Course Description

Title: Digital Hardware Design **Code:**
L- T-P Scheme: 3-0-0 **Credit: 3**

Prerequisite: Students should be studied the courses: "Digital Circuit Design".

Objective:

The course shall provide the students with advanced knowledge in modern electronic design with the help of a hardware description language. After successful completion of the course the student shall be able to design and implement the digital hardware circuits. Also the students will verify, synthesize and implement a design written in VHDL.

Learning outcomes:

Course Outcome	Description
CO1	Outline basics of digital electronics with respect to their needs in the digital system design. Classification of digital systems and examples of their applications.
CO2	Description of the RTL micro-operations and their symbolic notions.
CO3	Development of Arithmetic Logic Unit (ALU) for various operations to be performed.
CO4	Identification and use of the combinational and sequential logic circuits and their use in system implementation.
CO5	Application of various synchronous and asynchronous circuits on a given assignment.
CO6	Demonstration and deployment of designs based on RTL using VHDL.

Course content:

Unit I: Introduction: Digital Design Flow, Hardware Design Environment- Design and Verification, EDA Tools, Simulation and Synthesis process.

Unit II: Register transfer logic (RTL): Inter register transfer, arithmetic, logic and shifter micro-operations, conditional control, ASM chart, data-path and control logic design.

Unit III: Processor logic design: Processor organization, arithmetic logic unit, design of ALU, overflow, arithmetic shift, design of multi-purpose accumulator.

Unit IV: Asynchronous Sequential Machine: Introduction to asynchronous sequential machine. Analysis of asynchronous circuits, flow table, race condition, primitive flow table, state reduction, state assignment and synthesis of asynchronous circuit. hazards.

Unit V: Arithmetic logic design: Ripple carry adder, carry look-ahead adder, carry select adder, carry save adder, parallel multiplier, sign multiplication, Baugh-Wooly multiplication algorithm, radix-4 Booth multiplication algorithm

Unit VI: RTL simulation: Package declaration for different data types, use of generate statement, VHDL coding of generic logic components for combinational logic circuits (multiplexer, decoder, parallel adder/ subtractor, ALU and multiplier) and sequential logic circuits (registers and accumulator).

Teaching Methodology:

This course is introduced to help students to understand the basics of Digital circuit and system design. Starting from frontend development, the student will slowly progress to become to other aspects of digital VLSI. Design skills that are helpful for an engineer. The entire course is based on: Fundamental and Designing, EDA tool & Technologies and brief idea of the digital hardware. Each section includes digital circuit designs to help a student to gain basic knowledge of digital systems.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2, Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 to Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:

Tutorials and lecture notes/slides on Digital Hardware Design (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

[1] M. Morris Mano: Digital Logic and Computer Design, Prentice Hall of India.

Reference Books:

[1] M. Morris Mano: Digital Design, Prentice Hall of India.

[2] Charls Roth: Fundamental of Logic Design.

Web References:

[1] https://swayam.gov.in

Journals References:

[1] IET Computers & Digital Techniques - IET Digital Library

[2] IEEE Transactions on Computers

Title: FPGA based System Design **Code:**
L-T Scheme: 3-0-0 **Credits: 3**

Prerequisite: Students must have already studied courses, "*VLSI Circuits & System Design*".

Course Objectives:

In this course the students will learn logic design and optimization techniques using FPGA, VHDL and Verilog design concepts, Combinational logic concepts, sequential VHDL processing and FPGA.

Learning Outcomes:

Course Outcome	Description
CO1	Outline various hardware description language with respect to their needs for the development of digital systems
CO2	Description of digital systems using HDL subprograms.
CO3	Development of HDL code for a given logic circuit in various modeling styles.
CO4	Identification and use of test bench to verify the functionality of design.
CO5	Application of digital systems design with HDL on a given assignment/ project.
CO6	Demonstration and deployment of the FPGA for a given combinational and sequential digital systems.

Course Content:

Unit-I: Introduction: Concepts of Hardware Description Languages, VHDL: objects, types and subtypes, operators, packages

Unit-II: Logic synthesis: Design cycle, types of synthesizers, design optimization techniques, technology mapping, design organization.

Unit-III: Combinational Logic: Design units, entities and architectures, simulation and synthesis model, signals and ports, simple signal assignments, conditional signal assignments, selected signal assignment.

Unit-IV: Sequential logic design: Processes, variables, sequential statements, Registers: Simulation and synthesis model of register, register templates, clock types, gated registers, resettable registers, simulation model of asynchronous reset, asynchronous reset templates, registered variables, FSM: Moore and Mealy machine modelling.

Unit-V: Hierarchy: components, component instances, component declaration, generate statements, Configuration specifications, default binding, binding process, component packages Functions, procedures, declaring subprograms, Test benches, verifying responses, printing response values, reading data files, Verilog, Overview of Digital Design with Verilog HDL, Basic Concepts, Modules and Ports, Basics of -Gate-Level Modeling, Dataflow Modeling, Behavioral Modeling.

Unit-VI: FPGA: Introduction, Logic Block Architecture, Routing Architecture, Programmable, Interconnection, Design Flow, Xilinx Virtex-II , Artix-7 (Architecture), Boundary Scan, Programming FPGA's, Interface of FPGA board with input and output devices.

Teaching Methodology:

Lectures would cover the core theoretical and practical concepts that are explained in the text and reference materials with adequate examples. Lab sessions will have conceptual and logic building approach that would aid in strengthening the design principles and testing of Complex Digital systems on chip level.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1 and Unit-2
Test-2	25 Marks	Based on Unit-3 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 to Unit-6 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:

Tutorials and lecture slides on FPGA based System Design (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

[1] Charles H. Roth, Digital System Design Using VHDL , Jr.,Thomson, (2008)2nd Ed.
[2] Bhaskar, J., A VHDL Primer, Pearson Education/ Prentice Hall (2006)3rd Ed.

Reference Books/Material:

[1] Ashenden, P., The Designer's Guide To VHDL, Elsevier (2008) 3rd Ed.
[2] David C. Black and Jack Donovan, SystemC: From the Ground Up, Springer, (2014) 2nd Ed.
[3] Rushton, A., VHDL for Logic Synthesis, Wiley (1998) 2ed.
[4] Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Prentice Hall PTR (2003) 2nd Ed.

Web References:

[1] https://www.tutorialspoint.com/
[2] https://nptel.ac.in/

Journals References:

[1] IEEE Journal of digital system design
[2] IRE Transactions on Industrial Electronics

Title: IC Technology **Code:**
L- T-P Scheme: 3-0-0 **Credit: 3**

Prerequisite: Students should be studied the courses: "VLSI Design".

Objective:
The course shall provide the students with advanced knowledge in modern electronic design with the help of a hardware description language.

Learning outcomes:

Course Outcome	Description
CO1	Outline basics of IC technology with respect to their needs in the IC fabrication.
CO2	Description of the fabrication technologies.
CO3	Development of various lithography techniques
CO4	Progress of CMOS IC fabrication steps.
CO5	Application of various IC fab. techniques in MOS circuit design.

After successful completion of the course the student shall be able to know the IC fabrication techniques.

Course Content:
Unit-I: Introduction to IC Technology: Basic fabrication steps and their Importance. Environment of IC Technology: Concepts of Clean room and safety requirements, Concepts of Wafer cleaning processes and wet chemical etching techniques.
Unit-II: Impurity Incorporation: Solid State diffusion modeling and technology; Ion Implantation modeling, technology and damage annealing, characterization of Impurity profiles
Unit-III: Oxidation: Kinetics of Silicon dioxide growth both for thick, thin and ultra thin films, Oxidation technologies in VLSI and ULSI, Characterization of oxide films, High k and low k dielectrics for ULSI. Lithography: Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI, Mask generation.
Unit-IV: Chemical Vapour Deposition Techniques: CVD techniques for deposition of poly-silicon, silicon dioxide, silicon nitride and metal films; Epitaxial growth of silicon: modeling and technology. Metal Film Deposition: Evaporation and sputtering techniques, Failure mechanisms in metal interconnects Multi-level metallization schemes.
Unit-V: Plasma and Rapid Thermal Processing: PECVD, Plasma etching and RIE techniques; RTP techniques for annealing, growth and deposition of various films for use in ULSI.

Teaching Methodology:

This course is introduced to help students to understand the basics of Semiconductor devices and IC fabrication technologies.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2, Unit-3 and around 30% from coverage of Test-1

Test-3	35 Marks	Based on Unit-4 to Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:
Tutorials and lecture notes/slides on IC Technology (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

[1] S.M.Sze(2nd Edition)"VLSI Technology", McGraw Hill Companies Inc.
[2] C.Y. Chang and S.M.Sze (Ed), "ULSI Technology", McGraw Hill Companies Inc.

References Text Books:

[1] Stephena, Campbell, "The Science and Engineering of Microelectronic Fabrication", Second Edition, Oxford University Press.
[2] James D.Plummer, Michael D.Deal, "Silicon VLSI Technology" Pearson Education

Title: VLSI Verification and Testing **Code:**
L-T Scheme: 3-0-0 **Credits: 3**

Prerequisite: Students must have already studied courses, "*Digital Hardware Design*".

Course Objectives:
In this course the students will learn VLSI verification and testing methods.

Learning Outcomes:

Course Outcome	Description
CO1	Outline various VLSI testing and verification processes.
CO2	Description of various faults models.
CO3	Development of system testing models.
CO4	Design of verification techniques based on simulation
CO5	Application of VLSI testing and verification on a given assignment/ project.

Course Content:

Unit-I: Scope of testing and verification in VLSI design process. Issues in test and verification of complex chips, embedded cores and SOCs.
Unit-II: Fundamentals of VLSI testing. Fault models. Automatic test pattern generation. Design for testability. Scan design. Test interface and boundary scan.
Unit-III: System testing and test for SOCs. Idd_q testing. Delay fault testing. BIST for testing of logic and memories. Test automation.
Unit-IV: Design verification techniques based on simulation, analytical and formal approaches. Functional verification. Timing verification, Formal verification.
Unit-V: Basics of equivalence checking and model checking. Hardware emulation.

Teaching Methodology:
Lectures would cover the core theoretical and practical concepts that are explained in the text and reference materials with adequate examples.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1 and Unit-2
Test-2	25 Marks	Based on Unit-2 & Unit-3and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 to Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:
Tutorials and lecture slides on VLSI verification and testing (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

[1] M. L. Bushnell and V.D. Agrawal, Essentials of Electronic Testing for Digital Memory

[2] and Mixed Signal VLSI Circuits, Springer, 2005

[3] H. Fujiwara, Logic Testing and Design for Testability, MIT Press, 1985

[4] M. Abramovici, M. Breuer, and A. Friedman, Digital System Testing and Testable Design, IEEE Press, 1994

References Books:

[1] M. Huth and M. Ryan, Logic in Computer Science, Cambridge Univ. Press, 2004.

[2] T. Kropf, Introduction to Formal Hardware Verification, Springer Verilog, 2000

Title: Emerging Technology beyond 5G **Code:**
L-T-P scheme: 3-0-0 **Credit: 3**

Prerequisite: Students must have already studied courses, "*Wireless Communication*" and "Mobile Communication".

Objective:
The objective of the "Emerging Technology beyond 5G" syllabus is designed to provide students with a deep and comprehensive understanding of the advanced telecommunications technologies that drive the development and implementation of 5G networks and beyond. Here's a detailed breakdown of the course objectives:

a) To Understand Comprehensive 5G and Beyond Technologies
b) To Analyze and Implement Advanced Networking Solutions
c) To Prepare for Future Technological Shifts in Telecommunications
d) To Cultivate a Practical Understanding through Real-World Applications

Learning Outcomes:

Course Outcome	Description
CO1	Understanding the evolution from GSM to LTE-Advanced Pro and the role of 5G in enhancing mobile broadband capabilities.
CO2	Develop the capability to critically analyze the architectural nuances of the 5G core network, including the use of service-based interfaces, data transport mechanisms, and the complexities of non-3GPP access
CO3	Design capability and assess RAN areas, tracking areas, and the integration of 5G with legacy 4G technologies.
CO4	Address and propose the implications of radio propagation issues like diffraction, multipath fading, and coherence.
CO5	Master digital signal processing techniques specific to 5G technologies, including modulation and demodulation processes, OFDM, and adaptive modulation strategies.

Course Content:
Unit-1: Introduction of 5G,Architecture of a Mobile Telecommunication System, High-level Architecture, Internal Architecture of the Mobile, Coverage and Capacity, Architecture of the Core Network, Communication Protocols, Global System for Mobile Communications (GSM), Long-term Evolution (LTE), LTE-Advanced, LTE-Advanced Pro, 5G Research Projects, Enhanced Mobile Broadband, Network Operation, Technologies for 5G, Network Function Virtualization, Software-defined Networking, The 3GPP Specifications for 5G, Architecture of 5G, High-level Architecture.

Unit-II: Architecture of the Core Network
Release 8 Architecture, The 5G Core Network, Representation Using Reference Points, Representation Using Service-based Interfaces, Data Transport, Roaming Architectures, Data Storage Architectures, Non-3GPP Access to the 5G Core, Network Areas, Slices and Identities AMF Areas and Identities, UE Identities and registration areas, Non-3GPP Access, Signalling Protocols, Signalling Protocol Architecture, Example Signalling Procedures.

Unit-III: Architecture of the Radio Access Network

The Next-generation Node B, Carrier Aggregation, The Next-generation Node B, Deployment Options, Multi-radio Dual Connectivity, Options 1 and 3 – EPC, E-UTRAN and MeNB, Options

5 and 7 – 5GC, NG-RAN and MeNB, Options 2 and 4 – 5GC, NG-RAN and MgNB, Data Transport, Tracking Areas, RAN Areas, Cell Identities, 5G State Diagram, Interworking with 4G, Signalling Protocols, Signalling Protocol Architecture.

Unit-IV: Spectrum, Antennas and Propagation

Radio Spectrum, RadioWaves, Spectrum Allocations for 5G, Antenna Arrays for 5G, Radio Propagation Issues for Millimetre Waves, Diffraction and Reflection, Penetration Losses, Foliage Losses, Multipath, Fading and Coherence, Angular Spread and Coherence Distance, Doppler Spread and Coherence Time, Delay Spread and Coherence Bandwidth, Channel Reciprocity.

Unit-V: Digital Signal Processing

Modulation and Demodulation, Carrier Signal, Modulation and Demodulation Process, Channel Estimation, Adaptive Modulation, Multiplexing and Multiple Access, FDD and TDD Modes, Orthogonal Frequency Division Multiple Access, Subcarriers, OFDM Transmitters and Receivers, Inter-symbol Interference and the Cyclic Prefix, Signal-processing Issues for 5G, Power Consumption, Timing Jitter and Phase Noise, Choice of Symbol Duration and Subcarrier Spacing, Error Management, Hybrid ARQ.

Unit- VI: Architecture of the 5G New Radio

Air Interface Protocol Stack, 5G Protocol Stack, Channels and Signals, Information Flows, Frequency Bands and Combinations, Frequency Domain Structure, Transmission Bandwidth Configuration, Global and Channel Frequency Rasters, Common Resource Blocks, Virtual and Physical Resource Blocks, Time Domain Structure, Frame Structure, Timing Advance, TDD Configurations, Slot Format Combinations, Multiple Antennas, Relationships Between Antenna Ports, Data Transmission.

Teaching Methodology:

Regular lectures will be conducted to provide theoretical knowledge and foundational concepts related to 5G and beyond. Lectures will include multimedia presentations to illustrate complex network architectures, signal processing techniques, and future technology forecasts. Each lecture will be supplemented by interactive discussion sessions where students can ask questions, share ideas, and delve deeper into challenging concepts. This will encourage critical thinking and help clarify difficult topics in real-time. Regular quizzes and exams will be conducted to assess and reinforce learning. These assessments will also help students to stay engaged and keep pace with the course.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2 & Unit-3
Test-2	25 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-6 to Unit-8 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:

All the lecture material and relevant documents on “Emerging Technology beyond 5G” will be added on the JUET server (time to time).

Books and References:

5G Mobile and Wireless Communications Technology Afif Osseiran, Jose F. Monserrat, Patrick Marsch Cambridge University Press Second Edition 2011.

5G NR: The Next Generation Wireless Access Technology Erik Dahlman, Stefan Parkvall, Johan Sko ̈ld Elsevier First Edition 2016.

Fundamentals of 5G Mobile Networks Jonathan Rodriguez Wiley First Edition.

Web References:

https://www.qualcomm.com/5g/what-is-5g

https://link.springer.com/book/10.1007/978-3-319-34208-5

https://www.sciencedirect.com/topics/computer-science/5g-mobile-communication

https://5gmf.jp/en/about-5g/

Journals References:

Y. Kim et al., "Feasibility of Mobile Cellular Communications at Millimeter Wave Frequency," in IEEE Journal of Selected Topics in Signal Processing, vol. 10, no. 3, pp. 589-599, April 2016, doi: 10.1109/JSTSP.2016.2520901.

O. O. Erunkulu, A. M. Zungeru, C. K. Lebekwe, M. Mosalaosi and J. M. Chuma, "5G Mobile Communication Applications: A Survey and Comparison of Use Cases," in IEEE Access, vol. 9, pp. 97251-97295, 2021, doi: 10.1109/ACCESS.2021.3093213.

Z. Wei et al., "5G PRS-Based Sensing: A Sensing Reference Signal Approach for Joint Sensing and Communication System," in IEEE Transactions on Vehicular Technology, vol. 72, no. 3, pp. 3250-3263, March 2023, doi: 10.1109/TVT.2022.3215159.

J. Navarro-Ortiz, P. Romero-Diaz, S. Sendra, P. Ameigeiras, J. J. Ramos-Munoz and J. M. Lopez-Soler, "A Survey on 5G Usage Scenarios and Traffic Models," in IEEE Communications Surveys & Tutorials, vol. 22, no. 2, pp. 905-929, Secondquarter 2020, doi: 10.1109/COMST.2020.2971781.

T. Norp, "5G Requirements and Key Performance Indicators," in Journal of ICT Standardization, vol. 6, no. 1-2, pp. 15-30, 2018, doi: 10.13052/jicts2245-800X.612.

A. Ghosh, A. Maeder, M. Baker and D. Chandramouli, "5G Evolution: A View on 5G Cellular Technology Beyond 3GPP Release 15," in IEEE Access, vol. 7, pp. 127639-127651, 2019, doi: 10.1109/ACCESS.2019.2939938.

Title: Green Communication Technology **Code:**
L-T-P scheme: 3-0-0 **Credit: 3**

Prerequisite: Students must have already studied courses, "*Wireless Communication*" and "Mobile Communication".

Objective:
The objective of this course is to provide students with a comprehensive understanding of IoT devices and energy challenges in Human Activity Recognition (HAR). Students will explore different types of IoT devices, advanced machine learning techniques for activity recognition, and various energy harvesting methods such as solar, kinetic, thermal, and RF waves. The course will also cover the use of energy harvesters as sensors and the design of systems for simultaneous sensing and energy harvesting, illustrated through practical case studies and performance evaluations.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the various types of IoT devices, including implantable, wearable, and environmental sensors, and explain the energy challenges associated with Human Activity Recognition (HAR).
CO2	Utilize advanced machine learning techniques for HAR, including data acquisition, preprocessing, segmentation, feature extraction, model training, testing, and evaluation metrics, using relevant datasets.
CO3	Evaluate different energy harvesting techniques for IoT sensors, such as solar, kinetic, thermal, and RF waves, and analyze their effectiveness in various scenarios.
CO4	Assess the application of kinetic, solar, thermal, and RF energy harvesters as sensors through case studies on step count, audio signal detection, activity recognition, and transport mode detection.
CO5	Design and develop systems for simultaneous sensing and energy harvesting, considering detailed system design, hardware, and experimental setups, and perform comprehensive performance evaluations through practical case studies.

Unit I: IoT Devices and Energy Challenges for HAR, Types of IoT devices: Implantable, Wearable, Environmental, Energy challenges in IoT for HAR, Overview of research motivation and book organization.
Unit II: Advanced Techniques in Activity Recognition using IoT Mechanisms and wearable sensors for HAR, Deep dive into machine learning techniques for HAR: Data acquisition, preprocessing, segmentation, feature extraction, model training, testing, and evaluation metrics, Datasets for Developing and Evaluating HAR Algorithms.
Unit III: Energy Harvesting Techniques for IoT Sensors
Detailed exploration of energy harvesting modes: Solar, Kinetic, Thermal, RF Waves, Kinetic and Solar Energy Harvesting circuits, Operation of KEH transducer at MPP, Solar energy harvesting, circuits.
Unit IV: Utilizing Energy Harvesters as Sensors
Application of KEH, SEH, TEH, and RFEH as sensors, Case studies on step count, audio signal detection, activity recognition, transport mode detection.
Unit V: Simultaneous Sensing and Energy Harvesting in IoT System architecture and challenges for simultaneous sensing and energy harvesting, Detailed system design considerations, including hardware designs and experimental setups, Case study on transport mode detection and comprehensive performance evaluation.
Teaching Methodology:

The teaching methodology for this course includes interactive lectures to explain core concepts and energy challenges in IoT for HAR. Hands-on material will be provided for IoT devices, machine learning techniques, and energy harvesting methods. Lectures will foster problem-solving ability allowing students to design and evaluate HAR systems. Case studies will connect theoretical knowledge to real-world applications, demonstrating the use of energy harvesters as sensors. Continuous feedback will enhance learning and provide insights into cutting-edge developments.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2 & Unit-3
Test-2	25 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-6 to Unit-8 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:

All the lecture material and relevant documents on "Green Communication Technology" will be added on the JUET server (time to time).

Books and References:

[1] M. M. Sandhu, S. Khalifa, M. Portmann, and R. Jurdak, *Self-Powered Internet of Things: How Energy Harvesters Can Enable Energy-Positive Sensing, Processing, and Communication*. Cham, Switzerland: Springer Nature, 2023, doi: 10.1007/978-3-031-27685-9.

A. J. Sguarezi Filho, R. V. Jacomini, C. E. Capovilla, and I. R. S. Casella, Eds., *Smart Grids: Renewable Energy*. Cham, Switzerland: Springer Nature, 2022, doi: 10.1007/978-3-030-98944-9.

[2] R. Buyya and A. V. Dastjerdi, Internet of Things: Principles and Paradigms. San Francisco, CA, USA: Morgan Kaufmann, 2016.

[3] J. Soldatos, Machine Learning for the Internet of Things: Including IoT Architecture, Data Analytics, and Machine Learning Techniques. O'Reilly Media, 2019.

[4] S. Beeby and N. White, Energy Harvesting for Autonomous Systems. Norwood, MA, USA: Artech House, 2010.

[5] M. A. Labrador and O. D. Lara Yejas, Human Activity Recognition: Using Wearable Sensors and Smartphones. Boca Raton, FL, USA: CRC Press, 2013.

Web References:

[1] https://www.sciencedirect.com/topics/computer-science/green-communication

[2] https://www.computer.org/publications/tech-news/trends/power-of-green-communication/

[3] https://www.routledge.com/Green-Communication-Technologies-for-Future-Networks-An-Energy-Efficient-Perspective/Kaur-Srivastava/p/book/9781032206301

[4] https://digital-library.theiet.org/content/books/te/pbte091e

[5] https://www.comsoc.org/publications/journals/ieee-tgcn/cfp/green-communication-and-computing-technologies-6g-networks

Journals References:

[1] M. M. Mowla, I. Ahmad, D. Habibi and Q. V. Phung, "A Green Communication Model for 5G Systems," in IEEE Transactions on Green Communications and Networking, vol. 1, no. 3, pp. 264-280, Sept. 2017, doi: 10.1109/TGCN.2017.2700855.

[2] U. S. Toro, K. Wu and V. C. M. Leung, "Backscatter Wireless Communications and Sensing in Green Internet of Things," in IEEE Transactions on Green Communications and Networking, vol. 6, no. 1, pp. 37-55, March 2022, doi: 10.1109/TGCN.2021.3095792.

[3] F. K. Shaikh, S. Zeadally and E. Exposito, "Enabling Technologies for Green Internet of Things," in IEEE Systems Journal, vol. 11, no. 2, pp. 983-994, June 2017, doi: 10.1109/JSYST.2015.2415194.

[4] S. P. Raja, "Green Computing: A Future Perspective and the Operational Analysis of a Data Center," in IEEE Transactions on Computational Social Systems, vol. 9, no. 2, pp. 650-656, April 2022, doi: 10.1109/TCSS.2021.3093702.

[5] Abrol and R. K. Jha, "Power Optimization in 5G Networks: A Step Towards GrEEn Communication," in IEEE Access, vol. 4, pp. 1355-1374, 2016, doi: 10.1109/ACCESS.2016.2549641.

Title: Machine Learning for communication systems **Code:**
L-T-P scheme: 3-0-0 **Credit: 3**

Prerequisite: Students must have already studied courses, "*Neural Networks*", "*Mobile Communication"* and "Mobile Communication".

Objective:

The objective of this course is to equip students with a comprehensive understanding of the principles, methodologies, and applications of machine learning in communication systems. By the end of the course, students will be able to Understand Fundamental Concepts, Explore ML Techniques, Analyze Communication Systems, Design and Implement Algorithms, Optimize Network Performance.

Learning Outcomes:

Course Outcome	Description
CO1	Implement and Analyze Machine Learning Algorithms and demonstrate proficiency in implementing machine learning algorithms, understanding ML architecture, and applying them to real-world scenarios.
CO2	Assess the components, architectures, and applications of cognitive computing systems.
CO3	Apply Advanced Machine Learning Techniques in Wireless Networks including deep reinforcement learning, to optimize wireless communication systems.
CO4	Design and evaluate smart communication systems using cognitive computing and AI, focusing on resource management in cognitive radios and advanced wireless signal processing for 5G networks.
CO5	Develop and implement effective spectrum sensing and allocation schemes for cognitive radio networks, analyzing various detection techniques and addressing challenges in spectrum allocation while predicting future advancements.

Unit-I: Machine Learning Architecture and Framework,Machine Learning Algorithms, ML Architecture Data Acquisition, Latest Application of Machine Learning, Image Identification, Sentiment Analysis, Speech Recognition, Author Identification and Prediction, Services of Social Media, Medical Services, Recommendation for Products and Services, Future of Machine Learning.

Unit-II: Cognitive Computing: Architecture, Technologies and Intelligent Applications Introduction, Components of a Cognitive Computing System, Subjective Computing Versus Computerized Reasoning, Cognitive Architectures, Subjective Architectures and HCI, Cognitive Design and Evaluation. Cognitive Computing: Overview, The Future of Cognitive Computing.

Unit-III: Deep Reinforcement Learning for Wireless Network,Machine Learning to Deep Learning, Advance Machine Learning Techniques, Deep Reinforcement Learning (DRL), Applications of Machine Learning Models in Wireless Communication, Regression, KNN and SVM Models for Wireless, Bayesian Learning for Cognitive Radio, Deep Learning in Wireless Network, Deep Reinforcement Learning in Wireless Network.

Unit-IV: Cognitive Computing for Smart Communication,Cognitive Computing Evolution, Characteristics of Cognitive Computing, Basic Architecture, Resource Management Based on Cognitive Radios, Designing 5G Smart Communication with Cognitive Computing and AI, Advanced Wireless Signal Processing Based on Deep Learning, Applications of Cognition-Based Wireless Communication.

Unit-V: Spectrum Sensing and Allocation Schemes for Cognitive RadioFoundation and Principle of Cognitive Radio, Spectrum Sensing for Cognitive Radio Networks, Classification of Spectrum Sensing Techniques, Energy Detection, Matched Filter Detection, Cyclo-Stationary Detection Euclidean Distance-Based Detection, Spectrum Allocation for Cognitive Radio Networks, Challenges in Spectrum Allocation, Future Scope in Spectrum Allocation.

Teaching Methodology:
Regular lectures will be conducted to provide theoretical knowledge and foundational concepts related to Machine learning for Communication systems. Weekly hands-on lab sessions will provide practical experience, allowing students to implement algorithms and work with tools like Python and MATLAB. Additionally, case studies and the review of recent research papers will help students connect theoretical knowledge with current industry practices.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2 & Unit-3
Test-2	25 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-6 to Unit-8 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:
All the lecture material and relevant documents on "Machine Learning for communication systems" will be added on the JUET server (time to time).

Books and References:

[1]Fa-Long Luo," Machine Learning for Future Wireless Communications", John Wiley and Sons, 2020.

[2]Ruisi He, Z Ding, "Applications of Machine Learning in Wireless Communications", IET Telecommunication series 81.

[3]K. K. Singh, A. Singh, K. Cengiz, Dac-Nhuong Le, "Machine Learning and Cognitive Computing for Mobile Communications and Wireless Networks", Wiley 2020.

Web References:

[1]https://www.comsoc.org/publications/best-readings/machine-learning-communications

[2]https://www.itu.int/dms_pub/itu-s/opb/journal/S-JOURNAL-ICTF.VOL1-2018-1-P06-PDF-E.pdf

[3]https://ieeexplore.ieee.org/document/8542764

[4]https://www.dhillon.ece.vt.edu/mlcourse.html

[5]https://digital-library.theiet.org/content/books/te/pbte081e

Journals References:

[1]J. Park et al., "Communication-Efficient and Distributed Learning Over Wireless Networks: Principles and Applications," in Proceedings of the IEEE, vol. 109, no. 5, pp. 796-819, May 2021, doi: 10.1109/JPROC.2021.3055679.

[2]O. Simeone, "A Very Brief Introduction to Machine Learning With Applications to Communication Systems," in IEEE Transactions on Cognitive Communications and Networking, vol. 4, no. 4, pp. 648-664, Dec. 2018, doi: 10.1109/TCCN.2018.2881442.

[3]D. Gündüz, P. de Kerret, N. D. Sidiropoulos, D. Gesbert, C. R. Murthy and M. van der Schaar, "Machine Learning in the Air," in IEEE Journal on Selected Areas in Communications, vol. 37, no. 10, pp. 2184-2199, Oct. 2019, doi: 10.1109/JSAC.2019.2933969.

[4]M. E. Morocho-Cayamcela, H. Lee and W. Lim, "Machine Learning for 5G/B5G Mobile and Wireless Communications: Potential, Limitations, and Future Directions," in IEEE Access, vol. 7, pp. 137184-137206, 2019, doi: 10.1109/ACCESS.2019.2942390.

[5]D. Li, Y. Xu, M. Zhao, J. Zhu and S. Zhang, "Knowledge-Driven Machine Learning and Applications in Wireless Communications," in IEEE Transactions on Cognitive Communications and Networking, vol. 8, no. 2, pp. 454-467, June 2022, doi: 10.1109/TCCN.2021.3128597.

[6]D. Adesina, C. -C. Hsieh, Y. E. Sagduyu and L. Qian, "Adversarial Machine Learning in Wireless Communications Using RF Data: A Review," in IEEE Communications Surveys & Tutorials, vol. 25, no. 1, pp. 77-100, Firstquarter 2023, doi: 10.1109/COMST.2022.3205184.

[7] J. Joung, "Machine Learning-Based Antenna Selection in Wireless Communications," in IEEE Communications Letters, vol. 20, no. 11, pp. 2241-2244, Nov. 2016, doi: 10.1109/LCOMM.2016.2594776.

Title: Data Analytics for 5G **Code:**
L-T-P scheme: 3-0-0 **Credit: 3**
Prerequisite: Students must have already studied courses, "*Neural Networks*", "*Machine Learning*" and "*Mobile Communication*".
Objective:
The objective of the "Data Analytics for 5G" course is to equip students with the knowledge to leverage data analytics for maximizing the potential of 5G technology. Students will understand digital transformation and industry ecosystems, and explore the capabilities of 5G standalone (SA) and network slicing. They will learn about mobile edge computing, operational efficiency, and sustainability improvements. The course also covers private network deployment, standardization, and practical applications, culminating in the development of tailored business models for 5G. This prepares students to apply data analytics effectively in various industry settings using 5G technology.
Learning Outcomes:

Course Outcome	Description
CO1	Examine the impact of digital technologies and 5G on various industries to identify new business opportunities arising from digital disruption, Industry 4.0, and evolving business models.
CO2	Assess how smart and connected products, along with APIs, transform industry ecosystems by enhancing collaboration and data sharing, and contribute to the rise of the digital platform economy.
CO3	Comprehend the evolution towards 5G standalone (SA), including its technical foundations and new capabilities, and explain the significance and applications of network slicing in various industries.
CO4	Utilize mobile edge computing in industrial 5G applications to address challenges and leverage 5G for operational efficiency and sustainability improvements.
CO5	Develop tailored business models for 5G private networks by analyzing deployment models, interpreting enterprise and vertical requirements, and optimizing techno-economic factors for effective implementation.

Unit I: New Data-Driven Business Opportunities
Digital Disruption of Industries: Understand the impact of digital technologies on various industries, Role of Industrial 5G in Digital Transformation: Explore how 5G technology facilitates digital transformation, Industry 4.0 and the Ongoing Industrial Revolution: Discuss the characteristics and impacts of the fourth industrial revolution, Business Model Disruption: Study how new technologies disrupt existing business models and lead to new opportunities.

Unit II: Smart & Connected Products with APIs Transforming Industry Ecosystems Industry Ecosystems and Digital Transformation: Analyze how digital ecosystems transform industries, Benefits of Collaboration and Data Sharing: Understand the importance of collaboration and data sharing in industry ecosystems, Digital Platforms and Platform Economy: Examine the rise of digital platforms and their economic impact, Types of API and API Value Chain: Learn about different types of APIs and their roles in digital ecosystems.

Unit III: New Capabilities of 5G SA and Network Slicing Evolution Toward 5G Standalone: Overview of the transition from non-standalone to standalone 5G, Technical Foundations and New Capabilities: Understand the technical underpinnings and new features of 5G SA, Network Slicing and Its Importance: Explore the concept of network slicing and its applications in various industries.

Unit IV: Mobile Edge and Real-Time Data-Driven Innovations
Mobile Edge Computing and Industrial 5G: Discover how mobile edge computing complements 5G in industrial applications, Challenges and Opportunities in Industry: Examine the challenges

industries face and how they can leverage 5G for solutions, Operational and Sustainability Benefits: Discuss how 5G can improve operational efficiency and sustainability.

Unit V: Private Networks and Their Deployment in Industry
Private Networks Introduction and Standardization: Learn about the concept, significance, and standards of private networks, Deployment Models and Implementation Aspects: Understand different deployment models and key considerations for implementation, Case Studies and Practical Applications: Review case studies of private network implementation in various sectors.

Unit VI: Private Network Guidelines for Industry Verticals: Introduction to private networks and their significance, Network Deployment: Examination of SNSP and PNI-NPN deployment strategies, Deployment Models: Analysis of pros and cons for different deployment models, Techno-economic Optimization: Understanding techno-economic factors and optimization, Requirement Interpretation: Interpretation and assessment of enterprise and vertical requirements, Business Model Development: Developing business models tailored for 5G private networks.

Teaching Methodology:

The teaching methodology for "Data Analytics for 5G" integrates a blend of interactive lectures, and real-world case studies to ensure comprehensive understanding and practical application. Lectures will incorporate multimedia presentations and Q&A sessions to clarify complex concepts and engage students actively. Hands-on material will be provided for practical experience with data analytics tools and techniques relevant to 5G technologies. Case studies will link theoretical knowledge to industry practices, demonstrating the impact of 5G and data analytics on business models and industry ecosystems. Continuous formative feedback will further enhance learning; ensuring students are well-prepared to apply data analytics in the context of 5G technology.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2 & Unit-3
Test-2	25 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-6 to Unit-8 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	100 Marks	

Learning Resources:
All the lecture material and relevant documents on “Data Analytics for 5G” will be added on the JUET server (time to time).

Books and References:

[1]Alcardo Barakabitze; Andrew Hines, "5G Network Management for Big Data Streaming using Machine Learning," in Multimedia Streaming in SDN/NFV and 5G Networks: Machine Learning for Managing Big Data Streaming , IEEE, 2023, pp.19-33, doi: 10.1002/9781119800828.ch2.

[2]Joseph Hoy, "3GPP Network Types," in Forensic Radio Survey Techniques for Cell Site Analysis , Wiley, 2024, pp.91-156, doi: 10.1002/9781394197200.ch5.

[3] Chamitha de Alwis; Quoc-Viet Pham; Madhusanka Liyanage, "Security and Privacy of 6G," in 6G Frontiers: Towards Future Wireless Systems , IEEE, 2023, pp.115-149, doi: 10.1002/9781119862321.ch10.

Web References:

[1] https://www.ericsson.com/en/core-network/5g-core/network-data-analytics-function
[2] https://www.mpirical.com/blog/5g-network-data-analytics
[3] https://www.thalesgroup.com/en/markets/digital-identity-and-security/mobile/5g-data
[4] https://futurenetworks.ieee.org/images/files/pdf/applications/Data-Analytics-in-5G-Applications030518.pdf
[5] https://www.sandvine.com/blog/network-data-analytics-function-in-5g-automated-analytics-where-you-need-it
[6] Journals References:
[7] B. Ma, W. Guo and J. Zhang, "A Survey of Online Data-Driven Proactive 5G Network Optimisation Using Machine Learning," in IEEE Access, vol. 8, pp. 35606-35637, 2020, doi: 10.1109/ACCESS.2020.2975004.
[8] E. Pateromichelakis et al., "End-to-End Data Analytics Framework for 5G Architecture," in IEEE Access, vol. 7, pp. 40295-40312, 2019, doi: 10.1109/ACCESS.2019.2902984.
[9] J. Huang et al., "A Big Data Enabled Channel Model for 5G Wireless Communication Systems," in IEEE Transactions on Big Data, vol. 6, no. 2, pp. 211-222, 1 June 2020, doi: 10.1109/TBDATA.2018.2884489.
[10] M. Ramachandran, T. Archana, V. Deepika, A. A. Kumar and K. M. Sivalingam, "5G Network Management System With Machine Learning Based Analytics," in IEEE Access, vol. 10, pp. 73610-73622, 2022, doi: 10.1109/ACCESS.2022.3190372.

Title: Internet of Things **Code:**
L-T-P Scheme: 3-0-0 **Credit: 3**
Prerequisite: Students must have already studied courses, "Measurement & Instrumentation".
Objective:
Understand the Internet of Things (IoT) concept and possible future trends.
Review the various network protocols & end devices used in IoT.
Learning outcomes:

Course Outcome	Description
CO1	Familiarization with different physical device related to IoT
CO2	Understand the IoT levels and methodology
CO3	Apply the programming tools required in IoT
CO4	Analyze the various architectures and protocols of IoT
CO5	Design and implement IoT technologies, solutions, and applications

Course Contents:
Unit-I: Fundamentals: IoT definition, Internet of Everything (IoE), characteristics, conceptual framework, technology behind IoT, application, challenges, Machine-to-Machine (M2M), comparison.
Unit-II: Sensors and Actuators: Principles, classification, characteristics, analog and digital sensor, electric and electronic sensors, resistive, capacitive and inductive type displacement sensor etc. mechanical sensor, pneumatic and hydraulic, hall sensors, ultrasonic sensor, IR sensor, temperature and humidity Sensors, digital switch, Electro-Mechanical switches, Actuator concepts, types, actuator performance criteria and selection, fluidic actuators, piezo-electric actuators.
Unit-III: Architecture and Protocol: IoT Levels, IoT Design methodology, Functional View, Information View, Deployment and Operational View, Other relevant architectural views. Protocol classification, Message Queue Telemetry Transport (MQTT), Extensible Messaging and Presence Protocol (XMPP), Advanced Message Queuing Protocol (AMQP), Constrained Application Protocol (CoAP), comparison.
Unit-IV: IoT End Devices: Arduino uno, Raspberry pi, technical specification, operating system, Interfaces, Intel Edison & Intel Galileo board, pcduino, beagle black and cubieboard, Programming.
Unit-V: Domain specific applications: Home automation, Smart cities, Smart irrigation, Green house control, Weather monitoring, River flood detection, Smart grids, Machine diagnosis and prognosis, Health monitoring, Smart Perishable Tracking, Smart warehouse, Smart driver assistance system etc.

Teaching Methodology:
Lectures would be interactive and it would cover the core concepts that are explained in the text and reference materials with adequate examples.
Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15	Based on Unit-1 and Unit-2
Test-2	25	Based on Unit-2 , Unit-3 and around 30% from coverage of Test-1
Test-3	35	Based on Unit-4, Unit-5 and around 30% from coverage of Test-2
Assignment	10	
Tutorials	5	
Quiz	5	
Attendance	5	
Total	100	

Text Books:

[1]Bahga A. and Madisetti V., “Internet of Things-A Hands-on- Approach”, 1st Edi., VPT, 2014.
[2]D. Patranabis, “Sensors and Transducers”, PHI Learning Private Limited.
[3]Srinivasa K G ,Siddesh G. M. and Hanumantha R. R., “Internet of Things”, 2nd Edi. Cen. Edu., 2019.

[4]Reference Books:
[5]Kamal R., “Internet of Things”, 2nd Edi., McGraw-Hill Education, 2014.
[6]Julian W.Gardner and Vijay K Varadhan, “Microsensors, MEMS and Smart Devices”, John Wiley & sons, 2001.
[7] Shriram K V., Abhishek S N. and Sundram RMD, “Internet of Things”, 1st Edi., John Wiley & Sons,2019.

Web References:

[1] https://archive.nptel.ac.in/courses/106/105/106105166/
[2] https://www.edureka.co

Journals References:

[1] https://ieee-iotj.org/
[2] https://www.sciencedirect.com/journal/internet-of-things

Title: Artificial Intelligence of Things **Code:**
L-T-P Scheme: 3-0-0 **Credit: 3**

Prerequisite: Students must have already studied courses, “Machine Learning”.
Objective:

a) To learn the fundamentals concepts and principles of AI empowered IoT.
b) To develop an IoT systems and apply to real-world applications.

Learning outcomes:

Course Outcome	Description
CO1	Review the basics of artificial intelligence
CO2	Understand the fundamental concepts and challenges in AIoT
CO3	Apply data analytics and networking in IoT systems
CO4	Visualize IoT data-creating dashboard
CO5	Develop AIoT systems and apply to real-world applications

Course Contents:
Unit-I: AI Review: Basics of Artificial Intelligence, Moore’s law in context of AI, Need of fast computational resources, Hardware for training, Architectural Challenges for Training, Memory Challenges, Floating point accuracy.
Unit-II: Introduction to AIoT: Concepts and issues, Technical architecture, Technologies, Application segments, Cloud and Edge based, Challenges of AI in networks for IoT, Distributed intelligence at the edge of IoT systems , edge computing, block chain, etc., Robotics for AIoT.
Unit III: IoT Clouds and Computing: Apache Hadoop, Map Reduce model, Hadoop YARN. Python Packages for IoT, Amazon EC2, Autoscaling, S3, RDS, DynamoDB and MapReduce IoT Physical Servers –Cloud Storage Models, Communication APIs. Chef, Puppet, NETCONF-YANG.
Unit-IV: Artificial Intelligence and Data Analytics: AI for IoT data analytics and automation, Application of CPS in Machine tools, Digital production, Cyber Physical system Intelligence, Evaluation of Workforce and Human Machine Interaction: Worker and CPS, Strategies to support user intervention.
Unit-V: Visualization and Dashboard: Designing visual analysis for IoT data-creating dashboard– creating and visualizing alerts–basics of geo-spatial analytics-vector based methods-raster based methods- storage of geo-spatial data-processing of geo spatial data, Anomaly detection forecasting, Case study: pollution reporting problem.

Teaching Methodology:
Lectures would be interactive and it would cover the core concepts that are explained in the text and reference materials with adequate examples.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15	Based on Unit-1 & Unit-2
Test-2	25	Based on Unit-2, Unit-3 and around 30% from coverage of Test-1
Test-3	35	Based on Unit-4, Unit-5 and around 30% from coverage of Test-2
Assignment	10	
Tutorials	5	
Quiz	5	
Attendance	5	
Total	100	

Text Books:

[1] Francis DaCosta, “Rethinking the Internet of Things”, Apress Berkeley,2014.

[2] Kai Hwang and Min Chen. “Big-Data Analytics for Cloud, IoT and Cognitive Computing”, Wiley 2017.
[3] Amita Kapoor, “Hands-On Artificial Intelligence for IoT: Expert machine learning and deep learning techniques for developing smarter IoT systems”, Packt Publishing Ltd. 2018.

Reference Books:
[1] Fadi AI-Turjman “AIoT Innovation”, Springer. 2020
[2] Eugene Chang, “The Future of Artificial Intelligence, the Internet of Things, and Blockchain”. Amazon. 2019.

Web References:
[1] https://viso.ai/edge-ai/artificial-intelligence-of-things-aiot/
[2] https://www.techtarget.com/iotagenda/definition/Artificial-Intelligence-of-Things-AIoT

Journals References:
[1] https://www.jair.org/index.php/jair
[2] https://jisajournal.springeropen.com/about/new-content-item

Title: Industrial Internet of Things **Code:**
L-T-P Scheme: 3-0-0 **Credit: 3**
Prerequisite: Students must have already studied courses, "Artificial Intelligence of Things".
Objective:

a) Understand key skills employed in the IIoT & IoRT space building applications.
b) Design suitable network architecture and use appropriate learning algorithm.

Learning outcomes:

Course Outcome	Description
CO1	Understand the working of different sensors
CO2	Analyze the various architectures and protocols of IIoT
CO3	Demonstrate cyber physical and cyber manufacturing systems
CO4	Describe Architectural design patterns for IIoT
CO5	Analyze Internet of Robotics Things (IoRT)

Course Contents:
Unit-I: Understanding IIoT: Definition, Information Next Generation Sensors, Sensor's calibration and validate sensor measurements, placement of IoT devices, sensors, low-cost communication system design, Top application areas include manufacturing etc.
Unit-II: Methodology: Top operating systems used in IIoT deployments, networking and wireless communication protocols used in IIoT deployments. Smart Remote Monitoring Unit, components of monitoring system, control and management, Wireless Sensor Network (WSN).
Unit-III: IIoT Modeling: Cyber Manufacturing Systems(CMS), Application map for Industrial Cyber Physical Systems (CPS), Cyber Physical Electronics production, Modeling, Model based engineering of supervisory controllers for cyber physical systems, formal verification of system, components, Evaluation model for assessments of cyber physical production systems.
Unit-IV: Architectural Design Pattern: CPS-based manufacturing and Industries 4.0., Integration of Knowledge base data base and machine vision, Interoperability in Smart Automation, Enhancing Resiliency in Production Facilities through CPS. Communication and Networking of IIoT
Unit-V: Application of IIoT: Smart Metering, e-Health Body Area Networks, City Automation, Automotive Applications, Smart Cards, Plant Automation, Real life examples of IIOT in Manufacturing Sector.
Unit-VI: Internet of Robotic Things (IoRT): Introduction to stationary and mobile robots, Brief introduction to localization, mapping, planning, and control of robotic systems; Introduction to cloud-enabled robotics; Applications of IIoT in robotics; Architectures for IoRT, Examples and case studies: Open issues and challenges.
Teaching Methodology:

Lectures would be interactive and it would cover the core concepts that are explained in the text and reference materials with adequate examples.
Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15	Based on Unit-1 & Unit-2
Test-2	25	Based on Unit-2, Unit-3 and around 30% from coverage of Test-1
Test-3	35	Based on Unit-4, Unit-5 and around 30% from coverage of Test-2
Assignment	10	
Tutorials	5	
Quiz	5	

Attendance	5	
Total	100	

Text Books:

[1] Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress, 2016

[2] Sudip Misra,Chandana Roy,Anadarup Mukherjee, "Introduction to Industrial Internet of Things and Industry 4.0", CRC Press,2021

[3] Sabina Jeschke, Christian Brecher Houbing Song , Danda B. Rawat Editors "Industrial Internet of Things Cyber Manufacturing Systems"

Reference Books:

[1] Giacomo Veneri "Hands on Industrial Internet of Things", ,Antonio Capasso, Packt Press, 2018

[2] Ismail Butun ,"Industrial IoT Challenges, Design Principles, Applications, and Security".

[3] Mahmood, Zaigham, "The Internet of Things in the Industrial Sector,"

Web References:

[1] https://onlinecourses.nptel.ac.in/noc20_cs24/preview

[2] https://www.techtarget.com/iotagenda/definition/Industrial-Internet-of-Things-IIoT

Journals References:

[1] IEEE Transactions on Industrial Informatics

[2] Journal of Industrial Integration and Management