OpenUSD – NVIDIA Official Documentation (Self-paced)***
   Link: **https://docs.nvidia.com/learn-openusd/latest/index.html#start-learning**

MODULE – IV: Custom Application Development for Industrial Digital Twins	**09 Hours**

NVIDIA Omniverse Kit SDK, Developing Omniverse Extensions, Omni.UI framework, Custom 3D scene manipulator tools, Advanced layout tools, Building a 3D Product Configurator with OpenUSD, Omniverse

Action Graph and OmniGraph, Omniverse Kit App Template, Deploying Omniverse Kit-based applications at scale

NVIDIA Hands-on:

Build a custom Omniverse extension that loads an industrial facility USD, provides a UI to toggle asset states, and exports performance metrics.

NVIDIA DLI Courses:

1. ***Developing an Omniverse Kit-Based Application (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-11+V1
2. ***Build Beautiful, Custom UI for 3D Tools on NVIDIA Omniverse (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-16+V1
3. ***How to Build Custom 3D Scene Manipulator Tools on NVIDIA Omniverse (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-33+V1
4. ***Easily Develop Advanced 3D Layout Tools on NVIDIA Omniverse (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-49+V1
5. ***Develop, Customize, and Publish in NVIDIA Omniverse With Extensions (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-02+V1

MODULE – V: AI-Driven Simulation, Synthetic Data & Physical AI for Industrial Digital Twins	**09 Hours**

Physical AI and its role in industrial automation, Synthetic data generation using NVIDIA Omniverse Replicator, NVIDIA Cosmos World Foundation Models (WFMs), Sim-to-real transfer, Reinforcement learning in digital twins, AI-based anomaly detection and predictive maintenance using sensor data streamed from operational digital twins, NVIDIA Metropolis for intelligent video analytics, Digital twin-powered factory optimization, Future trends: generative AI for 3D world creation, neural rendering (NuRec), and agentic AI in industrial environments.

NVIDIA Hands-on:

Configure an Omniverse Replicator synthetic data pipeline for an industrial inspection task; visualize and validate generated training datasets.

NVIDIA DLI Courses:

1. ***How to Build OpenUSD Applications for Industrial Digital Twins (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-13+V1
2. ***Introduction to Robotic Simulations in NVIDIA Isaac Sim (~8 hrs):***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-25+V1
3. ***How to Build Custom 3D Scene Manipulator Tools on NVIDIA Omniverse (~8 hrs):***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-33+V1
4. ***Synthetic Data Generation for Training Computer Vision Models (~8 hrs):***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-26+V1
5. ***Building a 3D Product Configurator With OpenUSD and Omniverse (~8 hrs):***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-42+V1

AI Integration:

1. Python-based OpenUSD scene scripting using the USD Python API (pxr library): automating scene assembly, modifying attributes programmatically, and building data-driven digital twin workflows using Pandas and NumPy for sensor telemetry processing.
2. Implementation of supervised learning algorithms (classification and regression) using Scikit-learn for anomaly detection on industrial sensor data integrated with Omniverse digital twins; evaluating models on real-world telemetry datasets.
3. Implementing synthetic data generation pipelines using NVIDIA Omniverse Replicator with domain randomization; training computer vision models (object detection, segmentation) on synthetic factory imagery and validating sim-to-real transfer.
4. Reinforcement learning with NVIDIA Isaac Lab: training robotic agents in GPU-accelerated parallel digital twin environments; implementing policy networks with PyTorch and evaluating convergence, sample efficiency, and sim-to-real performance.
5. Deploying trained AI models within Omniverse digital twin pipelines using NVIDIA NIM microservices; model evaluation with metrics (mAP, F1-score, RMSE), hyperparameter optimization, and integration with real-time factory operational data streams.

Authentic Intelligence:

1. Critical evaluation of the accuracy and limitations of digital twins as representations of physical systems; understanding fidelity gaps, model drift, and the ethical implications of making industrial decisions based on simulated data.
2. Interpretability of AI models deployed within digital twin environments; risks of incorrect predictions in autonomous manufacturing decision-making; importance of explainability and auditability in safety-critical industrial AI applications.
3. Risks of sim-to-real transfer failures; responsible interpretation of synthetic training data; avoiding confirmation bias when validating digital twin models against real sensor streams.
4. Limitations of reinforcement learning policies trained in simulation: overfitting to simulated physics, sim-to-real gaps in contact dynamics, and the importance of safety-constrained deployment in real industrial environments.
5. Understanding data privacy and cybersecurity risks in connected industrial digital twins; responsible design of IoT-integrated Omniverse pipelines; ethical deployment of AI agents in shared physical-digital manufacturing environments.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the architecture, components, and working principles of Industrial Digital Twins including NVIDIA Omniverse platform, OpenUSD framework, and Virtual Facility Integration concepts.	L2
2	Analyse the OpenUSD scene composition, layer stack, composition arcs, and USD schemas for building modular, interoperable, and simulation-ready industrial digital twin environments.	L3
3	Apply physics-based simulation, real-time IoT data integration, and collaborative USD workflows to assemble facility-scale operational digital twins for manufacturing and industrial environments.	L3

4	Design and develop custom NVIDIA Omniverse Kit applications, extensions, UI tools, and 3D layout utilities for industrial digital twin data visualization and workflow automation.	L4
5	Evaluate AI-driven simulation strategies including synthetic data generation, reinforcement learning, and physical AI integration for optimizing industrial digital twin solutions using NVIDIA Omniverse.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1	-	-	2	1	1	-	-	-	-	2	3
CO2	2	3	-	2	3	-	-	-	-	-	-	2	3
CO3	2	1	3	2	3	-	2	-	-	-	-	2	3
CO4	2	1	3	-	3	-	-	-	2	2	2	2	3
CO5	2	3	-	3	3	-	2	1	-	-	-	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. **Grieves, M., 2014.** Digital Twin: Manufacturing Excellence Through Virtual Factory Replication. White Paper. Florida Institute of Technology.
2. **Kritzinger, W. et al., 2018.** Digital Twin in Manufacturing: A Categorical Literature Review and Classification. IFAC-PapersOnLine, 51(11), pp.1016-1022.
3. **NVIDIA Corporation, 2024.** OpenUSD Developer Guide. NVIDIA Technical Documentation. Available at: https://docs.nvidia.com/learn-openusd/latest/index.html
4. **Boschert, S. and Rosen, R., 2016. Digital Twin**—The Simulation Aspect. In: P. Hehenberger and D. Bradley, eds. Mechatronic Futures. Springer, pp.59-74.

REFERENCE BOOKS:

1. **Tao, F. et al., 2019.** Digital Twins and Cyber-Physical Systems toward Smart Manufacturing and Industry 4.0. Engineering, 5(4), pp.653-661.
2. **Fuller, A. et al., 2020.** Digital Twin: Enabling Technologies, Challenges and Open Research. IEEE Access, 8, pp.108952-108971.
3. **NVIDIA Corporation, 2024.** NVIDIA Omniverse Developer Documentation. Available at: https://docs.omniverse.nvidia.com/
4. **Lu, Y. et al., 2020.** Digital Twin-Driven Smart Manufacturing: Connotation, Reference Model, Applications and Research Issues. Robotics and Computer-Integrated Manufacturing, 61, p.101837.

E-Resources:

S. No.	Course / Resource Name	Instructor	Host Institute
1	NVIDIA Digital Twin Glossary	NVIDIA	NVIDIA
2	Develop, Customize, and Publish in Omniverse With Extensions	NVIDIA DLI	NVIDIA DLI
3	Learn OpenUSD – NVIDIA Documentation	NVIDIA	NVIDIA
4	Developing an Omniverse Kit-Based Application	NVIDIA DLI	NVIDIA DLI
5	Build Beautiful, Custom UI for 3D Tools on NVIDIA Omniverse	NVIDIA DLI	NVIDIA DLI
6	How to Build OpenUSD Applications for Industrial Digital Twins	NVIDIA DLI	NVIDIA DLI
7	Easily Develop Advanced 3D Layout Tools on NVIDIA Omniverse	NVIDIA DLI	NVIDIA DLI
8	Introduction to Robotic Simulations in NVIDIA Isaac Sim	NVIDIA DLI	NVIDIA DLI
9	How to Build Custom 3D Scene Manipulator Tools on NVIDIA Omniverse	NVIDIA DLI	NVIDIA DLI
10	Synthetic Data Generation for Training Computer Vision Models	NVIDIA DLI	NVIDIA DLI
11	Building a 3D Product Configurator With OpenUSD and Omniverse	NVIDIA DLI	NVIDIA DLI

Department of Electronics and Communication Engineering

INTRODUCTION TO NANOTECHNOLOGY AND ITS APPLICATIONS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To provide a comprehensive understanding of the fundamentals of power electronic converters and devices.
2. To understand electric vehicle architecture and propulsion systems.
3. To analyze the interaction between batteries, power electronics, and electric drives using modeling and simulation by adopting AI tools.
4. To study charging techniques, battery management systems, and energy recovery mechanisms by adopting AI tools for modeling and simulation
5. To familiarize with current trends and challenges in electric vehicle development.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:

Module 1: QUANTUM MECHANICS FOR NANOTECHNOLOGY:	**09 Hrs**

Introduction to Quantum Mechanics, Matter Waves, Heisenberg's Uncertainty Principle, Schrödinger Equation, Electron Confinement, Particle in a Box, Density of States, Particle in a Coulomb Potential, Tunneling of a Particle Through Potential Barrier and Electronic structure of solids

Applications: Quantum dot displays, tunnel diodes, flash memory, scanning tunnelling microscope (STM), MOSFET scaling at nanoscale, quantum well lasers, LED design, heterojunction semiconductors, qubit fundamentals in quantum computing, photovoltaic cells

MODULE 2: SYNTHESIS OF NANOMATERIALS	**09 Hrs**

Top-down and bottom-up approaches, Nucleation and Growth Mechanisms, Mechanical methods, Sol-gel method, Chemical vapor deposition (CVD), Atomic layer deposition (ALD) Hydrothermal/solvothermal synthesis, Lithography techniques, Chemical etching, Template-assisted synthesis, Self-assembly techniques, Hybrid methods combining top-down and bottom-up approaches and Current challenges in nanomaterials synthesis.

Applications: Semiconductor chip fabrication (CVD, ALD, lithography), MEMS and NEMS device manufacturing, nanoparticle-based drug delivery, thin film solar cells, carbon nanotube synthesis

MODULE 3: ANALYSIS TECHNIQUE:	**09 Hrs**

Scanning electron microscopy (SEM) and transmission electron microscopy (TEM), X-ray Diffraction (XRD), Overview of various spectroscopic methods such as UV-Vis spectroscopy, infrared spectroscopy (IR), and Raman spectroscopy, Introduction to surface analysis methods like scanning probe microscopy (SPM) and X-ray photoelectron spectroscopy (XPS), differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). Brief overview of atomic force microscopy (AFM), dynamic light scattering (DLS), and nuclear magnetic resonance (NMR).

Applications: Nanoparticle size and morphology characterization, crystal structure determination of thin films.

MODULE 4: PROPERTIES OF NANOMATERIALS	**09 Hrs**

Electrical properties of nanomaterials, Optical properties of nanomaterials, Surface plasmon resonance, Magnetic properties of nanomaterials, Mechanical properties of nanostructured materials, Thermal properties of nanomaterials, Quantum size effects, Surface-to-volume ratio and its influence on material properties, Size-dependent properties of nanomaterials, Transport phenomena in nanomaterials.

Applications: Nanowire-based transistors, plasmonic biosensors and SERS-based chemical detection, quantum dot displays and solar cells

MODULE 5: APPLICATION OF NANOMATERIALS	**09 Hrs**

Nanoparticles in Electronics and Optoelectronics: Use of nanoparticles in electronic devices, including transistors, displays, and memory storage and applications of quantum dots. Photocatalytic nanoparticles for hydrogen production. Applications of nanomaterials in wastewater treatment and groundwater remediation and heavy metal contamination. Nanoparticles in Consumer Products. Nanoparticles in Food and Agriculture: Use of nanomaterials in agriculture for crop protection, nutrient delivery, and soil remediation. Safety and regulatory considerations associated with the use of nanoparticles in food and agriculture. Role of Artificial Intelligence in nanomaterials research including materials discovery, property prediction, and optimization of nanomaterial-based applications.

Applications: AI-accelerated nanomaterial discovery and property prediction for drug delivery and energy storage.

AI Integration:

1. Machine learning for nanomaterial property prediction, synthesis optimization, and AI-driven materials discovery platforms such as Materials Project.
2. Neural networks for automated SEM/TEM image analysis, nanoparticle sizing, and deep learning-based spectral interpretation of XRD, Raman, and IR data.
3. Generative AI models for novel nanostructure design and AI-based toxicity prediction for nano-enabled consumer, agricultural, and biomedical products.

Authentic Intelligence:

1. Risks of deploying AI-predicted material properties without experimental validation; bias in materials discovery models due to limited and skewed training datasets.
2. Ethical concerns in use of nanoparticles in food, agriculture, and consumer products without long-term toxicity and environmental persistence data.
3. Regulatory gaps in nano-enabled products across IS, ISO, and EPA frameworks; responsible reporting of nanomaterial safety and environmental impact data.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Explain and apply the fundamental principles of quantum mechanics and their relevance to nanotechnology applications	L3
CO2	Contrast various synthesis methods and techniques to produce nanomaterials, while appraising their effectiveness and limitations.	L4
CO3	Understand and interpret data obtained from characterization techniques to assess the properties and behavior of nanomaterials.	L2
CO4	Apply knowledge of the societal, ethical, and environmental implications of nanoparticle applications to assess and integrate safety protocols and regulatory frameworks.	L3
CO5	Use MATLAB to model and simulate nanoscale phenomena such as quantum confinement, density of states, and particle behavior to analyze nanomaterial properties and device performance.	L3

COs	PO											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	-	-	2	2	-	-	-	-	-	-
CO2	3	2	1	-	-	2	2	-	-	-	-	-	-
CO3	3	2	-	-	-	2	-	-	-	-	-	-	-
CO4	3	2	-	-	-	3	3	-	-	-	-	2	1
CO5	3	2	-	-	3	3	2	-	-	-	-	-	-

TEXT BOOKS:

1. Sulabha K Kulkarni, "Nanotechnology: Principles and Practices", 3rd Ed. Springer, 2015.

REFERENCES:

1. Hari Singh Nalwa, "Encyclopedia of Nanoscience and Nanotechnology", American scientific publishers, 2011.
2. B. Rogers, J. Adams, and S. Pennathur, "Nanotechnology understanding small systems", CRC press, 3rd Ed. 2015.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	https://nptel.ac.in/courses/118102003 Introduction to Nanotechnology	Prof. A K Ganguli	IIT Delhi

ELECTRIC VEHICLE TECHNOLOGY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week L–	:	03 Hours	**Total Hours**	:	45 Hours
T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. Understand what electric vehicles are, how they work, and why the world is shifting from petrol and diesel to electric power.
2. Learn the key components of an electric vehicle — battery, motor, controller, and charging system — in simple, non-specialist terms.
3. Appreciate the environmental, economic, and social impact of electric mobility and India's EV policy landscape.
4. Explore how digital technologies such as AI, data analytics, and connected systems are being used to make EVs smarter and more efficient.
5. Develop awareness of career opportunities, challenges, and the future direction of the electric vehicle industry.

Teaching-Learning Process (General Instructions)

1. These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.
2. Use relatable, everyday examples: compare a petrol car engine to an EV motor, or a fuel tank to a battery pack, so students from any background can connect immediately.
3. Show video demonstrations: animations of battery charging, motor operation, regenerative braking, and real EV teardown videos (e.g. Tesla Model 3, Tata Nexon EV disassembly videos on YouTube).
4. Encourage Interactive Discussion: pose questions like 'Why can't we just use a regular car battery?' or 'What happens to old EV batteries?' to trigger curiosity.
5. Use Collaborative (Group) Learning: assign groups to research and present one real EV model (Ola S1, Nexon EV, Ather 450, Tesla, BMW iX) covering its specs, range, and price.
6. Apply Problem-Based Learning: give scenario-based problems such as 'Design a charging plan for a fleet of delivery EVs in Bengaluru' or 'What battery size does a 150 km range two-wheeler need?'
7. Invite Industry Speakers: arrange sessions from EV companies like Tata Motors, Ola Electric, Ather Energy, Bosch India, or ISRO's electric mobility division.
8. Connect every concept to the real world: discuss government schemes (FAME-II, PLI for batteries), real charging infrastructure challenges, and EV adoption data in India

COURSE CONTENT:

Module 1: Introduction to Electric Vehicles	**09 Hrs**

Electric Vehicles

Global and Indian push for clean mobility: climate commitments, rising fuel prices, and government targets, Brief history of EVs — from the 19th-century electric carriages to today's modern EVs, India's EV landscape: key statistics, two-wheelers, three-wheelers, and electric buses today.

Types of Electric Vehicles

Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), Fuel Cell Electric Vehicles (FCEV): How an Electric Vehicle Works, Main parts: battery pack, electric motor, power controller, and charging system, Energy flow, Comparing EV drivetrain to a conventional car: fewer moving parts, less maintenance, instant torque.

Applications: Electric two-wheelers (Ola, Ather), electric buses (BMTC e-buses), electric cars (Nexon EV), and electric delivery vehicles (Mahindra Treo).

NVIDIA DLI Courses (Relevant to this Module):

1. Generative AI Explained: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-07+V1

MODULE 2: EV Batteries and Energy Storage	**09 Hrs**

Battery Basics, Types of EV Batteries: Lead-Acid batteries, Lithium-Ion batteries, Lithium Iron Phosphate (LFP), Solid-State batteries.

Battery Pack Design (Conceptual Overview), Battery Management System (BMS)

Applications: Battery packs in Ola S1 Pro scooter, Nexon EV battery system, electric buses in Delhi and Bengaluru

NVIDIA DLI Courses (Relevant to this Module):

1. Fundamentals of Deep Learning: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3
2. Applications of AI for Anomaly Detection: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1

MODULE 3: EV Motors, Controllers, and Drivetrain	**09 Hrs**

Electric Motors Working: Comparison with a petrol engine: an IC engine has ~200 moving parts; an electric motor has fewer than 20. **Types of EV Motors: DC** Motors, AC Induction Motors, Permanent Magnet, Synchronous Motors (PMSM), Brushless DC Motors (BLDC), Comparison

Motor Controller and Power Electronics (Conceptual), Drivetrain Layout Options

- Single motor front-wheel drive vs. single motor rear-wheel drive vs. dual motor all-wheel drive.
- Hub motors
- Comparison of drivetrain layouts: efficiency, traction, and cost trade-offs

Applications: Ather 450X BLDC motor, Nexon EV PMSM drivetrain, Tesla dual-motor AWD system, ISRO's electric lunar rover concept.

MODULE 4: EV Charging, Infrastructure, and Range	**09 Hrs**

How EV Charging Works-The basic process, On-board charger vs. off-board charger, Key terms: charging time, charging power (kW), connector types (Type 1, Type 2, CCS, CHAdeMO, Bharat DC-001).

Levels of Charging: Battery swapping: an alternative model where the depleted battery pack is swapped for a charged one in minutes — used by Gogoro and being explored by Sun Mobility in India.

EV Range: Drive Cycle: How AI predicts remaining range: using GPS route data, driving patterns, weather, and battery condition.

Charging Infrastructure in India: Government initiatives: FAME-II scheme, BEE charging guidelines, and state EV policies, Challenges, Smart charging and Vehicle-to-Grid (V2G): EVs as mobile batteries that can sell power back to the grid during peak demand.

Applications: Tata Power EV charging network, Charge Zone, EESL public chargers, Sun Mobility battery swapping stations

NVIDIA DLI Courses (Relevant to this Module):

Accelerating End-to-End Data Science Workflows: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-DS-01+V2

MODULE 5: AI, Sustainability, and the Future of Electric Mobility	**09 Hrs**

AI and Smart Features in Modern EVs: Adaptive range prediction, intelligent charging scheduling, Predictive maintenance, and voice-controlled cabin systems, Connected EVs: the car as a data centre on wheels, Driver assistance in EVs, X-by wire systems, Autonomous vehicles and EVs

Environmental and Economic Impact of EVs: Life-cycle emissions, The green grid argument, Total cost of ownership, Battery recycling and second-life use, Social impact

Industry Landscape: Key Indian EV companies, Global leaders in EV and their products: BYD (China), Tesla (USA), Hyundai/Kia (South Korea).

Career Opportunities in the EV Sector: Engineering roles, Data and AI roles, Policy and sustainability roles, Entrepreneurship.

Applications: Ola Electric Future factory, ISRO's electric mobility research, Tata Motors EV platform, Niti Aayog EV policy roadmap 2030**.**

NVIDIA DLI Courses (Relevant to this Module):

1. Fundamentals of Deep Learning : https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3
2. Building RAG Agents with LLMs : https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-15+V1
3. Deploying and Optimizing AI Inference at Scale : https://www.nvidia.com/gtc/session-catalog/sessions/gtc26-dliw82274/

Agentic AI Explained : https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-39+V1

AI Integration

(Guided activity-based learning — no advanced coding required; spreadsheet tools and free online simulators used throughout)

1. Use a publicly available EV dataset (e.g. from Kaggle or data.gov.in) to plot battery range vs. temperature, speed, and load using Excel / Google Sheets; identify trends and draw conclusions.
2. Use Google's Teachable Machine (free, browser-based) to train a simple image classifier that can identify EV vs. non-EV vehicles from photos; reflect on model accuracy.
3. Simulate EV energy consumption for a given city route using the NEDC/WLTP cycle concept; calculate the estimated range for a battery of given capacity using basic arithmetic.
4. Explore an AI-powered EV range prediction tool (e.g. ABRP — A Better Route Planner, free web app); enter a journey and analyse how the AI adjusts predictions based on driving style and weather.
5. Group activity: research a real-world EV battery recall or failure event (e.g. Chevrolet Bolt, Ola S1 fire incidents); analyse the root cause and discuss how a better BMS with AI monitoring could have prevented it.

Authentic Intelligence

(Critical thinking and ethical awareness indicators)

6. Is an EV always greener than a petrol car? . Investigate and argue: consider battery manufacturing emissions, electricity grid mix in India, and vehicle end-of-life disposal.
7. Evaluate government EV subsidies: do FAME-II benefits reach rural buyers and low-income users, or do they primarily benefit urban, middle-class consumers? What would a more equitable policy look like?
8. What happens to millions of used EV batteries in 2030? Analyse the battery recycling challenge in India — infrastructure gaps, environmental risks, and circular economy opportunities.

Course Outcomes		
CO	**Description**	**Bloom's Taxonomy Level**
CO1	Describe the types of electric vehicles, their key components, and the basic principles of electric propulsion in simple terms.	L2
CO2	Explain how EV batteries work, what factors affect their performance and life, and the role of a Battery Management System.	L2
CO3	Identify different types of EV motors, charging levels, and drivetrain configurations, and compare their advantages and limitations.	L4
CO4	Analyse the environmental, economic, and social impact of electric vehicles and evaluate India's EV policy framework.	L5
O5	Recognise how AI and digital technologies are used in modern EVs and reflect critically on the ethical challenges of EV adoption.	L5

COs	**Programme Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	1	-	-	-	2	1	1	1	-	1	1	1
CO2	2	2	1	-	3	2	1	1	1	-	2	1	2
CO3	2	2	2	1	3	2	1	1	1	-	2	2	2
CO4	1	2	2	2	2	3	2	2	1	1	3	2	3
CO5	1	2	1	1	1	3	2	2	1	1	2	1	2

TEXT BOOKS

1. Husain, I. (2021). Electric and Hybrid Vehicles: Design Fundamentals. 3rd ed. CRC Press.
2. Ehsani, M., Gao, Y., Longo, S. and Ebrahimi, K.M. (2018). Modern Electric, Hybrid Electric, and Fuel Cell Vehicles. 3rd ed. CRC Press.
3. Chan, C.C. and Chau, K.T. (2001). Modern Electric Vehicle Technology. Oxford University Press.

REFERENCES

1. Larminie, J. and Lowry, J. (2012). Electric Vehicle Technology Explained. 2nd ed. John Wiley & Sons.
2. Niti Aayog. (2023). India EV Readiness Index and EV30@30 Campaign Reports. Government of India.
3. Bureau of Energy Efficiency (BEE). (2022). EV Charging Infrastructure Guidelines for India. Ministry of Power, Government of India.
4. IEA. (2024). Global EV Outlook 2024. International Energy Agency. Available at: https://www.iea.org/reports/global-ev-outlook-2024
5. NVIDIA Developer. (2024). NVIDIA DLI Course Catalogue. Available at: https://learn.nvidia.com

E.Resources:

Alternative NPTEL / SWAYAM Courses			
S.No.	**NPTEL Course Name**	**Instructor**	**Host Institute**
1	Introduction to Electric Vehicles	Prof. Praveen Kumar	IIT Delhi
2	Fundamentals of Electric vehicles: Technology & Economics https://nptel.ac.in/courses/108106170	Prof.Ashok junjhunwala, Prof. Kaushal Jha, Prof. L Kannan, Prof. Prabhjot Kaur	IIT Madras
3	Battery Pack Design and Development: Fundamentals https://elearn.nptel.ac.in/category/all-products	Prof. Atriya Biswas	IIT Madras
4	Smart Grid: Basics to Advanced Technologies https://nptel.ac.in/courses/108107113	Prof. N.P. Padhy, Prof. Premalata Jena	IIT Roorkee
5	Energy Resources, Economics and Environment https://nptel.ac.in/courses/109101171	Prof. Rangan Banerjee	IIT Bombay

HUMAN MACHINE INTERACTION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students

1. To understand the architecture, levels, and implementation aspects of Human Machine Interaction systems in industrial and embedded contexts.
2. To study HMI system design, including hardware-software integration, SCADA, PLC interfacing, and panel development.
3. To learn how data from HMI systems is processed, communicated, and stored using fog computing, cloud computing, and edge architectures.
4. To analyse latency issues in real-time HMI systems and study protocol-level and architectural solutions to minimise response time.
5. To explore AI-driven HMI, including intelligent dashboards, predictive alerts, and adaptive interfaces, and to evaluate the ethical and safety implications of automated decision-making in HMI systems

Teaching-Learning Process (General Instructions):

1. *Interactive Teaching:* Adopt Active Learning that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and role-playing.
2. Show *Video / Animation films* to explain HMI architectures, SCADA screen layouts, PLC ladder logic, and real-time data pipelines.
3. Encourage *Collaborative (Group) Learning* by assigning groups to design an HMI panel for a given process scenario and justify their design choices.
4. To make *Critical Thinking,* ask Higher Order Thinking questions such as ‘Why does a 200 ms latency spike cause failure in a press-line HMI but not in a building management system?’
5. Adopt *Problem-Based Learning,* which fosters students’ analytical skills and develops the ability to evaluate, generalise, and analyse information utilising AI tools.
6. Invite guest sessions from industry partners (Siemens, Rockwell, Schneider Electric, BHEL) to demonstrate live HMI panel deployments and SCADA configurations.
7. Discuss how every concept applies to the real world: connect HMI architecture to familiar systems in power plants, manufacturing lines, water treatment, and aerospace ground stations.

COURSE CONTENT:

MODULE 1: HMI Architecture and Levels	**09 Hrs**

Definition and Scope of HMI, Comparison with SCADA and DCS , Levels of HMI in Industrial Automation (ISA-95 / Purdue Model), IT/OT convergence, HMI Hardware Components, HMI Software Architecture:

Applications: BHEL power plant control room HMI, Siemens WinCC SCADA for water treatment, Allen-Bradley PanelView in automotive assembly, Schneider Electric EcoStruxure building management HMI

NVIDIA DLI Courses (Relevant to this Module):

1.Generative AI Explained: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-07+V1

MODULE 2: HMI Implementation: PLC Interfacing, Communication, and Screen Design	**09 Hrs**

PLC-HMI Interfacing, Direct driver-based communication, OPC-UA (Open Platform Communications Unified Architecture): Modbus RTU and Modbus TCP: PROFINET and EtherNet/IP. HMI Screen Design Principles and Engineering Standards, Alarm Management Implementation:

Applications: Siemens TIA Portal HMI configuration with S7-1500 PLC, Allen-Bradley FactoryTalk View with CompactLogix, Inductive Automation Ignition SCADA with OPC-UA, Modbus-based HMI for energy monitoring panels.

NVIDIA DLI Courses (Relevant to this Module)

1.Getting Started with AI on NVIDIA Jetson Nano L https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2

MODULE 3: Data Communication, Fog Computing, and Cloud-Based HMI	**09 Hrs**

HMI Data Communication Protocols:

Serial communication for HMI: RS-232, RS-485, and RS-422 physical layers; half-duplex vs. full-duplex; multi-drop network topologies for HMI-to-device wiring.

Industrial Ethernet for HMI, MQTT for HMI data transport, OPC-DA vs. OPC-UA, DNP3 and IEC 60870-5-104

Three-Tier HMI Architecture: Field, Fog, and Cloud: Field tier: sensors, actuators, PLCs, and local HMI panels; real-time closed-loop control, Fog tier (Edge / Fog computing), Cloud tier

Fog Computing in HMI Systems, Fog vs. edge computing, Standards and frameworks, Cloud-Based HMI and Remote Monitoring:

Applications: Siemens Mind Sphere cloud HMI for manufacturing analytics, PTC ThingWorx IoT platform with HMI integration, AWS IoT Greengrass as fog gateway for remote substations, Azure IoT Hub connected SCADA for water utilities in India.

NVIDIA DLI Courses (Relevant to this Module):

Accelerating End-to-End Data Science Workflows : https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-DS-01+V2

MODULE 4: Latency, Real-Time Performance, and HMI Cybersecurity	09 Hrs
Latency in HMI Systems — Definition and Sources, End-to-end latency budget, Latency classes by application, Real-Time Communication Protocols and Latency Reduction: PROFINET IRT (Isochronous Real-Time), Polling vs. subscription data models: Buffering and jitter management HMI Rendering and Display Performance Optimisation, HMI Cybersecurity: OT cybersecurity threats, IEC 62443 (Industrial Automation and Control Systems Security), Network segmentation and DMZ architecture, HMI hardening, Secure remote access, Incident response for HMI **Applications:** PROFINET IRT HMI in automotive stamping lines, TSN-based HMI for semiconductor fab equipment, IEC 62443 compliant SCADA for Indian power distribution utilities, secure remote HMI access for offshore oil and gas platforms.	
NVIDIA DLI Courses (Relevant to this Module): **Applications of AI for Anomaly Detection: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1**	
MODULE 5: AI-Driven HMI, Intelligent Dashboards, and Future Trends	**09 Hrs**
AI Integration in HMI Systems: Intelligent search and retrieval, Adaptive interface layouts Computer Vision and Gesture-Based HMI: Touchless HMI interaction, Operator presence detection, Augmented Reality (AR) HMI, Digital twin integration with HMI Voice and Conversational HMI in Industrial Settings, Deploying AI Models in HMI Environments, Future Trends in HMI: 5G-enabled wireless HMI, Metaverse and immersive HMI, Brain-computer interfaces (BCI), Self-healing HMI systems. **Applications:** Siemens Industrial Copilot AI-powered HMI assistant, PTC Vuforia AR-based maintenance HMI, Real Wear HMT-1 wearable HMI for field operators, NVIDIA Omniverse digital-twin-connected live-process HMI, 5G-connected mobile operator panel in an automotive body shop.	
NVIDIA DLI Courses (Relevant to this Module) **Computer Vision for Industrial Inspection**: https://www.nvidia.com/en-sg/training/instructor-led-workshops/computer-vision-for-industrial-inspection/	

AI Integration:

1. Configuration of a simulated HMI screen using a free browser-based SCADA tool (e.g. AVEVA System Platform trial, Node-RED Dashboard, or Ignition Designer Launcher trial); creation of a minimum five-screen HMI project with tag database, analog display, trend graph, and alarm table for a simulated tank-filling process.
2. Analysis of a provided HMI historian dataset (CSV time-series of process variables) using Python and Pandas; identification of chattering alarms using threshold crossings per hour, plotting of alarm frequency Pareto charts, and proposal of dead-band settings to reduce nuisance alarm rates by at least 30%.
3. Edge AI integration exercise: running a pre-trained anomaly detection model (provided as a TensorFlow Lite file) on a Raspberry Pi or NVIDIA Jetson Nano connected to simulated sensor inputs; logging inference results to an MQTT broker and displaying them on a Node-RED HMI dashboard; measurement of edge inference latency vs. cloud round-trip.

Authentic Intelligence:

1. Fog vs. cloud decision ethics: a fog computing architecture keeps patient data from a hospital ICU HMI locally on-site to comply with health data privacy regulations; a cloud-only solution offers better AI capabilities but requires off-site data transfer. Evaluate the engineering, legal, and ethical trade-offs in this architecture decision.
2. Autonomous HMI systems and operator deskilling: as AI increasingly monitors processes and raises fewer, higher-confidence alarms, operators may lose the situational awareness and manual control skills needed during AI failure events.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Describe the architecture, hardware components, and hierarchical levels of HMI systems in industrial automation, and distinguish between field-level, supervisory, and enterprise HMI roles.	L2
CO2	Implement HMI screen design using ISA-101 principles, configure tag databases, set up PLC-HMI communication using OPC-UA or Modbus, and apply structured alarm management practices.	L3
CO3	Explain the roles of fog computing and cloud computing in HMI architectures, design a three-tier HMI data flow, and select appropriate communication protocols based on latency and connectivity requirements.	L3
CO4	Analyse latency sources in real-time HMI systems, evaluate real-time communication protocols (PROFINET IRT, TSN, OPC-UA), and apply cybersecurity principles including IEC 62443 zone models and HMI hardening techniques.	L5
CO5	Evaluate AI-driven HMI technologies including predictive alarms, AR interfaces, and conversational operator tools, and critically assess the ethical, safety, and accountability implications of AI integration in safety-critical HMI systems.	L5

COs	**PO**											**PSO**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	-	-	-	2	1	1	1	-	2	2	1
CO2	3	3	2	2	2	2	1	1	1	-	3	2	2
CO3	3	3	3	2	3	2	1	1	1	-	3	2	2
CO4	2	3	3	3	3	2	1	1	1	1	3	3	3
CO5	2	2	2	2	2	3	2	2	1	1	3	2	3

TEXT BOOKS:

1. Shneiderman, B., Plaisant, C., Cohen, M., Jacobs, S. and Elmqvist, N. (2016). Designing the User Interface: Strategies for Effective Human-Computer Interaction. 6th ed. Pearson.
2. Boyer, S.A. (2009). SCADA: Supervisory Control and Data Acquisition. 4th ed. ISA Press.
3. Parr, E.A. (2003). Programmable Controllers: An Engineer's Guide. 3rd ed. Newnes / Elsevier.

REFERENCES:

1. Human Machine Interfaces for Process Automation Systems. International Society of Automation. ISA-101.01-2015.
2. IEC 62443 Series: Industrial Automation and Control Systems Security. International Electrotechnical Commission.
3. ISA-18.2-2016: Management of Alarm Systems for the Process Industries. International Society of Automation.
4. Huba, M. and Bistak, P. (2022). Industrial Internet of Things and Fog / Edge Computing. Springer.
5. NVIDIA Developer. (2024). NVIDIA Deep Learning Institute Course Catalogue. Available at: https://learn.nvidia.com

E.Resources:

Alternative NPTEL/SWAYAM Course			
S. No.	**NPTEL Course Name**	**Instructor**	**Host Institute**
1	Human Computer Interaction https://onlinecourses.nptel.ac.in/e-learning/preview/noc19_cs86	Prof. Ponnurangam Kumaraguru	IIT Delhi
2	Industrial Automation and Control https://nptel.ac.in/courses/108105063	Prof. S. Mukhopadhyay	IIT Kharagpur
3	SCADA and Industrial Automation https://nptel.ac.in/courses	Prof. Ramesh Singh	IIT Bombay
4	Introduction to Internet of Things https://nptel.ac.in/courses/106105166	Prof. Sudip Misra	IIT Kharagpur
5	Introduction to Machine Learning https://nptel.ac.in/courses/106106139	Prof. Balaraman Ravindran	IIT Madras

RADAR AND NAVIGATION SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER - VIII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Develop the knowledge on fundamentals of radar and parameters of general radarequation.
2. Demonstrate the Doppler Effect and the concepts of continuous wave radars, MTI radarsand delay line cancellers.
3. Analyze the performance of tracking radar systems.
4. Identify the various navigational aids.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate theattainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming,discussing, group work, focused listening, formulating questions, note taking, annotating, and role playing.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information ratherthan simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students tocome up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible,it helps improve the students' understanding.

Module I: Introduction to RADAR	**09 Hours**

Simple form of RADAR equation, Radar block Diagram and Operation, Applications of RADAR, The Radar Equation: Prediction of Range Performance, minimum Detectable Signal, Receiver Noise, Probability-density Functions, Signal-to-noise Ratio, Integration of Radar Pulses, Power Pulse Repetition Frequency and Range Ambiguities, Antenna parameters, System Losses, Propagation Effect.

Application: Used in air traffic control and weather monitoring for range prediction and detection.

Relevant NVIDIA DLI Course:

GPU Teaching Kit – Accelerated Computing:

Supports simulation of radar equations, SNR calculations, and performance prediction using CUDA-based accelerated computing.

https://www.nvidia.com/en-in/search/?q=GPU+Teaching+Kit+%E2%80%93+Accelerated+Computing%3A+&page=1

Module II: Types of RADAR	**09 Hours**
CW and Frequency-Modulated Radar, The Doppler Effect, Frequency- modulated CW Radar, Airborne Doppler Navigation, Introduction to MTI RADAR: - delayline cancelers - MTI Signal Processor and pulse doppler RADAR, Range and Doppler Measurement, Block Diagram and Characteristics (Approaching/ Receding Targets) Tracking with RADAR **Application:** Applied in speed enforcement, airborne navigation, and pulse Doppler target tracking.	
Module III: Tracking RADAR	**09 Hours**
Tracking with Radar, Sequential Lobing, Conical Scan, Monopulse Tracking Radar, Target-Reflection Characteristics and Angular Accuracy, Tracking in Range, Acquisition, Comparison of Trackers, Tracking with Surveillance Radar. **Application:** Enables precision missile guidance, satellite monitoring, and surveillance security systems.	
Relevant NVIDIA DLI course: **Generative AI Teaching Kit** Useful for modeling decision systems and anomaly detection in radar tracking scenarios. https://www.nvidia.com/en-in/search/?q=Generative+AI+Teaching+Kit+&page=1	
Module IV: Radio Navigation:	**09 Hours**
Navigation - methods of navigation - Radio direction finder - loop antenna – goniometer - Radio Navigation systems - ADF / NDB – Radio compass ADF, VHFphase comparison using ADF - Hyperbolic navigation systems – basic principle - LORAN, Omega, DECCA - Radio ranges – VOR – ground equipment – VOR receiver - Doppler VOR – DME **Application:** Supports aircraft and marine navigation using VOR, LORAN, DECCA, and Doppler systems.	
Relevant NVIDIA DLI Course: **Edge AI & Robotics Teaching Kit:** Maps to embedded navigation systems, real-time signal interpretation, and AI-based inspection for navigation aids. https://www.nvidia.com/en-in/search/?q=Edge%20AI%20%26%20Robotics%20Teaching%20Kit%3A&page=1	
Module V: Navigation Aids:	**09 Hours**
Approach and landing aids Instrument Landing System (ILS) – elements – localizer - glide slope – marker beacons -lighting systems – operation – limitation - Microwave Landing System (MLS) – operation – advantages – disadvantages - Navigation systems – INS – DNS - Satellite Navigation systems – GPS – DGPS – GNSS – COMPASS – DORIS – GALILEO – IRNSS – QZSS **Application:** Facilitates safe aircraft landing (ILS/MLS) and global positioning via GPS, GALILEO, IRNSS.	

AI Integration:

1. GPU-accelerated simulation of radar equations, SNR calculations, and range prediction using CUDA-based workflows.
2. Implementation of Doppler signal processing and MTI radar operations using MATLAB and Python-based AI toolkits.
3. Application of generative AI models for anomaly detection and decision support in radar tracking scenarios.
4. Edge AI integration for real-time radio navigation signal interpretation, embedded system inspection, and adaptive control.
5. Use of machine learning algorithms for satellite navigation error correction, GNSS signal integrity monitoring, and predictive performance modeling.

Authentic Intelligence:

1. Understanding the limitations of AI-driven radar simulations, including risks of oversimplified propagation models and sampling bias.
2. Responsible deployment of anomaly detection systems in radar tracking to avoid false alarms and misinterpretation of targets.
3. Ethical considerations in navigation AI systems, particularly in safety-critical applications such as landing aids and GNSS-based positioning.
4. Interpretability challenges in AI-assisted decision systems for radar and navigation, emphasizing the importance of transparent model selection.
5. Balancing automation with human oversight in navigation aids, ensuring reliability and accountability in real-world operational environments.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply the fundamental principles of radar systems and radar equation to determine key performance parameters.	L3
2	Apply Doppler principles and signal processing concepts to examine CW and MTI radar operations using MATLAB tools.	L3
3	Analyze and compare different radar tracking techniques based on performance characteristics and operational constraints.	L4
4	Analyze the working principles and performance of radio navigation systems in practical scenarios.	L4
5	Analyze the operation and characteristics of navigation aids and satellite navigation systems.	L4

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	3	2	-	2	3	-	2	-	-	3	3	2
CO2	3	3	2	-	2	-	-	2	2	-	3	3	2
CO3	3	-	3	-	2	-	-	2	2	-	3	3	-
CO4	3	-	3	-	2	2	-	2	-	-	3	3	-
CO5	3	-	-	-	-	2	-	3	-	-	3	3	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. M. I. Skolnik, 'Introduction to Radar Systems', 3rd ed. New York, NY, USA: McGraw-Hill, 2001.

REFERENCE BOOKS:

1. A. K. Sen and A. B. Bhattacharya, 'Radar Systems and Radio Aids to Navigation'. New Delhi, India: Khanna Publishers, 2010.
2. N. S. Nagaraja, 'Elements of Electronic Navigation'. New Delhi, India: Tata McGraw-Hill, 1996.

E-Resources:

Sl.No.	NPTEL Course Name	Instructor	Host Institute
1	Principles and Techniques of Modern Radar Systems https://archive.nptel.ac.in/courses/108/105/108105154/	Prof. Amitabha Bhattacharya	IIT Kharagpur

AI IN HEALTHCARE & BIOMEDICAL SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VIII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to:

1. **Understand** biomedical signal acquisition and characteristics.
2. **Apply** classical DSP techniques to biomedical signals.
3. **Integrate** AI/ML models for analysis and classification.
4. **Develop** intelligent healthcare signal processing systems.
5. **Interpret** results with ethical and explainable AI perspectives.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** includes traditional and modern teaching techniques to explain deep learning concepts clearly. Different approaches like **presentations and coding demos** are used for better understanding.
2. **Interactive teaching** methods like group discussions, brainstorming, and peer learning are encouraged. These activities help students stay engaged and actively participate in the learning process.
3. Show **Video/animation** to explain complex topics like CNNs, RNNs, and backpropagation visually.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Discuss how every **concept can be applied to the real world** - and when that's possible, it helps improve the students' understanding.

Module I: Introduction to Biomedical Signal Processing	**08 Hours**

Acquisition, Generation of Bio-signals, Origin of bio-signals, Types of bio-signals: ECG, EEG, EMG, PCG, Study of diagnostically significant bio-signal parameters, Biomedical signal acquisition systems, Clinical significance of parameters.

Applications

- **Cardiac Monitoring Systems:** ECG-based heart condition analysis
- **Brain Signal Analysis:** EEG for epilepsy and neurological disorders

NVIDIA Course Mapping

- Fundamentals of Deep Learning
  https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3

Module II: Bio-Signal Acquisition & Conditioning	**08 Hours**
Electrode-electrolyte interface, polarization, electrode skin interface and motion artefact, biomaterial used for electrode, Types of electrodes (body surface, internal, array of electrodes, microelectrodes), Practical aspects of using electrodes, Acquisition of bio-signals (signal conditioning) and Signal conversion (ADC's DAC's) Processing, Artefact removal techniques **Applications** • **Wearable Health Devices:** Smartwatches for ECG/SpO_2 monitoring • **ICU Monitoring Systems:** Continuous real-time patient monitoring • **Portable Diagnostic Devices:** Handheld biomedical instruments	
• **NVIDIA Course Mapping** • Getting Started with AI on NVIDIA Jetson Nano https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2	
Module III: Classical Biomedical Signal Processing	**09 Hours**
Biomedical signal processing by Fourier analysis, Biomedical signal processing by wavelet (time frequency) analysis, Analysis (Computation of signal parameters that are diagnostically significant), Classification of signals and noise, Spectral analysis of deterministic. **Applications** • **Speech & Hearing Analysis:** Signal processing in hearing aids • **Sleep Analysis:** EEG-based sleep stage classification • **Cardiac Signal Analysis:** Frequency analysis of ECG signals	
NVIDIA Course Mapping • Accelerating End-to-End Data Science Workflows https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-DS-02+V1	
Module IV: Machine Learning for Biomedical Signals	**10 Hours**
Supervised learning: SVM, k-NN, Decision Trees, Unsupervised learning: k-means clustering, Feature selection & dimensionality reduction (Principal component analysis: PCA, Independent component analysis: ICA), Model evaluation metrics (Accuracy, ROC, F1-score). **Applications:** • ECG arrhythmia classification • EEG signal classification	
NVIDIA Course Mapping • Applications of AI for Anomaly Detection https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+T-OV-01+V1	

Module V: Deep Learning & Intelligent Systems	**10 Hours**
Neural networks basics, CNN for biomedical signal/image analysis, RNN, LSTM for time-series biomedical signals, Transfer learning in healthcare, Explainable AI (XAI) in medical diagnosis **Applications:** • Real-time health monitoring systems • AI-based disease prediction • Wearable healthcare devices	
NVIDIA Course Mapping • Medical AI Development with MONAI https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-HX-02+V1	

AI Integration in Healthcare

1. Integration of AI models with biomedical signal processing pipelines (ECG, EEG, EMG)
2. Integration with healthcare systems: EHR, HIS, PACS and biomedical instrumentation
3. Deployment of AI in wearable and IoT-based biomedical devices
4. Edge vs cloud-based AI for real-time biomedical signal analysis
5. Real-time AI integration in ICU monitoring and remote healthcare systems
6. Interoperability and implementation challenges in clinical environments

Authentic Intelligence in Healthcare

1. Concept of trustworthy and explainable AI in biomedical applications
2. Explainable AI (XAI) methods (SHAP, LIME) for biomedical signal interpretation
3. Trade-off between accuracy and interpretability in clinical decision systems
4. Bias, fairness, and ethical issues in AI-based diagnosis
5. Model validation using clinical datasets and performance metrics
6. Regulatory and safety considerations in healthcare AI deployment

Course Outcome	**Description**	**Bloom's Taxonomy Level**
At the end of the course the student will be able to:		
CO1	**Understand** biomedical signal types and acquisition. Understand biomedical signal types, characteristics, and acquisition methods	L2
CO2	**Apply** signal conditioning, preprocessing, and artifact removal techniques to biomedical signals	L3
CO3	**Analyze** biomedical signals using DSP techniques such as FFT and wavelet transforms	L4
CO4	**Develop and evaluate** machine learning models for biomedical signal classification tasks	L5
CO5	**Design** AI-enabled healthcare systems incorporating ethical and explainable AI principles	L5

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	–	–	1	–	–	–	–	–	1	3	3	–
CO2	3	2	2	2	–	–	–	–	–	1	3	3	–
CO3	3	2	3	2	–	–	–	–	–	2	2	2	2
CO4	3	3	3	3	1	–	1	2	1	2	3	3	2
CO5	2	3	2	2	3	2	3	2	2	2	2	2	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. R.M. Rangayyan Biomedical Signal analysis: A Case study approach, IEEE press, John Wiley & Sons. Inc, 2002.
2. C. Raja Rao, SK Guha, Principles of Medical Electronics and Biomedical instrumentation, Universities Press, 2001.

REFERENCE BOOKS:

1. W. J. Tompkins, *Biomedical Digital Signal Processing,* Prentice Hall, 1993.
2. Eugene N Bruce, *Biomedical Signal Processing and Signal Modeling* , John Wiley & Son's publication, 2001.
3. D C Reddy, *Biomedical Signal Processing,* McGraw Hill, 2005.
4. Duda, R. O., Hart, P.E. and Stork, D.G., *Pattern classification,* JohnWiley & sons, 2012.
5. Pattern Recognition & Machine Learning, Christopher Bishop, Springer 2006.

E-Resources:

Sl.No.	Course Name	Instructor	Host Institute
1	Basic Course in Biomedical Research https://onlinecourses.nptel.ac.in/noc20_ee41/preview	Dr. Rizwan SA, MBBS, MD, Dr. Navaneeth S Krishna, MBBS	ICMR-National Institute of Epidemiology
2	Biomedica http://www.biomedicahelp.altervista.org	Prof. Stefano	Politecnico di Milano
3	Biomedical Signal Processing https://www.digimat.in/nptel/courses/video/108105101/L12.html	Prof. Sudipta Mukhopadhyay	IIT Kharagpur

Activity Based Learning (Suggested Activities in Class):

1. Students will participate in a flip classroom
2. Mini project for the preprocessing of biomedical signals can be taken up.

AI AND ML FOR VLSI CAD

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VIII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Explain the VLSI design flow (RTL to GDSII) and identify key challenges in design automation, including placement, routing, timing, and power optimization.
2. Utilize supervised, unsupervised, and reinforcement learning methods to address problems such as timing prediction, congestion estimation, and yield analysis.
3. Develop and apply ML models (e.g., regression, classification, clustering) to solve problems such as timing prediction, congestion estimation, and power modeling.
4. Formulate and solve sequential decision-making problems in VLSI CAD (e.g., placement and routing optimization) using reinforcement learning techniques.
5. Assess ML models using appropriate metrics, and analyze trade-offs between accuracy, runtime, power, and area in VLSI design.
6. Propose and develop innovative AI/ML-based solutions for real-world VLSI design challenges.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate theattainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming,discussing, group work, focused listening, formulating questions, note taking, annotating, and role playing.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information ratherthan simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students tocome up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible,it helps improve the students' understanding.

Module I: Overview of AI and ML in VLSI CAD	09 Hours
Importance and applications of AI and ML in VLSI design; Key concepts of AI and ML, including supervised and unsupervised learning; Introduction to neural networks, decision trees, and their relevance in CAD tools; Basic principles and terminologies of AI/ML algorithms.	
NVIDIA DLI Learning: Fundamentals of Deep Learning https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3	
Module II: Application of AI for pattern recognition	**09 Hours**
Feature extraction and classification techniques, Case studies on pattern recognition in layout design Case studies and real-world applications of pattern recognition.	
NVIDIA DLI Learning: Computer Vision for Industrial Inspection https://www.nvidia.com/en-sg/training/instructor-led-workshops/computer-vision-for-industrial-inspection/	
Module III: Optimization Techniques with ML	**09 Hours**
Optimization algorithms such as genetic algorithms, simulated annealing, and particle swarm optimization; Applications of ML for optimizing VLSI CAD tools: area, timing, power, and signal integrity optimization.	
NVIDIA DLI Learning: Optimizing CUDA ML Codes with NsightProfiling Tools https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-AC-03+V2	
Module IV: DRC with machine learning models	**09 Hours**
Enhancing Design Rule Checking (DRC) with machine learning models (classification, regression); Using ML for identifying violations and proposing fixes; Case studies on ML-based DRC optimization Applications: Automated DRC Violation Detection	
NVIDIA DLI Learning: Applications of AI for Anomaly Detection **https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-TC-01+V1**	
Module V: AI/ML techniques for Physical design	**09 Hours**
AI/ML techniques for automated layout generation, Considerations for area, power, and signal integrity in layout design, Case studies on automated layout generation. case studies on performance prediction in VLSI CAD. Applications: AI-Based Floorplanning and Layout Generation	
NVIDIA DLI Learning: Building AI Applications with Jetson Nano /Isaac ROS **https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-RX-02+V2**	

AI Integration:

1. AI/ML techniques are applied in pattern recognition, optimization, design rule checking (DRC), and layout generation.
2. Algorithms such as neural networks, decision trees, classification, and regression models are used to analyze complex design data.
3. Optimization techniques including genetic algorithms, simulated annealing, and particle swarm optimization improve design parameters like: Area, Power, Timing, Signal integrity
4. AI enables: Automatic detection of design rule violations, Intelligent suggestion of fixes, Faster and more efficient design cycles
5. AI/ML also supports: Automated layout generation, Performance prediction of VLSI circuits

Authentic Intelligence:

1. The course emphasizes real-world case studies in:
   - Pattern recognition
   - Layout design
   - DRC optimization
2. It promotes:
   - Problem-based learning
   - Critical thinking and analytical skills
   - Application of concepts to real engineering challenges
3. Students are trained to:
   - Apply ML models to detect defects in IC layouts
   - Optimize VLSI designs using intelligent algorithms
   - Develop automated solutions for chip design
4. Authentic Intelligence ensures:
   - Learning goes beyond theory
   - Students gain industry-relevant skills
   - AI is used for meaningful engineering problem-solving

Course Outcome	Description	Bloom's TaxonomyLevel
At the end of the course the student will be able to:		
1	Understand the basic principles of AI and ML algorithms and their applications in VLSI CAD tools	L2
2	Apply pattern recognition techniques for IC layout analysis and defect detection.	L3
3	Implement ML-based optimization algorithms to improve VLSI design parameters.	L3
4	Utilize machine learning techniques for DRC and violation detection in chip design.	L4
5	Develop AI/ML-based models for automated layout generation and performance prediction in VLSI circuits.	L5

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	1	1	-	-	-	-	-	-	-	-	1	-
CO2	3	2	2	-	-	-	-	-	-	-	-	1	-
CO3	3	3	2	-	1	-	-	-	-	-	-	1	-
CO4	3	3	2	-	-	-	-	-	-	-	-	1	-
CO5	3	3	2	-	1	-	-	-	-	-	-	1	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Ibrahim M. Elfadel, Duane S. Boning, Xin Li – Machine Learning in VLSI Computer-Aided Design, Springer, 1st Edition, 2019.
2. Abhishek Kumar, Suman Lata Tripathi – Machine Learning Techniques for VLSI Chip Design, Wiley, 1st Edition, 2023.
3. Joobbani, R. An Artificial Intelligence Approach to VLSI Routing. Springer Science & Business Media, 2012.
4. Sait, Sadiq. VLSI Physical Design Automation. World Scientific, 1999.

REFERENCE BOOKS:

1. Naveed A. Sherwani, Algorithms for VLSI Physical Design Automation, 3rd Edition, Springer, 1999.
2. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition, Wiley, 2001.
3. Stuart Russell, Peter Norvig, Artificial Intelligence: A Modern Approach, 4th Edition, Pearson, 2021.
4. Tom M. Mitchell, Machine Learning, McGraw-Hill, 1997.
5. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 2nd Edition, O'Reilly Media, 2019.

E-Resources:

Sl.No.	Course Name	Instructor	Host Institute
1	CAD for VLSI Design I https://archive.nptel.ac.in/content/storage2/courses/106106088/pdf/nptel-cad1-01.pdf	Prof. V. Kamakoti, Prof. Shankar Balachandran	IIT Madras
2	CAD for VLSI Design II https://archive.nptel.ac.in/content/storage2/courses/106106089/pdf/nptel-cad2-01.pdf	Prof. V. Kamakoti, Prof. Shankar Balachandran	IIT Madras

Embedded Linux

[As per Choice Based Credit System (CBCS) scheme]

Semester VIII

Subject Code	:		**Credits**	:	04
Hours / Week	:	03 Hours	**Total Hours**	:	45
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to

1. To understand the fundamentals of embedded systems, Linux operating system, and Embedded Linux architecture including boot process and development environment.
2. To learn Linux kernel architecture and develop basic Linux Kernel Modules (LKM) for system-level programming.
3. To design and implement character device drivers using Linux kernel interfaces and file operations.
4. To analyze and develop block and USB device drivers, understanding data transfer mechanisms and device communication.
5. To apply debugging techniques and tools to identify, analyze, and resolve errors in Linux device drivers**.**

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods where teacher can use to accelerate the attainment of the various course outcomes.

1. ***The lecture method*** means it includes not only the traditional lecture method, but also different *type of teaching methods* may be adopted to develop the course outcomes.
2. ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show ***Video/animation*** films to explain functioning of various concepts.
4. Encourage ***Collaborative*** (Group Learning) Learning in the class.
5. To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
6. Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information utilizing AI tools.
7. Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

COURSE CONTENT:

UNIT – I : INTRODUCTION TO EMBEDDED LINUX	09 Hours
Introduction to Embedded Systems, characteristics and applications of embedded systems, overview and features of Linux, difference between embedded Linux and desktop Linux, advantages of embedded Linux, embedded Linux architecture (hardware layer, bootloader, kernel, device drivers, root file system), development platforms (Raspberry Pi, BeagleBone, NVIDIA Jetson), development environment (host system, target system, cross compiler, toolchain), introduction to Yocto Project for building custom embedded Linux distributions, basic Yocto concepts (layers, recipes, image creation). **Applications**: Embedded systems | IoT devices | Consumer electronics | Robotics | Automotive systems | Custom Linux distribution development	
UNIT – II : LINUX KERNEL MODULES AND CHARACTER DEVICE DRIVERS	**09 Hours**
Overview of Linux device drivers, role of device drivers in OS, Linux kernel architecture, kernel space vs user space, introduction to Linux Kernel Modules (LKM), building and running kernel modules, setting up environment, Hello World module, fundamentals of character device drivers, major and minor numbers, device registration, file operations (open, read, write, close). **Applications**: sensor drivers, serial communication devices. **Text Book 1:** Chapter 3	
UNIT – III : BLOCK DEVICE DRIVERS	**09 Hours**
Block Driver Architecture, Registration of Block Device Drivers, Structure of Block Devices in Linux, Block Device Operations and Interfaces, Request Queue and Request Processing Mechanisms, I/O Scheduling for Block Devices, Writing a Simple Block Device Driver, Implementing Essential Block Device Operations, Compilation, Loading, and Testing of Block Device Drivers in Linux. **Applications:** Hard disk, SSD, file systems, storage devices	
UNIT – IV : USB DEVICE DRIVERS	**09 Hours**
USB Device Basics, USB Subsystem in Linux, USB Core APIs, USB Device Architecture, Writing a Basic USB Device Driver, Handling USB Device Enumeration, Communication between USB Devices and the Linux Kernel, Compilation and Testing of USB Device Drivers. **Applications:** USB devices, plug-and-play systems, embedded peripherals.	
NVIDIA DLI Courses (Relevant to this Module): Fundamentals of Accelerated Networking with NVIDIA DOCA https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+T-AC-11+V1	
UNIT – V : DEBUGGING TECHNIQUES	**09 Hours**
Debugging Support in the Linux Kernel, Debugging by Printing (printk), Debugging by Querying Kernel Data Structures, Debugging by Watching Variables and System State, Kernel Debugging Tools, Debuggers and Related Tools, Techniques for Identifying and Fixing Errors in Device Drivers. **Applications:** Driver debugging, system troubleshooting, performance optimization	

AI Integration:

1. Introduction to Intelligent Embedded Linux Systems with AI context:

Overview of embedded Linux systems in modern applications; interaction between hardware, bootloader, kernel, and device drivers; role of AI in enhancing system performance, automation, and reliability; differences between traditional embedded systems and AI-assisted systems; system logs, kernel messages, and real-time constraints; role of AI in enabling adaptive and self-monitoring embedded platforms.

2. AI-assisted techniques for embedded system and driver development:

Use of machine learning for system monitoring, driver behavior analysis, fault detection, and performance tuning; supervised and unsupervised learning techniques for analyzing kernel logs and device activity; challenges of applying AI in embedded environments with constraints such as CPU, memory, power, and latency; limitations of traditional debugging and monitoring approaches.

3. Integration of AI models into embedded Linux workflows:

Collection and preprocessing of kernel logs (dmesg, syslog) and system performance metrics; training and validation of models for detecting abnormal device behavior; integration with embedded Linux tools and utilities; automation of system monitoring and driver debugging using AI-based insights.

4. Optimization and performance enhancement using AI:

Use of AI techniques to optimize CPU utilization, memory management, I/O operations, and driver performance; identification of bottlenecks in interrupt handling, device communication, and kernel operations; application of lightweight models suitable for embedded systems; balancing performance improvements with system overhead and resource constraints.

5. Real-time deployment and monitoring in embedded systems:

Deployment of AI-assisted monitoring tools in embedded Linux environments; real-time analysis of system logs, device activity, and driver performance; automated alerts for faults and abnormal behavior; continuous monitoring, optimization, and updates; considerations of reliability, power efficiency, system stability, and security.

Authentic Intelligence:

1. Understanding well-posed embedded system problems and constraints:

Challenges of developing embedded Linux systems under limited memory, computation, and power constraints; handling hardware variability, interrupts, concurrency, and real-time requirements; risks due to improper system configuration, driver design, and hardware interfacing; importance of understanding kernel architecture and system design.

2. Interpretability of system and driver behavior:

Need to understand system outputs such as kernel logs, driver messages, and performance metrics; challenges in interpreting embedded system behavior and debugging outputs; risks due to incorrect assumptions, improper configurations, or lack of system visibility.

3. Risks of misinterpretation in embedded systems:
Errors due to race conditions, deadlocks, memory leaks, improper interrupt handling, and incorrect synchronization; risks arising from misinterpreting logs, incomplete testing, or ignoring edge cases; challenges in deploying systems across different hardware platforms and kernel versions.

4. Limitations of embedded Linux systems and drivers:
Trade-offs between performance, latency, memory usage, power consumption, and reliability; limitations in handling complex hardware interactions under constrained environments; constraints imposed by kernel design, hardware capabilities, and system configuration; need for efficient and optimized system design.

5. Understanding trade-offs and validation in embedded system development:
Balancing system performance with stability, reliability, and security; importance of rigorous testing, debugging, and validation of drivers and embedded applications; use of kernel debugging tools and logs; ensuring scalability, robustness, and safe deployment in real-world applications.

COURSE OUTCOMES:

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Explain the fundamentals of Embedded Linux architecture and dev	L2 elopment enviro ment.
2	Apply Linux kernel module concepts to develop basic device drivers.	L3
3	Analyze block device driver operations and storage management in Linux.	L4
4	Demonstrate USB device driver development and device communication in Linux.	L3
5	Evaluate debugging techniques for identifying and resolving device driver errors.	L5

Table: Mapping Levels of COs to POs / PSOs														
COs	**Program Outcomes (POs)**												**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**
CO1	3	2	1	-	-	-	-	-	-	-	-	1	2	1
CO2	3	3	2	2	1	-	-	-	-	-	-	1	3	2
CO3	2	3	2	2	-	-	-	-	1	-	-	1	3	1
CO4	2	3	2	3	2	-	-	-	1	-	-	1	3	3
CO5	2	3	2	2	2	-	-	-	-	-	-	2	3	2

TEXT BOOKS:

1. **Linux Device Drivers**
   Jonathan Corbet, Alessandro Rubini, and Greg Kroah-Hartman. *Linux Device Drivers*. O'Reilly Media, 2005.
2. **Embedded Linux Primer**
   Christopher Hallinan. *Embedded Linux Primer: A Practical Real-World Approach*. Prentice Hall, 2nd Edition.

REFERENCE BOOKS:

1. **Linux Device Drivers Development**
   John Madieu. *Linux Device Drivers Development*. Packt Publishing, 2017.
2. **Linux Device Driver Development Cookbook**
   Rodolfo Giometti. *Linux Device Driver Development Cookbook*. Packt Publishing, 2019.
3. **Embedded Linux Systems with the Yocto Project**
   Rudolph J. Streif. *Embedded Linux Systems with the Yocto Project*. Pearson, 2016.

E.Resources:

Sl no	Course name	Instructor	Host institute
1	Linux Administration Bootcamp https://www.udemy.com/course/linux-administration-bootcamp	Jason Cannon	Udemy
2	Introduction to Linux https://www.udemy.com/course/intro-to-linux	Danny	Coursera
3	Linux System Administration https://www.udemy.com/course/linux-foundation-certified-systems-administrator-lfcs	Mumshad Mannambeth	Udemy

CHIP PACKAGING AND SEMICONDUCTOR MANUFACTURING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VIII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

COURSE LEARNING OBJECTIVES:

This course will enable students to:

1. Explain the fundamentals of semiconductor manufacturing processes and packaging concepts, and their significance in modern electronic systems.
2. Apply the principles of traditional packaging technologies and assembly processes to select appropriate packaging solutions based on design requirements.
3. Analyze advanced packaging technologies, including 2.5D/3D integration and system-level packaging, to assess performance and integration challenges.
4. Evaluate interconnect technologies, packaging materials, and thermal management techniques to ensure reliability, signal integrity, and optimal system performance.
5. Develop AI- and machine learning-based approaches for defect detection, yield prediction, design optimization, and thermal analysis in semiconductor manufacturing and packaging.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

1. **Lecture method** means it includes not only traditional lecture method, but different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** Adopt the **Active learning** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Show **Video/animation** films to explain functioning of various concepts.
4. Encourage **Collaborative** (Group Learning) Learning in the class.
5. To make **Critical thinking**, ask at least three Higher order Thinking questions in the class.
6. Adopt **Problem Based Learning**, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information ratherthan simply recall it.
7. Show the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.
8. Discuss how every **concept can be applied to the real world** - and when that's possible,it helps improve the students' understanding.

Module I: Introduction to Semiconductor Packaging	**09 Hours**
Definition of semiconductor packaging and its significance in various industries,Introduction to Packaging and its importance in Modern Electronics Overview of semiconductor manufacturing process flow: wafer fabrication, assembly, and packaging ,Wafer processing basics: oxidation, photolithography, etching, doping, and deposition techniques Introduction to cleanroom concepts and yield considerations Introduction to AI in semiconductor manufacturing and packaging (defect detection, yield prediction, process optimization)	
Module II: Traditional Packaging Technologies	**09 Hours**
Overview of conventional packaging technologies,Leaded and leadless packages.Surface Mount Technology (SMT),Ball Grid Array (BGA),Characteristics, advantages, and limitations,Factors influencing selection of packaging technology AI-assisted design selection and optimization in traditional packaging (predictive modeling for reliability and cost)	
Module III: Advanced Packaging Technologies	**09 Hours**
Definition and need for advanced packaging,Benefits and challenges of advanced packaging,Introduction to 2.5D packaging,Introduction to 3D packaging,Integration trends and system-level packaging concepts Machine learning applications in advanced packaging design (design space exploration, performance prediction)	
Module IV: Interconnects and Materials in Advanced Packaging	**09 Hours**
Interconnect technologies: flip-chip bumping, solder balls, Through-Silicon Vias (TSVs),Working principles and design considerations,Impact on electrical performance and signal integrity,Packaging materials and substrates: organic substrates, build-up substrates,Redistribution Layers (RDLs), interposers, fan-out substrates,Material properties, fabrication techniques, and selection criteria AI-based material selection and interconnect reliability prediction (signal integrity and failure analysis)	
Module V: Thermal Management in Advanced Packaging	**09 Hours**
Importance of thermal management in packaging.Heat dissipation challenges in high-density systems,Thermal management techniques: heat sinks, thermal interface materials (TIMs), thermal vias,Design considerations for effective thermal performance,Reliability and performance optimization AI-driven thermal analysis and optimization (predictive thermal modeling and real-time monitoring)	

AI Integration:

1. AI enables rapid defect detection and yield prediction using data-driven models in semiconductor manufacturing.
2. Machine learning optimizes fabrication processes through real-time monitoring and adaptive control.
3. AI assists traditional packaging design by predicting reliability, thermal performance, and cost.
4. Advanced packaging benefits from ML-driven design space exploration and performance prediction.
5. AI improves material selection and interconnect reliability through signal integrity and failure analysis.

Authentic Intelligence:

1. Combines human expertise with AI to ensure accurate and meaningful decision-making.
2. Emphasizes transparency and explainability in AI-driven semiconductor processes.
3. Engineers validate and interpret AI outputs for defect analysis and yield improvement.
4. Human insight ensures practical constraints and reliability in design and material selection.
5. Promotes collaboration between AI systems and engineers for sustainable innovation.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Describe semiconductor packaging fundamentals and outline the role of AI in manufacturing, defect detection, and process optimization.	L2
2	Analyze traditional packaging technologies and apply AI-assisted methods for design selection, reliability prediction, and cost optimization.	L4
3	Evaluate advanced packaging technologies such as 2.5D and 3D integration using AI/ML techniques for design space exploration and performance prediction.	L5
4	Analyze interconnect technologies and packaging materials using AI-based approaches for signal integrity analysis, material selection, and reliability prediction.	L4
5	Design thermal management strategies for advanced packaging systems and implement AI-driven methods for thermal analysis and performance optimization.	L6

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	–	1	–	–	–	–	–	–	–	1	3
CO2	2	3	2	2	1	–	–	–	–	–	–	1	3
CO3	2	3	3	2	2	–	–	–	–	–	–	1	3
CO4	2	3	2	2	2	–	–	–	–	–	–	1	3
CO5	2	3	2	2	1	–	–	–	–	–	–	1	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Rao R. Tummala "Fundamentals of Device and Systems Packaging: Technologies and Applications" McGrawHill Publications, 2nd Edition, 2020.
2. Peter Van Zant, Microchip Fabrication: A Practical Guide to Semiconductor Processing, McGraw-Hill Publications, 6th Edition, 2014.
3. Rao R. Tummala, Eugene J. Rymaszewski, and Alan G. Klopfenstein "Microelectronics Packaging Handbook: Semiconductor Packaging" Springer US, 2nd Edition, 1997.
4. S. M. Sze & Kwok K. Ng, Physics of Semiconductor Devices, Wiley, 4th Edition, 2021.

REFERENCE BOOKS:

1. John H. Lau, "Semiconductor Advanced Packaging", Springer, 2022.

E-Resources:

Sl.No.	Course Name	Instructor	Host Institute
1	Optimizing Semiconductor Defect Classification with Generative AI and Vision Foundation Models https://developer.nvidia.com/blog/optimizing-semiconductor-defect-classification-with-generative-ai-and-vision-foundation-models/	Dr. Tim Lin Dr. HJ Chen	NVIDIA
2	Accelerate computational lithography https://developer.nvidia.com/culitho		NVIDIA

ROBOTICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VIII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P	:	3–0–0			

Course Learning Objectives:

This course enables students to:

1. Understand the fundamental principles of robotics simulation using NVIDIA Isaac Sim, including USD-based scene composition, physics simulation, and robot assembly workflows.
2. Analyse robot asset ingestion pipelines, sensor integration, and synthetic data generation techniques for training AI perception models.
3. Apply software-in-the-loop (SIL) and hardware-in-the-loop (HIL) development paradigms for testing and validating robot software stacks using Isaac Sim and ROS 2.
4. Design and train robot learning policies using NVIDIA Isaac Lab, leveraging reinforcement learning and sim-to-real transfer techniques.
5. Evaluate AI-based robot development frameworks using NVIDIA Isaac ROS, NITROS, and GPU-accelerated perception pipelines for real-world deployment.

Teaching-Learning Process (General Instructions)

These are sample pedagogical methods where teachers can use to accelerate the attainment of the various course outcomes.

1. **Interactive Teaching:** *Adopt Active Learning* that includes brainstorming, hands-on simulation labs, group work, and formulating questions. Show
2. **Video/animation films** from NVIDIA DLI courses to explain robot simulation, learning, and deployment.
3. Encourage **Collaborative (Group Learning)** through Isaac Sim/Isaac Lab project exercises.
4. Foster **Critical Thinking** by asking Higher Order Thinking questions around sim-to-real transfer and robot policy evaluation.
5. Adopt **Problem Based Learning** to develop analytical skills using AI tools like Isaac Lab for RL training. Discuss how every concept can be applied to real-world robotics deployments.

MODULE – I: Introduction to NVIDIA Isaac Sim & OpenUSD for Robotics	**09 Hours**

Overview of NVIDIA Isaac Platform: Introduction to Physical AI and the NVIDIA Isaac ecosystem — Isaac Sim, Isaac Lab, and Isaac ROS. Understanding the three-computer solution for robotics: simulation, training, and deployment. Role of Omniverse and USD (Universal Scene Description) in robot simulation.

OpenUSD Fundamentals: USD architecture: stages, layers, prims, attributes, and relationships. Composition arcs: references, payloads, inherits, specializes, and variants. Working with USD schemas and metadata for

robot scene description. Using Omniverse USD Composer and Code for scene authoring. Introduction to PhysicsX for rigid body dynamics, joints, and collision simulation.

Getting Started with Isaac Sim: Isaac Sim interface overview, extensions, and workflow. Building a simple differential-drive robot from scratch: links, joints, and collision geometry. Configuring articulation physics, drive types (position/velocity), and stiffness/damping. Running physics simulation: step controls, timeline, and debugging.

Robot Sensors in Isaac Sim: Adding and configuring camera, LiDAR, IMU, and contact sensors. Accessing sensor data via Python scripting API. Introduction to Replicator for synthetic data annotation pipelines. Applications in industrial automation, warehouse robotics, and autonomous mobile robots (AMR).

NVIDIA DLI Courses:

1. ***Introduction to Omniverse***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-35+V1
2. ***Introduction to OpenUSD —***
   Link: https://docs.nvidia.com/learn-openusd/latest/index.html#start-learning
3. ***Building Your First Robot in Isaac Sim***
   Link:https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-sim/latest/building-your-first-robot-in-isaac-sim/index.html

MODULE – II: Robot Asset Ingestion, Simulation & Synthetic Data Generation	**09 Hours**

Ingesting Robot Assets into Isaac Sim: URDF (Unified Robot Description Format) overview: links, joints, and sensor definitions. Using the Isaac Sim URDF importer to convert robot descriptions to USD. Configuring joint drives, physics materials, and articulation controllers post-import. Comparing URDF and USD representations for fidelity and extensibility.

Preparing and Simulating Robots: Setting up physics scenes: gravity, timestep, and solver configurations. Adding and calibrating camera, depth, and LiDAR sensors to imported robots. Accessing articulation state (position, velocity, effort) via Python scripting. Running closed-loop control simulations: trajectory following and task-space control. Using pre-built robot assets from the NVIDIA Asset Library (Franka, Carter, Jetbot).

Synthetic Data Generation (SDG) for Perception: Role of synthetic data in bridging the sim-to-real perception gap. Introduction to NVIDIA Replicator: randomizer graph, writers, and annotators. Domain randomization techniques: lighting, texture, object placement, and camera pose. Generating annotated datasets: bounding boxes, segmentation masks, depth, and keypoints. Fine-tuning and validating AI perception models (object detection, pose estimation) using synthetic datasets. Applications in bin-picking, assembly inspection, and autonomous navigation.

NVIDIA DLI Courses:

1. ***Ingesting Robot Assets and Simulating Your Robot in Isaac Sim***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-sim/latest/ingesting-robot-assets-and-simulating-your-robot-in-isaac-sim/index.html
2. ***Synthetic Data Generation for Perception Model Training in Isaac Sim***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-sim/latest/synthetic-data-generation-for-perception-model-training-in-isaac-sim/index.html
3. ***Introduction to Omniverse for Industrial Digitalization***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-42+V1

MODULE – III: Software-in-the-Loop (SIL), Hardware-in-the-Loop (HIL) & ROS 2 Integration	09 Hours

Software-in-the-Loop (SIL) Development: Concept of SIL in robotics: decoupling hardware from software validation. Architecture of SIL pipelines in Isaac Sim: robot software stack integration, virtual sensing, and actuator emulation. Connecting robot application code (navigation, manipulation planners) to Isaac Sim via Python and REST APIs. Testing and iterating control algorithms, safety policies, and perception pipelines entirely within simulation. Debugging robot software using Isaac Sim's action graphs and omnigraph.

Hardware-in-the-Loop (HIL) with ROS 2: Introduction to ROS 2 (Robot Operating System 2): nodes, topics, services, actions, and the DDS communication middleware. Connecting Isaac Sim to ROS 2 via the Isaac ROS bridge: clock synchronization, TF tree, and sensor topic publishing. Publishing camera images, LiDAR scans, and odometry from Isaac Sim to ROS 2 nodes. Subscribing to ROS 2 control commands in Isaac Sim for closed-loop HIL testing. Integrating Nav2 (ROS 2 Navigation Stack) and MoveIt 2 for autonomous navigation and manipulation testing.

Practical ROS 2 Workflows: Launch files, ROS 2 bags, and visualization with RViz2 and Foxglove. Multi-robot simulation and namespace management in Isaac Sim. Performance benchmarking of robot software stacks using Isaac Sim metrics. Applications: autonomous mobile robot (AMR) navigation, pick-and-place manipulation, and multi-sensor fusion.

NVIDIA DLI Courses:

1. ***Developing Robots with SIL in Isaac Sim***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-sim/latest/developing-robots-with-sil-in-isaac-sim/index.html
2. ***Leveraging ROS 2 and HIL in Isaac Sim***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-sim/latest/leveraging-ros-2-and-hil-in-isaac-sim/index.html
3. ***An Introduction to AI-Based Robot Development with Isaac ROS***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-ros/latest/an-introduction-to-ai-based-robot- development-with-isaac-ros/index.html

MODULE – IV: Custom Application Development for Industrial Digital Twins	09 Hours

Introduction to Robot Learning: Categories of robot learning: supervised learning, unsupervised learning, imitation learning, and reinforcement learning (RL). Why simulation is essential for robot learning: data efficiency, safety, and parallelism. Evolution of NVIDIA robotics learning environments: Isaac Gym Standalone, Isaac Sim, and Isaac Lab. Architecture of Isaac Lab: task environments, managers (observation, action, reward, termination), and curriculum learning.

Training Your First Robot with Isaac Lab: Setting up Isaac Lab: installation, workspace configuration, and environment registration. Anatomy of an Isaac Lab task: environment configuration, reward shaping, and observation space design. Training a locomotion policy for a legged robot (e.g., Anymal, Unitree H1) using Proximal Policy Optimization (PPO). Monitoring training with TensorBoard: reward curves, episode lengths, and policy rollouts. Evaluating trained policies in Isaac Sim and exporting them for deployment.

Training a Second Robot — Dexterous Manipulation: Training a multi-fingered robotic hand (e.g., Shadow Hand, Allegro) for in-hand object manipulation. Reward engineering for contact-rich tasks: sparse vs. dense rewards, success metrics, and curriculum design. Using tiled rendering for massively parallel training across thousands of environments. Comparing PPO, SAC, and other RL algorithms for manipulation policy learning. Sim-to-real transfer strategies: domain randomization, actuator modeling, and sensor noise injection.

NVIDIA DLI Courses:

1. ***Developing an Omniverse Kit-Based Application (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-11+V1
2. ***Build Beautiful, Custom UI for 3D Tools on NVIDIA Omniverse (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-16+V1
3. ***How to Build Custom 3D Scene Manipulator Tools on NVIDIA Omniverse (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-33+V1
4. ***Easily Develop Advanced 3D Layout Tools on NVIDIA Omniverse (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-49+V1
5. ***Develop, Customize, and Publish in NVIDIA Omniverse With Extensions (~8 hrs)***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-02+V1

MODULE – V: Sim-to-Real Transfer, Isaac ROS & AI-Powered Robot Deployment	**09 Hours**

Transferring Robot Learning Policies from Simulation to Reality: The sim-to-real gap: sources of discrepancy in dynamics, sensing, and actuation. Techniques to close the gap: system identification, adaptive domain randomization, and real2sim2real. Policy deployment workflow: exporting RL policies from Isaac Lab to ONNX/TensorRT for edge inference. Hardware deployment on NVIDIA Jetson (AGX Orin, Orin NX): setup, containerization, and latency profiling. Real-world evaluation protocols: success rate measurement, robustness to disturbances, and safety guardrails.

NVIDIA Isaac ROS Framework: Architecture of Isaac ROS: GEM packages, NITROS (NVIDIA Isaac Transport for ROS), and hardware-accelerated pipelines. NITROS: zero-copy GPU memory transfers between ROS 2 nodes for high-throughput perception. Key Isaac ROS packages: Visual SLAM, AprilTag detection, Nvblox (3D reconstruction), DNN stereo disparity, and object detection. Integrating Isaac ROS with Nav2 for GPU-accelerated autonomous navigation. Benchmarking Isaac ROS pipelines: latency, throughput, and GPU utilization metrics.

AI-Enabled Robot Applications & Emerging Trends: Foundation models for robotics: large language models (LLMs) as robot task planners, CLIP/SAM for open-vocabulary perception. NVIDIA Project GR00T: humanoid robot foundation model and training paradigm. Digital twins for robot fleet management and predictive maintenance. Edge AI deployment patterns: model quantization, INT8/FP16 inference with TensorRT, and Triton Inference Server. Applications: surgical robotics, agricultural automation, last-mile delivery, and human-robot collaboration in smart manufacturing.

NVIDIA DLI Courses:

1. ***Transferring Robot Learning Policies from Simulation to Reality***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-lab/latest/transferring-robot-learning-policies-from-simulation-to-reality/index.html
2. ***An Introduction to AI-Based Robot Development with Isaac ROS***
   Link: https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-ros/latest/an-introduction-to-ai-based-robot-development-with-isaac-ros/index.html
3. ***Developing Simulation-Based Digital Twins with NVIDIA Omniverse***
   Link: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-41+V1

AI Integration:

1. Introduction to Python-based robotics simulation scripting using Isaac Sim API; robot scene construction, physics configuration, and sensor data extraction using NumPy and USD Python bindings for building intelligent simulation workflows.
2. Implementation of synthetic data generation pipelines using NVIDIA Replicator; domain randomization scripting and automated dataset creation for training perception models (object detection, pose estimation) with PyTorch and TensorFlow.
3. Applying reinforcement learning algorithms (PPO, SAC) using Isaac Lab for robot locomotion and manipulation policy training; reward function design, observation space engineering, and training monitoring using TensorBoard and Weights & Biases.
4. Implementation of sim-to-real transfer pipelines: exporting trained RL policies to ONNX/TensorRT format; deploying quantized models on NVIDIA Jetson using TensorRT inference optimization and performance benchmarking.
5. Integration of Isaac ROS GPU-accelerated perception packages with Nav2 for autonomous navigation; NITROS-based zero-copy pipelines, Visual SLAM, and Nvblox 3D reconstruction for real-time robot environment mapping and localization.

Authentic Intelligence:

1. Understanding the ethical dimensions of deploying AI-trained robots in safety-critical environments; limitations of simulation fidelity in capturing real-world dynamics; risks of over-reliance on synthetic training data; responsible evaluation of sim-to-real transfer performance in physical deployments.
2. Interpretability of reinforcement learning policies for robotic manipulation; risks of reward hacking and unintended robot behaviors; importance of safety constraints, kill-switch mechanisms, and human oversight in autonomous robot systems.
3. Risks of distributional shift between simulation and real environments; responsible practices for domain randomization to avoid overfitting to synthetic conditions; ethical considerations in deploying robots alongside human workers.
4. Limitations of RL-trained locomotion policies on unseen terrain; importance of robust failure detection and graceful degradation; bias in training environment design and its impact on generalization to real-world robot deployments.
5. Understanding the limitations of GPU-accelerated perception pipelines in edge cases (occlusion, adverse lighting, sensor noise); responsible benchmarking of Isaac ROS perception systems; ethical considerations in deploying AI-powered robots in public spaces and healthcare.

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Understand the architecture of NVIDIA Isaac Sim, OpenUSD scene composition, and physics simulation principles for building and configuring robot models in a virtual environment.	L2
2	Analyse robot asset ingestion workflows, sensor integration techniques, and synthetic data generation pipelines for training AI-based perception models using Isaac Sim and Replicator.	L3

3	Apply software-in-the-loop (SIL) and hardware-in-the-loop (HIL) development paradigms by integrating Isaac Sim with ROS 2 for testing robot software stacks and navigation systems.	L3
4	Design and train reinforcement learning-based robot policies using NVIDIA Isaac Lab for locomotion and manipulation tasks, and implement sim-to-real transfer strategies for physical deployment.	L4
5	Evaluate AI-based robot development pipelines using NVIDIA Isaac ROS, NITROS, and GPU-accelerated perception modules for autonomous navigation and real-world robot system deployment.	L5

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	1	-	-	2	1	1	-	-	-	-	2	3
CO2	2	3	-	2	3	-	-	-	-	-	-	2	3
CO3	2	3	3	2	3	1	-	-	-	-	-	2	3
CO4	2	2	3	3	3	-	-	1	2	-	-	2	3
CO5	2	3	-	3	3	1	1	1	-	-	-	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Matthias Wasenmuller and Bernd Jager, 2023. Robotics with NVIDIA Isaac Sim: Building and Training Intelligent Robots in Simulation. NVIDIA Technical Publications.
2. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, 2016. Robotics: Modelling, Planning and Control. Springer.
3. Peter Corke, 2017. Robotics, Vision and Control: Fundamental Algorithms in Python. 2nd Edition, Springer.

REFERENCE BOOKS:

1. Craig, J.J., 2005. Introduction to Robotics: Mechanics and Control. 3rd Edition, Pearson Prentice Hall.
2. Thrun, S., Burgard, W. and Fox, D., 2005. Probabilistic Robotics. MIT Press.
3. Goodfellow, I., Bengio, Y. and Courville, A., 2016. Deep Learning. MIT Press.
4. Sutton, R.S. and Barto, A.G., 2018. Reinforcement Learning: An Introduction. 2nd Edition, MIT Press.

E-Resources:

Sl.No.	Course Name	Instructor	Host Institute
1	Getting Started with Isaac Sim https://docs.isaacsim.omniverse.nvidia.com/4.5.0/introduction/quickstart_index.html	NVIDIA DLI	NVIDIA
2	Getting Started with Isaac Lab https://docs.nvidia.com/learning/physical-ai/getting-started-with-isaac-lab/latest/index.html	NVIDIA DLI	NVIDIA
3	Getting Started with Isaac ROS https://developer.nvidia.com/isaac/ros	NVIDIA DLI	NVIDIA
4	Introduction to OpenUSD https://www.nvidia.com/en-in/glossary/openusd/	NVIDIA Omniverse	NVIDIA
5	Robotics: Science and Systems https://ocw.mit.edu/courses/2-12-introduction-to-robotics-fall-2005/	Multiple Faculty	MIT OpenCourseWare
6	Deep Reinforcement Learning https://rail.eecs.berkeley.edu/deeprlcourse/	Sergey Levine	UC Berkeley (CS285)
7	Robot Operating System 2 (ROS 2) Tutorials https://docs.ros.org/en/foxy/Tutorials.html	Open Robotics	docs.ros.org