Industrial Data Networks		Semester	VII
Course Code	**BRA701**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	04	Exam Hours	03

Course objectives:

- To educate on the basic concepts of data networks
- To introduce the basics of internet working and serial communications
- To provide details on HART and Field buses
- To educate on MODBUS, PROFIBUS and other communication protocol
- To introduce industrial Ethernet and wireless communication

Pedagogy (General Instructions)

These are sample Strategies; which teacher can use to accelerate the attainment of the various course outcomes.

1. Lecturer method (L) does not mean only traditional lecture method, but different type of teaching methods may be adopted to develop the outcomes.
2. Arrange visits to nearby power plants, receiving station and substations to give brief information about the electrical power generation.
3. Show Video/animation films to explain functioning of various machines
4. Encourage collaborative (Group Learning) Learning in the class
5. Ask at least three HOTS (Higher order Thinking) questions in the class, which promotes critical thinking
6. Adopt Problem Based Learning (PBL), which fosters student's Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information rather than simply recall it.
7. Topics will be introduced in a multiple representation.
8. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them.
9. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.
10. Individual teacher can device the innovative pedagogy to improve the teaching-learning.

Module-1 INTRODUCTION

Modern instrumentation and control systems – Terminology – Topology – Mechanisms - Protocols – Standards – Common problems and solutions – Grounding/shielding and noise - EIA-232 interface standard – EIA-485 interface standard –Current loop and EIA-485 converters - Fibre optic cable components and parameters – Basic cable types – Connection fibers – troubleshooting.

Pedagogy	Power Point Presentations and Videos. Discussion on current research from the research papers, patents.

Module-2 COMMUNICATION BUS PROTOCOLS

Overview – Protocol structure – Function codes – Modbus plus protocol –Data Highway – AS interface (AS-i)- Device Net: Physical layer – Topology – Device taps –Profibus PA/DP/FMS: Protocol stack – System operation. CAN BUS: Concepts of bus access and arbitration – CAN: Protocol-Errors: Properties – detection – processing – Introduction to CAN 2.0B

Pedagogy	Power Point Presentations and Videos. Discussion on current research from the research papers, patents.

Module-3 ETHERNET SYSTEMS

IEEE 802.3 – Physical layer - Medium access control – Collisions - Ethernet design rules - Fast and gigbit Ethernet systems - design considerations - Internet layer protocol - UDP - TCP/IP - ProfiNet - LAN system components – Structured cabling – Industrial Ethernet – Troubleshooting Ethernet.

Pedagogy	Power Point Presentations and Videos. Discussion on current research from the research papers, patents.

Module-4 WIRELESS COMMUNICATIONS

Radio spectrum – Frequency allocation – Radio modem – Intermodulation – Implementing a radio link – RFID: Basic principles of radio frequency identification – Transponders – Interrogators, Wireless HART.

Pedagogy	Power Point Presentations and Videos. Discussion on current research from the research papers,patents.

Module-5 APPLICATIONS
Automotive communication technologies – Design of automotive X-by-Wire systems, - The LIN standard – The IEC/IEEE Train communication network: Applying train communication network for data communications in electrical substations.

Pedagogy	Power Point Presentations and Videos. Discussion on current research from the research papers, patents.

PRACTICAL COMPONENT OF IPCC

Sl. No.	Experiments
1.	Write a program for a HLDC frame to perform the following i) Bit Stuffing ii) Character Stuffing
2.	Write a program for distance vector algorithm to find suitable path for transmission.
3.	Implement Dijkstra's algorithm to compute the shortest routing path.
4.	Write a program for congestion control using leaky bucket algorithm.
5.	Implementation of stop and wait protocol and sliding window protocol.
6.	For the given data, use CRC-CCITT polynomial to obtain CRC code. Verify the program for the cases i) With error ii) Without error

Course outcome (Course Skill Set)

At the end of the course the student will be able to:
CO1: Define basic concepts of data communication and its importance.
CO2: Explain the various internet working devices involved in industrial networks
CO3: Apply the various serial communication used in process industries.
CO4: Illustrate, compare and explain the working of HART and Field bus used in process digital communication.
CO5: summarize the operation of MODBUS, PROFIBUS protocol and its applications.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of the IPCC (maximum marks 50)

1. IPCC means practical portion integrated with the theory of the course.
2. CIE marks for the theory component are 25 marks and that for the practical component is 25 marks.
3. 25 marks for the theory component are split into 15 marks for two Internal Assessment Tests (Two Tests each of 15

Marks with 01-hour duration, are to be conducted) and 10 marks for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.

4. Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory Component of IPCC (that is for 25 marks).
5. The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

CIE for the practical component of the IPCC

1. 15 marks for the conduction of the experiment and preparation of laboratory record, and 10 marks for the test to be conducted after the completion of all the laboratory sessions.
2. On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.
3. The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments write-ups are added and scaled down to 15 marks.
4. The laboratory test (duration 02/03 hours) after completion of all the experiments shall be conducted for 50 marks and scaled down to 10 marks.
5. Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for 25 marks.
6. The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

SEE for IPCC Semester-End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (duration 03 hours).

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), should have a mix of topics under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to 50 Marks.

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component.

Suggested Learning Resources:

TEXTBOOKS:

1. Steve Mackay, Edwin Wright, Deon Reynders and John Park, ―Practical Industrial Data Networks: Design, Installation and Troubleshooting, Newnes (Elsevier), 2004.
2. Dominique Paret, ―Multiplexed Networks for Embedded Systems‖, John Wiley & Sons, 2007.

REFERENCES:

1. Richard Zurawski, ―The Industrial Communication Technology Handbook‖, Taylor and Francis, 2005.
2. Deon Reynders and Edwin Wright, ―Practical TCP/IP and Ethernet Networking‖, IDC Technologies, 2006.
3. James Powell, Henry Vandelinde, ―Catching the Process Fieldbus an Introduction to PROFIBUS for Process Automation", Momentum Press, 2013.
4. Albert Lozano-Nieto, ―RFID Design Fundamentals and Applications‖, CRC Press, 2011

Web links and Video Lectures (e-Resources):

- Digital Protocols - Process Control https://www.coursera.org/lecture/sensor-manufacturing-process-control/6-digital-protocols-MaSd4
- Introduction to Industry 4.0 and Industrial Internet of Things https://onlinecourses.nptel.ac.in/noc20_cs24/preview

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to the industries/ reputed universities or colleges to explore the applications of networking.

INDUSTRY 4.0 and INDUSTRIAL IOT		Semester	VII
Course Code	BRA702	CIE Marks	50
Teaching Hours/Week (L:T:P:S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory+8-10 hours Lab	Total Marks	100
Credits	04	Exam Hours	03

Course Objectives

The course will enable the students to:

- Understand the core concepts and technologies of Industry 4.0 and IIoT.
- Learn about smart sensors, communication protocols, and data analytics.
- Develop practical skills in implementing IIoT solutions.
- Explore the impact of Industry 4.0 on industrial operations and management.

Teaching-Learning Process(General Instructions)

These are sample strategies, which teacher scan use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students analytical skills and develops thinking skills such as evaluating, generalizing,and analysing information.
6. Conduct Laboratory Demonstrations and Practical Experiments to enhance experiential skills

Module-1

INTRODUCTION TO INDUSTRY 4.0 AND IIOT

INDUSTRY 4.0: Overview, Evolution from previous industrial revolutions.Key technologies and principles, Industry 4.0 functions, applications and benefits,Components of Industry 4.0.

INDUSTRIAL IOT (IIOT): Definition and components,Role of IIoT in Industry 4.0,Concepts and applications of Industry 4.0 implementations, Future of Automated Factory.

Module-2

IIOT ARCHITECTURE

IoT architectures and standards,IoT Open source architecture (OIC)- OIC Architecture & Design principles- IoT Devices and deployment models, An Open source IoT stack , IoTivity stack architecture,Resource model and Abstraction, IoT and Big Data,Web of Things versus Internet of Things,Two Pillars of the Web Architecture Standardization for WoT Platform Middleware for WoT Unified Multitier WoT Architecture.

Module-3

IIOT TECHNOLOGIES AND COMMUNICATION PROTOCOLS

IoT Devices and Sensors,Types of sensors and actuators,Data acquisition and processing Communication Protocols,MQTT, CoAP, and HTTP,Wireless technologies ,Wi-Fi, Bluetooth, LoRa WAN,Networking in IIoT, Protocol Standardization for IoT ,M2M and WSN Protocols,SCADA and RFID Protocols,Issues with IoT Standardization,Unified Data Standards,Protocols-IEEE802.15.4, BACNet Protocol, Modbus, KNX, Zigbee,Network layer ,APS layer ,Security.

Module-4

DATA ANALYTICS,MACHINE LEARNING IN IIOT AND CYBERSECURITY IN INDUSTRY 4.0

Data Analytics:Data collection and storage,Big Data technologies and tools

Machine Learning:Introduction to machine learning techniques,Applications of machine learning in industrial contexts

Cybersecurity Fundamentals:Basic principles of cybersecurity,Common threats and vulnerabilities

Industrial Cybersecurity,Securing industrial networks and systems,Compliance and standards, Security Protocols and Practices,Encryption, authentication, and access control,Incident response and recovery.

Module-5

APPLICATIONS AND IMPLEMENTATION OF INDUSTRIAL IOT

IoT applications for industry,Future Factory Concepts, Brownfield IoT, Smart Objects, Smart Applications,Study of existing IoT platforms/middleware, Implementation of IIoT Solutions,Design and integration of IIoT systems and prototypes.

PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	Setting up and configuring IoT sensors and devices
2	Implementing basic communication protocols (MQTT, HTTP)
3	Analyzing data from IIoT systems using analytics tools
4	Developing a simple predictive maintenance model
5	Securing an IIoT network and analyzing potential vulnerabilities
6	Design and integration of IIoT systems and prototypes

Course Outcomes (COs)

At the end of the course,the student will be able to:

CO1: Understand the core concepts and technologies of Industry 4.0 and Industrial IoT, including smart manufacturing, IoT devices, and communication protocols.

CO2: Explain the IoT communication protocols and integrate various IoT devices into a functional system for data collection and remote monitoring.

CO3: Analyze data from IIoT systems to derive actionable insights and evaluate the performance of predictive maintenance models in real-world scenarios.

CO4: Evaluate the cybersecurity measures implemented in an IIoT system and reflect on their effectiveness in safeguarding against potential threats and vulnerabilities

CO5: Design and develop an end-to-end IIoT solution, including system architecture, data processing, and integration with cloud platforms, to address a specific industrial application.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of the IPCC(Maximum marks 50)

- IPCC means practical portion integrated with the theory of the course.
- CIE marks for the theory component are **25marks** and that for the practical component is **25marks**.
- 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests,each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2.The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.
- Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

CIE for the practical component of the IPCC

- **15 marks** for the conduction of the experiment and preparation of laboratory record,and**10 marks** for the test to be conducted after the completion of all the laboratory sessions.
- On completion of every experiment/program in the laboratory,the students shall be evaluated including viva-voce and marks shall be awarded on the same day.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments write-ups are added and scaled down to**15 marks**.
- The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be conducted for 50 marks and scaled down to**10 marks.**
- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable,with common question papers for the course(**duration03hours**)

1. The question paper will have ten questions. Each question is set for 20 marks.

2. There will be 2 questions from each module.Each of the two questions under a module(with a maximum of 3 sub-questions),should have a mix of topics under that module.
3. The students have to answer 5 full questions,selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to50 Marks

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component.

Suggested Learning Resources

Text Books

1. "Industry 4.0: The Industrial Internet of Things" by Alasdair Gilchrist, 2016, Apress Publisher.
2. "Internet of Things: Principles and Paradigms" by Rajkumar Buyya et al., 2016, Elsevier publisher.
3. "Introduction to Industry 4.0: Concepts, Technologies, and Applications" by S. A. K. Narayana, 2023, CRC Press.

Reference Books

1. "Practical Guide to Industry 4.0: Transforming Manufacturing with IoT" by S. P. Sinha, 2018, Springer publisher.
2. "Cybersecurity for Industry 4.0: Securing the Digital Transformation" by A. N. Mehta, 2017, published by Springer.

Web links and Video lectures (e-resources)

- NOC:Design for internet of things, IISc Bangalore - NPTEL **https://nptel.ac.in/courses/108108098**
- Introduction To Industry 4.0 and Industrial Internet of things **https://onlinecourses.nptel.ac.in/noc22_cs52/preview**
- MOOC Practical Internet of Things(IoT) **https://www.youtube.com/watch?v=LdHdVBNBAJQ**
- **https://www.youtube.com/playlist?list=PL8bSwVy8_IcO1kFUjq-9rU12u2JYU0u3**

Activity based learning/practical based learning

- Learn how to set up and integrate various IoT sensors and actuators.
- Practical skills in data pre-processing and local analytics.
- Practical experience in system design and integration and manage IIoT solutions.
- Insight into real-world applications of Industry 4.0 and ability to analyze and communicate complex case study findings.

PLC & SCADA		Semester	VII
Course Code	**BRA703**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 8-10 Lab slots	Total Marks	100
Credits	04	Exam Hours	3 Hours
Examination nature (SEE)	Theory + Practical		

Course objectives:
This course will enable students to:

- To Understand the Fundamentals of Programmable Logic Controllers (PLCs)
- To Develop Skills in PLC Hardware Configuration and Troubleshooting
- To Master PLC Programming Techniques
- To Apply PLC Programming to Real-World Control Systems
- To Integrate Advanced PLC Functions in Automation Systems

Teaching-Learning Process (General Instructions)
These are sample Strategies; that teachers can use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through Power Point presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Flipped classroom teaching method.
4. Collaborative (Group) learning in the class.
5. Problem Based Learning (PBL), which fosters students' analytical skills and develops thinking skills such as evaluating, generalizing, and analysing information.

MODULE-1

Programmable Logic Controllers:
Introduction, Parts of a PLC, Principles of Operation, Modifying the Operation, PLCs versus Computers, PLC Size and Application.

PLC Hardware Components:
The I/O Section, Discrete I/O Modules, Analog I/O Modules, Special I/O Modules, I/O Specifications, The Central Processing Unit (CPU), Memory Design, Memory Types, Programming Terminal Devices, Recording and Retrieving Data, Human Machine Interfaces (HMIs).

Basics of PLC Programming:
Processor Memory Organization, Program Scan, PLC Programming Languages, Relay-Type Instructions, Instruction Addressing, Branch Instructions, Internal Relay Instructions, Programming Examine If Closed and Examine If Open Instructions, Entering the Ladder Diagram, Modes of Operation.

MODULE-2

Developing Fundamental PLC Wiring Diagrams and Ladder Logic Programs:
Electromagnetic Control Relays, Contactors, Motor Starters, Manually Operated Switches, Mechanically Operated Switches, Sensors, Output Control Devices, Seal-In Circuits, Latching Relays, Converting Relay Schematics into PLC Ladder Programs, Writing a Ladder Logic Program Directly from a Narrative Description.

Programming Timers:
Mechanical Timing Relays, Timer Instructions, On-Delay Timer Instruction, Off-Delay Timer Instruction, Retentive Timer, Cascading Timers.

MODULE-3

Programming Counters:
Counter Instructions, Up-Counter, Down-Counter, Cascading Counters, Incremental Encoder-Counter Applications, Combining Counter and Timer Functions.

Program Control Instructions:
Master Control Reset Instruction, Jump Instruction, Subroutine Functions, Immediate Input and Immediate Output Instructions, Forcing External I/O Addresses, Safety Circuitry, Selectable Timed Interrupt, Fault Routine, Temporary End Instruction, Suspend Instruction.

MODULE-4

Data Manipulation Instructions:
Data Manipulation, Data Transfer Operations, Data Compare Instructions, Data Manipulation Programs, Numerical Data I/O Interfaces, Closed-Loop Control.
Math Instructions:
Math Instructions, Addition Instruction, Subtraction Instruction, Multiplication Instruction, Division Instruction, Other Word-Level Math Instructions, File Arithmetic Operations.

MODULE-5

Sequencer and Shift Register Instructions:
Mechanical Sequencers, Sequencer Instructions, Sequencer Programs, Bit Shift Registers, Word Shift Operations.
Process Control, Network Systems, and SCADA:
Types of Processes, Structure of Control Systems, On/Off Control, PID Control, Motion Control, Data Communications, Supervisory Control and Data Acquisition (SCADA).

PRACTICAL COMPONENT OF IPCC *(May cover all / major modules)*
Modern computing tools are preferred to be used for analysis wherever possible.

Sl.NO	Experiments
1	Develop the logical instructions involved in Development of programmable logic controller for various operations.
2	Construct the Ladder Logic for various operation using PLC and SCADA for industrial Environment.
3	Design the SCADA System for industrial Environment.
4	Study of various logic Execution in ladder diagram.
5	Interfacing of Lamp & button with PLC for ON&OFF Operation. Verify all logic gates.
6	PLC based thermal ON/OFF Controller.
7	Develop ladder logic to develop MUX and DE-MUX.
8	Combination of counter &timer for lamp ON/OFF Operation.
9	Study& implement ON & OFF delay timer in PLC
10	To study & implement of counter in PLC programming. counter-up & counter-down.
11	PLC based temperature sensing using RTD.
12	Parameter reading of PLC in SCADA, Temperature sensing using SCADA.

Course outcomes (Course Skill Set):
At the end of the course, the student will be able to:
CO1: Discuss history of PLC and describe the hardware components of PLC: I/O modules, CPU, memory devices, other support devices, operating modes and PLC programming.
CO2: Describe field devices Relays, Contactors, Motor Starters, Switches, Sensors, Output Control Devices, Seal-In Circuits, and Latching Relays commonly used with I/O module.
CO3: Analyse PLC timer and counter ladder logic programs and describe the operation of different program control instructions
CO4: Discuss the execution of data transfer instructions, data compare instructions and the basic operation of PLC closed-loop control system.
CO5: Describe the operation of mechanical sequencers, bit and word shift registers, processes and structure of control systems and communication between the processes.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). The student is declared as a pass in the course if he/she secures a minimum of 40% (40 marks out of 100) in the total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

The IPCC means the practical portion integrated with the theory of the course. CIE marks for the theory component are **25 marks** and that for the practical component is **25 marks**.

CIE for the theory component of the IPCC

- 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests, each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.
- Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

CIE for the practical component of the IPCC

- **15 marks** for the conduction of the experiment and preparation of laboratory record, and **10 marks** for the test to be conducted after the completion of all the laboratory sessions.
- On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to **15 marks**.
- The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be conducted for 50 marks and scaled down to **10 marks.**
- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours**)

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to 50 Marks

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component.

- The minimum marks to be secured in CIE to appear for SEE shall be 10 (40% of maximum marks-25) in the theory component and 10 (40% of maximum marks -25) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included. The maximum of 04/05 sub-questions are to be set from the practical component of IPCC, the total marks of all questions should not be more than 20 marks.

- SEE will be conducted for 100 marks and students shall secure 35% of the maximum marks to qualify for the SEE. Marks secured will be scaled down to 50.
- The student is declared as a pass in the course if he/she secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Suggested Learning Resources:

Text Book

1. Programmable Logic Controllers Frank D Petruzella McGraw Hill, 4th Edition, 2011

Reference Books:

1. Programmable Logic Controllers an Engineer's Guide E A Parr Newnes 3rd Edition, 2013.
2. Introduction Programmable Logic Controllers Gary Dunning Cengage 3rd Edition, 2006

Web links and Video Lectures (e-Resources):

- https://www.eit.edu.au/courses/professional-certificate-of-competency-programmable-logic-controllers-plcs-scada-systems/
- https://instrumentationtools.com/learn-programmable-logic-controller-plc/

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- To identify and label the different parts of a physical PLC system, including I/O modules, cpus, and memory components.
- Practice wiring a basic PLC system, connecting input devices (e.g., sensors) and output devices (e.g., motors), and ensuring proper communication with the CPU.
- Using a PLC simulator or physical plc's, design and implement ladder logic programs to control a simple system, such as a motor starter circuit or a light control system.
- Program a PLC to count items on a conveyor belt using sensors and create a system that triggers an action (like stopping the belt) after a certain count is reached.
- PLC to perform mathematical operations (e.g., calculating the total weight of items on a conveyor) and output the result to an HMI.
- Configure a small-scale SCADA system using PLCs and HMI software.

Smart Sensors		Semester	VII
Course Code	BRA714A	CIE Marks	50
Teaching Hours/Week(L:T:P:S)	3-0-0-0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Objectives

The course will enable the students to:

- To introduce the fundamentals of sensors and their role in smart systems.
- To explore the principles, types, and applications of smart sensors in modern technology.
- To analyze the integration of sensors with communication protocols and IoT systems.
- To understand signal conditioning, data processing, and calibration techniques for smart sensors.
- To provide practical knowledge of designing and implementing smart sensor-based systems for real world applications.

Teaching-Learning Process(General Instructions)

These are sample strategies, which teacher scan use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students analytical skills and develops thinking skills such as evaluating, generalizing,and analysing information.

Module-1

Fundamentals of Sensors and Smart Sensors:Introduction to sensors: Basic concepts, types, and working principles. Definition and characteristics of smart sensors. Differences between conventional and smart sensors. Signal transduction mechanisms: Resistive, capacitive, inductive, and optical. Applications of smart sensors in robotics, healthcare, and IoT.

Teaching-Learning Process	1. Power-point Presentation, 2. Video demonstration or Simulations, 3. Chalk and Talk are used for Problem Solving/ Whiteboard

Module-2

Signal Conditioning and Data Acquisition: Signal conditioning circuits: Amplifiers, filters, and analog-to-digital conversion,Noise reduction and signal amplification techniques. Calibration and linearization of sensor outputs. Data acquisition systems and their components. Interfacing sensors with microcontrollers and processors

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Module-3

Smart Sensor Technologies and Architectures: Microelectromechanical systems (MEMS) and Nanoelectromechanical systems (NEMS). Self-calibrating and self-diagnosing sensors. Sensor fusion and integration, Wireless sensor networks and power management. Advanced materials for smart sensors: Piezoelectric, nanomaterials, and polymers

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-4

Communication Protocols and IoT Integration: Communication protocols: I2C, SPI, UART, and CAN. Wireless communication: Zigbee, Bluetooth, LoRa, and Wi-Fi. IoT architecture and role of smart sensors in IoT systems. Edge computing and cloud integration. Real-time data monitoring and analytics

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-5

Applications, Challenges, and Future Trends: Applications in robotics, automotive systems, healthcare, and agriculture. Environmental monitoring and smart cities. Ethical considerations and challenges in smart sensor implementation. Emerging trends: AI and machine learning in sensor systems. Case studies on innovative smart sensor solutions

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Course Outcomes (COs)

At the end of the course the student will be able to:

CO1: Explain the working principles and characteristics of smart sensors.
CO2: Evaluate sensor selection criteria for specific applications.
CO3: Integrate smart sensors with IoT and communication protocols.
CO4: Design signal conditioning and data processing circuits for smart sensor systems.
CO5: Develop practical smart sensor applications in fields like robotics, healthcare, and environmental monitoring.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50)in the semester-end examination(SEE),and a minimum of 40% (40 marks out of 100)in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous Internal Evaluation:

Three Unit Tests each of 20 Marks(duration 01 hour)

1. First test at the end of 5th week of the semester
2. Second test at the end of the 10th week of the semester
3. Third test at the end of the 15th week of the semester

Two assignments each of 10 Marks

4. First assignment at the end of 4th week of the semester
5. Second assignment at the end of 9th week of the semester

Group discussion/Seminar/quiz any one of three suitably planned to attain the COs and POs for 20 Marks (duration 01hours)

6. At the end of the13th week of the semester

The sum of three tests, two assignments,and quiz/seminar/group discussion will be out of 100 marks and will be Scaled down to 50 Marks

(To have less stressed CIE, the portion of the syllabus should not be common/repeated for any of the methods of the CIE.Each method of CIE should have a different syllabus portion of the course).

CIE methods/question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (duration 03 hours)

7. The question paper will have ten questions. Each question is set for20 marks.
8. There will be2 questions from each module.Each of the two questions under a module (with a maximum of 3 sub-questions), should have a mix of topics under that module.

Suggested Learning Resources

Text Books

1. "Smart Sensors and MEMS" Authors: S. Nihtianov, A. Luque, 2018, Woodhead Publishing ISBN: 9780081020560.
2. "Sensors and Transducers", D. Patranabis, 2003, PHI Learning, ISBN: 9788120311560

Reference Books

1. "Introduction to Smart Sensors", Joseph Watson and Andrew Mason, 2014, Springer, ISBN: 9783030385432.
2. "Internet of Things and Smart Sensors", Arun K. Somani, 2020, Springer, ISBN: 9789811559411

Web links and Video Lectures (e-Resources)

1. IIoT Fundamentals: Smart Sensors & Actuators in Automation, https://www.realpars.com/courses/iiot-sensors-actuators?utm
2. Introduction to Sensors, https://online.stanford.edu/courses/me220-introduction-sensors?utm
3. Concept of Smart Sensors and Their Important Features, https://www.youtube.com/watch?v=aUe1251TxS8&utm
4. Smart Sensors Systems Design (Online Course), https://www.sensorsportal.com/HTML/Sensors_Systems.htm?utm

Activity Based Learning/Practical Based learning

- Visit to the industries/ reputed universities or colleges to explore the applications of networking.

Micro and Nano Robotics		Semester	VII
Course Code	BRA714B	CIE Marks	50
Teaching Hours/Week(L:T:P:S)	3-0-0-0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course objectives

The course will enable the students to:

- To provide an in-depth understanding of the fundamentals of micro and Nano robotics.
- To introduce students to fabrication techniques, control systems, and application areas of micro and Nano robots.
- To analyze the challenges associated with scaling, materials, and sensing at micro and Nano levels.
- To explore real-world applications of micro and Nano robotics in medicine, manufacturing, and environmental monitoring.
- To equip students with the knowledge to design and develop micro and Nano robotic systems.

Teaching-Learning Process(General Instructions)

These are sample strategies, which teacher scan use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students analytical skills and develops thinking skills such as evaluating, generalizing,and analysing information.

Module-1

Introduction to Micro and Nano Robotics: Overview of robotics at micro and Nano scales, Scaling laws and challenges (e.g., surface forces, adhesion). Historical development and milestones. Fundamental principles of micro and Nano robotics. Applications in medicine, manufacturing, and space exploration

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-2

Materials and Fabrication Techniques: Selection of materials (biocompatible materials, polymers, MEMS/NEMS). Fabrication methods: Lithography, self-assembly, and 3D printing. Nanostructuring and functionalization techniques. Case studies: MEMS sensors and actuators

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Module-3

Actuation and Control Mechanisms: Actuation mechanisms: Piezoelectric, electrostatic, magnetic, and thermal. Energy harvesting and power systems at Nano scales. Control strategies: Feedback control, AI-based control systems. Simulation tools for micro and Nano robot control

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-4

Sensing and Communication: Nano sensors and transducers, Communication at micro and Nano scales (optical, electromagnetic, chemical). Imaging techniques: AFM, TEM, SEM, and other Nano-scale imaging tools. Integration of sensing, actuation, and control in Nano robots

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-5

Applications, Challenges, and Future Trends: Biomedical applications: Drug delivery, minimally invasive surgery. Environmental monitoring and remediation. Industrial applications: Nano assembly and precision manufacturing. Ethical, environmental, and societal implications of micro and Nano robotics. Emerging trends and future prospects

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Course Outcomes (COs)

At the end of the course the student will be able to:

CO1: Describe the principles and unique characteristics of micro and Nano robots.

CO2: Analyze fabrication techniques and materials used in building micro and Nano robots.

CO3: Develop control algorithms and techniques for micro and Nano-scale robotics.

CO4: Evaluate the challenges and limitations associated with micro and Nano robotics.

CO5: Propose innovative applications for micro and Nano robots in various industries.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50)in the semester-end examination(SEE),and a minimum of 40% (40 marks out of 100)in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous Internal Evaluation:

Three Unit Tests each of 20 Marks(duration 01 hour)

1. First test at the end of 5th week of the semester
2. Second test at the end of the 10th week of the semester
3. Third test at the end of the 15th week of the semester

Two assignments each of 10 Marks

4. First assignment at the end of 4th week of the semester
5. Second assignment at the end of 9th week of the semester

Group discussion/Seminar/quiz any one of three suitably planned to attain the COs and POs for 20 Marks (duration 01hours)

6. At the end of the13th week of the semester

The sum of three tests, two assignments,and quiz/seminar/group discussion will be out of 100 marks and will be Scaled down to 50 Marks

(To have less stressed CIE, the portion of the syllabus should not be common/repeated for any of the methods of the CIE.Each method of CIE should have a different syllabus portion of the course).

CIE methods/question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (duration 03 hours)

7. The question paper will have ten questions. Each question is set for20 marks.
8. There will be2 questions from each module.Each of the two questions under a module (with a maximum of 3 sub-questions), should have a mix of topics under that module.

The students have to answer 5 full questions, selecting one full question from each module.Marks scored out of 100 shall be reduced proportionally to 50 marks

Suggested Learning Resources

Text Books

1. "Micro and Nano Robotics", Toshio Fukuda and Wenhui Dong, Springer, ISBN: 9783540743124.

2. "Nanorobotics: Current Approaches and Techniques", Constantinos Mavroidis, Antoine Ferreira, Springer, ISBN: 9781441911250

Reference Books

1. "Nanotechnology for Robotics", S. V. Suryanarayana and S. K. Kulkarni, IK International Publishing, ISBN: 9788189866426.
2. "Fundamentals of Micro fabrication and Nanotechnology", Marc Madou, CRC Press, ISBN: 9781439893232

Web links and Video Lectures (e-Resources)

1. "The Robotics Part of Micro and Nano Robotics" by Prof. Bradley Nelson, https://www.youtube.com/watch?v=ec-Y79VYu48&utm
2. "The Robotics Part of Micro and Nano Robots" by Brad Nelson, https://www.youtube.com/watch?v=jO656oFhaoo&utm
3. TED Talk: "Tiny Robots with Giant Potential" by Paul McEuen and Marc Miskin, https://www.ted.com/talks/paul_mceuen_and_marc_miskin_tiny_robots_with_giant_potential?utm

Activity Based Learning/Practical Based learning

- Visit to the industries/ reputed universities or colleges to explore the applications of networking.

Robots for Agriculture Applications		Semester	VII
Course Code	BRA714C	CIE Marks	50
Teaching Hours/Week(L:T:P:S)	3-0-0-0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course objectives

The course will enable the students to:

- Understand Key Concepts in Agricultural Robotics
- Explore the Role of Robotics in Precision Agriculture
- Analyze the Integration of AI and Machine Learning in Agricultural Robotics
- Equip students with practical skills to design, prototype, and implement robotic systems for various agricultural tasks, ensuring the development of efficient and reliable solutions.
- Encourage students to critically evaluate the economic, environmental, and social implications of deploying robots in agriculture

Teaching-Learning Process(General Instructions)

These are sample strategies, which teacher scan use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students analytical skills and develops thinking skills such as evaluating, generalizing,and analysing information.

Module-1

INTRODUCTION TO AGRICULTURAL ROBOTICS

Overview of Agricultural Robotics,History and evolution of robotics in agriculture,Current trends and future directions,Types of Agricultural Robots,Harvesting robots,Planting robots,Weeding and pest control robots,Applications and Benefits,Enhancing productivity and efficiency,Reducing labor costs and environmental impact.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-2

ROBOTIC SYSTEMS AND COMPONENTS FOR AGRICULTURE

Robotic Platforms:Types of robotic platforms used in agriculture such as wheeled, tracked, aerial
Sensors and Actuators:Types of sensors,cameras, LIDAR, GPS,and their applications,Actuators used in agricultural robots
Navigation and Control Systems:Techniques for autonomous navigation,Control systems for precision agriculture

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Module-3

VISION AND PERCEPTION IN AGRICULTURAL ROBOTICS

Computer Vision Techniques,Image processing and analysis for crop monitoring,Object detection and recognition, Machine Learning in Agriculture,Training models for plant disease detection and classification, Data-driven approaches for precision farming ,Case studies for implementations of vision-based systems in agriculture.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-4

INTEGRATION AND AUTOMATION IN AGRICULTURAL PROCESSES

System Integration,Integrating robots with existing agricultural machinery and systems,Automation in Farming,Automated planting, irrigation, and harvesting systems,Challenges and Solutions,Addressing environmental and operational challenges,Innovations and technological advancements in agricultural automation.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-5

PRACTICAL APPLICATIONS AND CASE STUDIES
Real-World Applications, Case studies of agricultural robots in action,Analysis of performance and impact,Design and simulation of an agricultural robotic system.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Course outcome (Cos)

At the end of the course the student will be able to:

CO1: Understand the fundamental components and working principles of agricultural robots, including sensors, actuators, and control systems.

CO2: Explain the application of robotic technologies in various agricultural operations, such as planting, monitoring, and harvesting.

CO3: Describe basic robotic systems to solve specific agricultural challenges, demonstrating their ability to relate engineering principles in real-world scenarios.

CO4: Evaluate the performance and efficiency of different robotic systems used in precision agriculture,considering factors like productivity, energy consumption, and cost-effectiveness.

CO5: Design innovative robotic solutions for emerging agricultural needs, integrating advanced technologies to enhance functionality and autonomy.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50)in the semester-end examination(SEE),and a minimum of 40% (40 marks out of 100)in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous Internal Evaluation:

Three Unit Tests each of 20 Marks(duration 01 hour)

1. First test at the end of 5th week of the semester
2. Second test at the end of the 10th week of the semester
3. Third test at the end of the 15th week of the semester

Two assignments each of 10 Marks

4. First assignment at the end of 4th week of the semester
5. Second assignment at the end of 9th week of the semester

Group discussion/Seminar/quiz any one of three suitably planned to attain the Cos and Pos for 20 Marks (duration 01hours)

6. At the end of the13th week of the semester

The sum of three tests, two assignments,and quiz/seminar/group discussion will be out of 100 marks and will be Scaled down to 50 Marks

(To have less stressed CIE, the portion of the syllabus should not be common/repeated for any of the methods of the CIE.Each method of CIE should have a different syllabus portion of the course).

CIE methods/question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (duration 03 hours)

7. The question paper will have ten questions. Each question is set for20 marks.
8. There will be2 questions from each module.Each of the two questions under a module (with a maximum of 3 sub-questions), should have a mix of topics under that module.

The students have to answer 5 full questions, selecting one full question from each module.Marks scored out of 100 shall be reduced proportionally to 50 marks

Suggested Learning Resources

Text Books

1. "Robotics in Agriculture and Forestry" by M. J. Fischer, S. M. Z. Hasan, 2016, Springer Publisher.
2. "Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms" by Nikolaus Correll et al., 2022, MIT Press.

Reference Books

1. "Robotic Systems for Agriculture: Design and Implementation" by V. R. Sharma, 2018, Published CRC Press.
2. "Machine Learning for Agricultural Robotics" by S. P. Sharma, 2023, CRC Press.
3. "Agricultural Automation: Technologies and Applications" by P. R. Kumar, 2024, CRC Press.
4. "Case Studies in Agricultural Robotics: Successes and Lessons Learned" by M. K. Gupta, 2022, Springer.

Web links and Video Lectures (e-Resources)

- Autonomous Robots Lab provides lecture slides, video explanations, and resources focused on designing and applying robots, including their applications in agricultural contexts-**Autonomous Robots Lab**
- Emerj Artificial Intelligence Research offers a deep dive into current and emerging applications of agricultural robots, including videos on robots for tasks such as crop harvesting and planting-**Emerj Artificial Intelligence Research**

Activity Based Learning/Practical Based learning

- Setting up a mock agricultural field, and students program autonomous robots to navigate through it while avoiding obstacles, simulating real-world challenges like crop rows, uneven terrain, and obstacles.
- Equipping a robotic platform with various sensor and deploy it in a controlled environment.
- Design and program a robotic arm to simulate harvesting tasks such as picking fruits or vegetables.
- Use a drone equipped with cameras and spraying mechanisms to monitor crop health and perform targeted spraying of pesticides or fertilizers

INTRODUCTION TO MOBILE ROBOTS		Semester	VII
Course Code	BRA714D	CIE Marks	50
Teaching Hours/Week(L:T:P:S)	3-0-0-0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course objectives

The course will enable the students to:

- Provide knowledge on the application of mobile robotics
- Understand the fundamentals of mobile robotics and their components.
- Learn the design and control strategies for mobile robots.
- Develop skills in programming and simulation of mobile robotic systems.
- Apply knowledge to real-world scenarios and projects.

Teaching-Learning Process(General Instructions)

These are sample strategies, which teacher scan use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk andTalk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students analytical skills and develops thinking skills such as evaluating, generalizing,and analysing information.

Module-1

INTRODUCTION TO MOBILE ROBOTICS

Overview of Mobile Robotics,Definition and classification of mobile robots,Historical development and current trends Types of Mobile Robots,Wheeled, tracked, and legged robots,Autonomous vehicles, remote-controlled robots, Applications in Industrial, medical, exploration, and service robots.

Teaching-Learning Process	Power-pointPresentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-2

KINEMATICS AND DYNAMICS OF MOBILE ROBOTS

Kinematics, Forward and inverse kinematics, Differential drive and omni-wheeled robots Dynamics,Forces and torques,Motion planning and control, Path Planning,Trajectory planning and obstacle avoidance.

Teaching-Learning Process	Power-pointPresentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Module-3

SENSORS AND PERCEPTION

Types of Sensors,Range sensors ,LIDAR, sonar, IR,Vision sensors ,cameras, computer vision techniques, Sensor Fusion,Combining data from multiple sensors Environmental Perception,Mapping and localization techniques ,SLAM, Implementing basic SLAM algorithms.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-4

CONTROL SYSTEMS FOR MOBILE ROBOTS

Control Architectures,Reactive, deliberative, and hybrid control,Control Algorithms,PID control, State-space control, and adaptive control,Simulation and Implementation,Using simulation software tools like MATLAB or ROS to model and control mobile robots.

Teaching-Learning Process	Power-point Presentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/ Whiteboard

Module-5

INTEGRATION AND ARCHITECTURE.

System Integration with Combining sensors, actuators, and control systems, Real-world Applications, Design and implementation of a mobile robot for a specific application,Performance of mobile robots controlled through the web–System Description–Software,Case studies of mobile robots in various industries.

Teaching-Learning Process	Power-pointPresentation, Video demonstration or Simulations, Chalk and Talk are used for Problem Solving/Whiteboard

Course outcome (Cos)

At the end of the course the student will be able to:

CO 1: Describe the fundamental principles and types of mobile robots, including their components and applications

CO 2: Explain the kinematic and dynamic models to analyze and solve problems related to the movement and control of mobile robots.

CO 3: Evaluate the performance of different sensor systems and their integration in mobile robots for environmental perception and navigation

CO 4: Assess the performance of a mobile robot system through simulation and experimentation, and reflect on the results to propose improvements.

CO 5:Design and implement control algorithms for mobile robots, including PID control and other control strategies, to achieve desired behaviors and performance

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50)in the semester-end examination(SEE),and a minimum of 40% (40 marks out of 100)in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous Internal Evaluation:

Three Unit Tests each of 20 Marks(duration 01 hour)

1. First test at the end of 5^{th} week of the semester
2. Second test at the end of the 10^{th} week of the semester
3. Third test at the end of the 15^{th} week of the semester

Two assignments each of 10 Marks

4. First assignment at the end of 4^{th} week of the semester
5. Second assignment at the end of 9^{th} week of the semester

Group discussion/Seminar/quiz any one of three suitably planned to attain the COs and POs for 20 Marks (duration 01hours)

6. At the end of the13th week of the semester

The sum of three tests, two assignments,and quiz/seminar/group discussion will be out of 100 marks and will be Scaled down to 50 Marks

(To have less stressed CIE, the portion of the syllabus should not be common/repeated for any of the methods of the CIE.Each method of CIE should have a different syllabus portion of the course).

CIE methods/question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (duration 03 hours)

7. The question paper will have ten questions. Each question is set for20 marks.
8. There will be2 questions from each module.Each of the two questions under a module (with a maximum of 3 sub-questions), should have a mix of topics under that module.

The students have to answer 5 full questions, selecting one full question from each module.Marks scored out of 100 shall be reduced proportionally to 50 marks

Suggested Learning Resources

Text Books

1. "Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms" by Nikolaus Correll et al., 2022, MIT Press.
2. "Robotics: Modelling, Planning and Control" by Bruno Siciliano et al., 2009, Springer.
3. "Mobile Robotics: Technology and Applications" by D. K. Pratihar, 2007 by Alpha Science International Ltd.

Reference Books
1. "Probabilistic Robotics" by Sebastian Thrun et al., published by MIT Press on August 19, 2005, ISBN: 9780262201629 2. "Robotics: Principles and Practice" by S.K. Saha, McGraw Hill Education (India) Private Limited, 2014, ISBN: 978-93-3290-280-0.
Web links and Video Lectures (e-Resources)
• Control of Multiple Robots-AdvancedTopics **https://www.coursera.org/lecture/robotics-flight/control-of-multiple-robots-sLAoY** • MIT Open Courseware: Principles of Autonomy and Robotics
Activity Based Learning /Practical Based learning • Hands-on activity: Exploring a basic mobile robot kit • Simulation of kinematics using software tools • Hands-on with different sensors and integration • Designing and implementing control systems for a mobile robot • Design and implementation of a mobile robot for a specific application

ROS and Robot Programming		Semester	VII
Course Code	BRA755A	CIE Marks	50
Teaching Hours/Week (L: T:P: S)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03
Examination nature (SEE)	Theory		

Course objectives:

- Understand the fundamental architecture, structure, and components of the Robot Operating System (ROS) and its applications in robotics.
- Gain hands-on experience in creating, managing, and deploying ROS packages, including custom messages, services, and actions.
- Explore robot programming concepts, including robot modeling and simulation, using ROS-supported tools like RViz, Gazebo, and URDF.
- Develop skills in debugging, visualizing, and maintaining ROS projects using community-supported tools and best practices.
- Learn the principles and applications of ROS-Industrial, including its benefits, history, and advanced configurations for industrial robots.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teachers can use to accelerate the attainment of the various course outcomes.

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Flipped classroom teaching method.
4. Collaborative (Group) learning in the class.
5. Problem Based Learning (PBL), which fosters students' analytical skills and develops thinking skills such as evaluating, generalizing, and analysing information.

Module-1

Introduction to ROS, ROS file system, ROS Packages, ROS Meta Packages, ROS Services, ROS Nodes, ROS Messages, ROS Topics, ROS bags, ROS Master, ROS Parameter, ROS community level.

Module-2

Creating a ROS package, Working with ROS topics, Creating ROS nodes, Building the nodes, adding custom msg and srv files, Working with ROS services, Working with ROS actionlib, Creating the ROS action server, Creating the ROS action client, Building the ROS action server and client, creating launch files, Applications of topics, services, and actionlib, Maintaining the ROS package, Releasing ROS package

Module-3

Introduction to Robot Programming, ROS equation, History of ROS, Robots and Sensor support for ROS, ROS Architecture, ROS File System.
ROS packages for robot modeling, robot modeling using URDF, ROS package for the robot description

Module-4

Visualization tools: RViz, rqt_graph, rqt_plot, Simulation tools: Gazebo, Stage, Debugging tools: rqt_console, rqt_logger_level, Package creation and structure, Dependency management with rospack and rosdep

Module-5

ROS-Industrial packages, Goals of ROS-Industrial, ROS-Industrial – a brief history, Benefits of ROS-Industrial, Installing ROS-Industrial packages, Block diagram of ROS-Industrial packages, creating a URDF for an industrial robot, Creating, Updating and Testing the MoveIt! configuration

Course outcome (Course Skill Set)

At the end of the course, the student will be able to :

CO1: Demonstrate proficiency in using ROS fundamentals such as nodes, topics, services, messages, and the ROS File system for robotics development.

CO2: Design and build ROS packages, including creating and deploying custom message types, services, and action servers/clients.

CO3: Apply robot programming concepts to model robots and simulate their behavior in virtual environments using ROS tools.

CO4: Debug and optimize ROS-based applications using visualization and debugging tools like RViz, rqt, and Gazebo.

CO5: Implement ROS-Industrial packages to design and configure industrial robots, showcasing the ability to integrate MoveIt! and URDF for advanced robotic tasks.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours).**

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

Suggested Learning Resources:

Text Books

1. Lentin Joseph, "Mastering ROS for Robotics Programming", Packt Publishing, 2015.
2. Studies in Computational Intelligence, 1051, Anis Koubaa - Robot Operating System (ROS) The Complete Reference 7 (2023, Springer)

Reference Books

1. Lentin Joseph, Aleena Johny - Robot Operating System (ROS) for Absolute Beginners_ Robotics Programming Made Easy (2022, Apress)
2. Lentin Joseph_ Jonathan Cacace - Mastering ROS for Robotics Programming - Second Edition_ Design, build,

and simulate complex robots using the Robot Operating Sy (2018, Packt Publishing)

Web links and Video Lectures (e-Resources):

- https://www.udemy.com/topic/robot-operating-system/?p=3&utm_source=adwords&utm_medium=udemyads&utm_campaign=Search_DSA_GammaCatchall_NonP_la.EN_cc.India&campaigntype=Search&portfolio=India&language=EN&product=Course&test=&audience=DSA&topic=&priority=Gamma&utm_content=deal4584&utm_term=_._ag_166578677881_._ad_700948726517_._kw__._de_c_._dm__._pl__._ti_dsa-1456167871416_._li_1007768_._pd__._&matchtype=&gad_source=1&gclid=CjwKCAiArva5BhBiEiwA-oTnXXqoIyFKoelwoasdmOpz2kPAc4SklQRneqldrWA7Kq7yOkypp5kf7xoCXBsQAvD_BwE
- https://www.udemy.com/course/ros-basics-program-robots/?srsltid=AfmBOoo5jAkzESV_pQN1RwabVrAytpGe8d0j44ZzYkLe7Q4t824vbpv7
- https://rsl.ethz.ch/education-students/lectures/ros.html

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to the industries/ reputed universities or colleges to explore the applications of networking.
- Mini project / model based analysis

Microcontroller for Robots		Semester	VII
Course Code	BRA755B	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03
Examination nature (SEE)	Theory		

Course objectives:

- Understand the architecture and programming of ARM Cortex-M Microcontroller microcontrollers.
- Develop proficiency in embedded systems programming using C.
- Interface sensors and actuators with microcontrollers for robotics applications.
- Apply hands-on skills in building and programming robotic systems.

Pedagogy (General Instructions)

These are sample Strategies; which teacher can use to accelerate the attainment of the various course outcomes.

1. Lecturer method (L) does not mean only traditional lecture method, but different type of teaching methods may be adopted to develop the outcomes.
2. Arrange visits to nearby power plants, receiving station and substations to give brief information about the electrical power generation.
3. Show Video/animation films to explain functioning of various machines
4. Encourage collaborative (Group Learning) Learning in the class
5. Ask at least three HOTS (Higher order Thinking) questions in the class, which promotes critical thinking
6. Adopt Problem Based Learning (PBL), which fosters student's Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information rather than simply recall it.
7. Topics will be introduced in a multiple representation.
8. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them.
9. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.
10. Individual teacher can device the innovative pedagogy to improve the teaching-learning.

Module-1

Introduction to Microcontrollers and Robotics

Overview of Microcontrollers in Robotics: Basics, applications, and comparison with microprocessors.

Microcontroller Architecture: Common architectures (ARM etc.).

Embedded Systems and RTOS: Basics of embedded systems, introduction to real-time operating systems.

Text Book.1

Module-2

C Programming Basics for Embedded Systems: Data types, control structures, and functions.

Low-Level Programming: Direct hardware access, interrupts, and timers.

Memory Management in Embedded Systems: Static and dynamic memory allocation.

Hands-on Labs: Writing and debugging C programs for embedded systems tasks (e.g., interrupt handling, timer-based tasks). Text Book.2

Module-3

Introduction to Sensors: Overview of different types of sensors (e.g., temperature, ultrasonic, light).

Sensor Interfacing: Techniques for connecting sensors to microcontrollers.

Data Acquisition and Processing: Reading and interpreting sensor data.

Hands-on Labs: Building sensor-based applications (e.g., temperature monitoring, proximity detection).

Text Book.3

Module-4

Introduction to Actuators: Types of actuators (e.g., DC motors, servos, stepper motors).

Motor Control Techniques: PWM, H-bridge, and motor drivers.

Building Simple Robots: Designing and assembling basic robotic systems.

Hands-on Labs: Motor control for simple robotic tasks (e.g., line following, obstacle avoidance). Text Book 4

Module-5

Integrating Sensors and Actuators: Combining sensor input and actuator control for autonomous robot behavior.

Prototyping and Testing: Building and troubleshooting complete robotic systems.

Final Project: Design and implement a fully functional robot, incorporating sensors, actuators, and control logic.

Case Studies: Examples of successful robotic projects and their underlying principles.

Text Book.3,4

Course outcome (Course Skill Set)

At the end of the course, the student will be able to :

CO1: Understand and apply ARM Cortex-M Microcontroller architecture in embedded systems.

CO2: Develop and debug embedded C programs for micro controller-based tasks.

CO3: Interface sensors and actuators for real-world applications.

CO4: Design and build functional robotic systems using microcontrollers.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
2. The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
3. Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
4. For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours).**

5. The question paper will have ten questions. Each question is set for 20 marks.
6. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
7. The students have to answer 5 full questions, selecting one full question from each module.
8. Marks scored shall be proportionally reduced to 50 marks

Suggested Learning Resources:

Text Books

1. Embedded Systems: Introduction to Arm® Cortex™-M Microcontrollers" by Jonathan W. Valvano.
2. "Microcontroller and Embedded Systems", Raj Kamal, Tata Mc-Graw Hill Education, ISBN: 9781259006829
3. Make: Sensors: A Hands-On Primer for Monitoring the Real World with Arduino and Raspberry Pi" by Tero Karvinen

Reference Book:

1. "Microcontrollers: Principles and Applications", Ajay V. Deshmukh, Tata McGraw Hill Education. ISBN: 9780070585959.
2. "Fundamentals of Microcontrollers and Applications in Embedded Systems", Ramesh Gaonkar, Penram

International Publishing, ISBN: 9788187972884

Web links and Video Lectures (e-Resources):

- Microcontroller Basics – A Comprehensive Guide for Beginners: https://www.embedded-robotics.com/microcontroller-basics/?utm
- A Beginner's Guide to Microcontrollers - Instructables: https://www.instructables.com/A-Beginners-Guide-to-Microcontrollers/?utm
- Microcontrollers: A Beginner's Guide to Get Started: https://nerdyelectronics.com/microcontrollers-a-beginners-guide-to-get-started/?utm
- How Does a Microcontroller Work in Robotics for Beginners? https://www.youtube.com/watch?v=gfUjyjfL1Lo&utm
- Introduction to Robotics: Introduction to a Microcontroller: https://www.youtube.com/watch?v=8gPg0YmVAnE&utm

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Assignments: Weekly programming and interfacing tasks.
- Labs: Hands-on projects for sensor integration and motor control.
- Mid-Term Project: A mini-project integrating concepts from Modules 1-3.
- Final Project: A comprehensive robot-building project.

Collaborative Robots		Semester	VII
Course Code	BRA755C	CIE Marks	50
Teaching Hours/Week (L: T:P: S)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03
Examination nature (SEE)	Theory		

Course objectives:

- Understand the evolution of collaborative robotics and its impact on modern workplaces.
- Explore the integration of artificial intelligence (AI) in collaborative robotic systems to enhance decision-making and productivity.
- Examine ethical, regulatory, and societal implications of deploying robots in various industries.
- Analyze the interplay between humans and collaborative robots in complex, dynamic environments such as manufacturing, healthcare, and logistics.
- Develop knowledge about the technical foundations of robotics, including sensors, actuators, and data processing systems.

Pedagogy (General Instructions)

These are sample Strategies; which teacher can use to accelerate the attainment of the various course outcomes.

1. Lecturer method (L) does not mean only traditional lecture method, but different type of teaching methods may be adopted to develop the outcomes.
2. Arrange visits to nearby power plants, receiving station and substations to give brief information about the electrical power generation.
3. Show Video/animation films to explain functioning of various machines
4. Encourage collaborative (Group Learning) Learning in the class
5. Ask at least three HOTS (Higher order Thinking) questions in the class, which promotes critical thinking
6. Adopt Problem Based Learning (PBL), which fosters student's Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information rather than simply recall it.
7. Topics will be introduced in a multiple representation.
8. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them.
9. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.
10. Individual teacher can device the innovative pedagogy to improve the teaching-learning.

Module-1

Preparing for the Future of Work: Will Robots Replace You? Impact of Robotics on Work , Living with Robots Technology Definitions: Definitions, Rules That Don't Work, Bots, and Chatbots, Robots, Collaboration, and Collaborative Robots, Smart Buildings As Robots Without Arms, Research Progress.

Module-2

Robotic Process Automation: Increasing the Automation of Business Processes, Process Management, Selection, and Optimization, RPA Implementations, RPA: Advantages, Challenges, and Caveats,
Robots in Teams, An Introduction to Cobots, Cobots in Complex Environments, Search-and-Rescue, Surgery, Warehouses, Intelligent Automation, Bots, and Chatbots, Working Alongside Humans, Teamwork: From Conversational Interfaces to Physical Cobots

Module-3

Robots Without Arms: Smart Buildings, Autonomous Vehicles, Making Sense for Robots and Society: Robots in a World of Data, Data Fusion Definitions, Humans: The Data Fusion Mavens, Infrastructure Complexity Drives Data Fusion, Data Fusion Challenges for Collaborative Robots, Supporting Research Projects

Module-4

Robots in Society: What Can Go Wrong? Can Robots Be Ethical and Self-Regulating? Legal Remedies, Robots in Corporations, Corporations in Robots, Privacy by Design, Ethics by Design, Design Representative of Diversity, Accountability, Explainability, and Transparency, Governance, Safety, Social Impact and Well-Being

Module-5

Work in the Future: The Transformation of Work, Artificial intelligence, Working with Automation and Robots, Final Thought

Course outcome (Course Skill Set)

At the end of the course, the student will be able to :

CO1: Apply key principles of collaborative robotics to optimize human-robot interaction in industrial settings.

CO2: Evaluate the advantages and limitations of AI-powered robotics in enhancing organizational efficiency.

CO3: Formulate strategies to address ethical and legal challenges related to robotic automation.

CO4: Design solutions incorporating robotics and automation to solve real-world problems in diverse industries.

CO5: Demonstrate proficiency in identifying and deploying appropriate robotic technologies to foster innovation in the workplace.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

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7. The students have to answer 5 full questions, selecting one full question from each module.

Suggested Learning Resources:

Text Books

1. Automation and Collaborative Robotics A Guide to the Future of Work, Peter Matthews, Steven Greenspan, PhD, https://doi.org/10.1007/978-1-4842-5964-1
2. Andrey Ronzhin, Roman Shishkin, and Victor Filaretov, Interactive Collaborative Robotics, **10.1007/978-3-031-23609-9**

Reference Book

1. Bruno Siciliano and Luigi Villani, Human-Robot Collaboration: Unlocking the Potential for Industrial

Applications, DOI: 10.1049/pbce134e

Web links and Video Lectures (e-Resources):

- https://www.udemy.com/course/francobotics/?utm_source=adwords&utm_medium=udemyads&utm_campaign=Search_DSA_GammaCatchall_NonP_la.EN_cc.India&campaigntype=Search&portfolio=India&language=EN&product=Course&test=&audience=DSA&topic=&priority=Gamma&utm_content=deal4584&utm_term=_._ag_166578677881_._ad_700948726520_._kw__._de_c_._dm__._pl__._ti_dsa-1456167871416_._li_1007768_._pd__._&matchtype=&gad_source=1&gclid=CjwKCAiArva5BhBiEiwA-oTnXZzWfQOSAP-9kUN6gYt1qCDOghjHN7iqNulajVizUb2qXBbpZSH7jBoCZM4QAvD_BwE&couponCode=IND21PM
- https://www.coursera.org/learn/collaborative-robot-safety

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Visit to the industries/ reputed universities or colleges to explore the applications of networking
- Project based learning
- Mini project