

Curriculum of Diploma Programme
in
Electronics & Communication
Engineering



**Department of Science, Technology and Technical
Education (DSTTE), Govt. of Bihar**

**State Board of Technical Education
(SBTE), Bihar**

Semester – VI

Teaching & Learning Scheme

| Course Codes | Category of course | CourseTitles | Teaching & Learning Scheme (Hours/Week) | | | | | |
|--------------|--------------------|---|---|----------|----------------------|-------------------------|---------------------------|-------------------|
| | | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | | L | T | | | | |
| 2421601 | PCC | Data Communication and Computer Networking | 03 | - | 04 | 02 | 09 | 06 |
| 2421602 | PCC | Electromagnetic Theory and its Applications | 03 | - | 04 | 02 | 09 | 06 |
| 2421603 | PEC | Programme Electives* - Any One | 03 | - | 04 | 02 | 09 | 06 |
| 2400604 | OEC | Open Electives** / COE (Advanced -Any One) | 03 | - | 04 | 02 | 09 | 06 |
| 2421605 | PSI | Major Project (Common for all programmes) | - | - | 08 | 04 | 12 | 06 |
| Total | | | 12 | - | 24 | 12 | 48 | 30 |

Note: Prefix will be added to course code if applicable (T for Theory Paper, P for Practical Paper and S for Term Work)

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

*: AI and Machine Learning/ Industrial Electronics/ Biomedical Electronics/ Advance Communication System

** : 3D Printing & Design/ Artificial Intelligence/ Drone Technology/ Electric Vehicles / Industrial Automation /Internet of Things / Robotics/ Transformer Manufacturing and Repairing/ Optical Fiber and 5G Communication

Note:TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

Semester - VI Assessment Scheme

| Course Codes | Category of course | Course Titles | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|--------------|--------------------|---|-------------------------------------|-----------------------------|--|------------|----------------------------------|---------------------------------|-------------------------|
| | | | Theory Assessment (TA) | | Term work & Self-Learning Assessment (TWA) | | Lab Assessment(LA) | | |
| | | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421601 | PCC | Data Communication and Computer Networking | 30 | 70 | 20 | 30 | 20 | 30 | 200 |
| 2421602 | PCC | Electromagnetic Theory and its Applications | 30 | 70 | 20 | 30 | 20 | 30 | 200 |
| 2421603 | PEC | Programme Electives* - Any One | 30 | 70 | 20 | 30 | 20 | 30 | 200 |
| 2400604 | OEC | Open Electives** / COE (Advanced -Any One) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |
| 2421605 | PSI | Major Project (Common for all programmes) | - | - | 20 | 30 | 50 | 100 | 200 |
| Total | | | 120 | 280 | 100 | 150 | 130 | 220 | 1000 |

Note: Prefix will be added to course code if applicable (T for Theory Paper, P for Practical Paper and S for Term Work)

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

*: AI and Machine Learning/ Industrial Electronics/ Biomedical Electronics/ Advance Communication System

** : 3D Printing & Design/ Artificial Intelligence/ Drone Technology/ Electric Vehicles / Industrial Automation /Internet of Things / Robotics/ Transformer Manufacturing and Repairing/ Optical Fiber and 5G Communication

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respectivecourse. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

- A) **Course Code** : 2421601(T2421601/P2421601/S2421601)
 B) **Course Title** : Data Communication and Computer Networking
 C) **Pre- requisite Course(s)** : Introduction to IT system, Basics of computer networking
 D) **Rationale**

Data communication deals with the transmission of digital data through networks. Many applications like Airline Reservations, Railway reservations, e-banking, e-governance, Online Shopping, and e-learning can be managed with a single click. Diploma Engineers should be able to select, classify, install, troubleshoot, and maintain different industrial data communication networks. This course gives vital basic concepts and skills related to data communication and networking that are essential for diploma engineers and prepare them for the present needs of Industry.

- E) **Course Outcomes (COs):** The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COS associated with the above mentioned competent.

After completion of the course, the students will be able to-

- CO-1** Maintain wired computer network topologies.
CO-2 Use the relevant network model for the specified data communication system.
CO-3 Maintain relevant transmission medium and modem for data transmission.
CO-4 Analyze error detection/correction and flow control of data in the data network.
CO-5 Configure the network component with IP address assignment.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|--------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO- 1 | PSO- 2 |
| CO-1 | 3 | 1 | - | 2 | 1 | 1 | 1 | | |
| CO-2 | 3 | 1 | 2 | 1 | - | 1 | 1 | | |
| CO-3 | 3 | 2 | 2 | 1 | - | 1 | 1 | | |
| CO-4 | 2 | 1 | 1 | 1 | - | 1 | - | | |
| CO-5 | 3 | - | 2 | 1 | - | 1 | 1 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|--|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2421601 | Data Communication and Nomputer Networking | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|--|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421601 | Data Communication and Computer Networking | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2421601**

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p><i>TSO 1a.</i> Explain the function of the given component in the process of data Communication.</p> <p><i>TSO 1b.</i> Describe the given data transmission method with its frame format</p> <p><i>TSO 1c.</i> Explain the given source of noise and its effect.</p> <p><i>TSO 1d.</i> Analyze the computer network considering particular topology.</p> <p><i>TSO 1e.</i> Classify networks on the basis of the given parameter.</p> | <p>Unit-1.0 Fundamentals of Data Communication and Network Topology</p> <p>1.1 Data communication and its characteristics</p> <ul style="list-style-type: none"> • Basic block diagram of data communication system • Components of data communication: Transmitter, Receiver, Medium, Message, error, noise, Protocol. • Standards, Standard organizations <p>1.2 Data Transmission: Serial, Parallel Synchronous, Asynchronous, Isochronous transmission</p> <p>1.3 Transmission characteristics: Signaling rate, data rate, bit rate, baud rate</p> <p>1.4 Need of computer networks, Network criteria, advantages of networking, Schematic diagram, working</p> <p>1.5 Network topologies: Mesh, Star, Bus, Tree, Ring and Hybrid topologies: working, disadvantages and applications.</p> <p>1.6 Network Classification:</p> <ul style="list-style-type: none"> • Based on Transmission Technologies: Point to-point, Multipoint • Physical size (scale): PAN, BAN, LAN, MAN, WAN, VPN • Based on Architecture: Peer to Peer, Client Server, advantages of Client Sever over Peer-to-Peer Model | CO1 |
| <p><i>TSO 2a.</i> Describe the function of the given layer of TCP/IP Reference model.</p> <p><i>TSO 2b.</i> Explain the relationship of layers with addresses in TCP/IP.</p> <p><i>TSO 2c.</i> Differentiate between various addressing schemes for TCP/IP.</p> <p><i>TSO 2d.</i> Describe the functions of the given layer of OSI reference model.</p> | <p>Unit-2.0 Network Models</p> <p>1.1 TCP/IP protocol suite with define protocols in respective Layers: Physical layer, Data Link Layer, Network Layer, Transport Layer, and Application Layer</p> <p>1.2 Addressing in TCP/IP: Physical, logical, Port and specific</p> <p>1.3 The ISO-OSI model: Physical layer, Data Link Layer, Network Layer, Transport Layer, Session Layer, Presentation Layer, Application Layer</p> | CO2 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| <p><i>TSO 3a.</i> Describe the principle of given multiplexing technique.</p> <p><i>TSO 3b.</i> Select the transmission media for transmitting the given signal for the given application.</p> <p><i>TSO 3c.</i> Describe the construction of the given cable with labeled sketches.</p> <p><i>TSO 3d.</i> Compare different types of Transmission medium on the basis of given parameter</p> <p><i>TSO 3e.</i> Explain with sketches working of the given type of modem.</p> <p><i>TSO 3f.</i> Compare different multiplexing/ switching techniques based on the given parameters.</p> | <p>Unit-3.0 Physical Layer</p> <p>3.1 Multiplexing: Basic concept</p> <ul style="list-style-type: none"> • Frequency• Division Multiplexing • Wavelength• Division Multiplexing • Synchronous Time-Division Multiplexing <p>3.2 Transmission medium: classification based on electromagnetic wave spectrum</p> <p>3.3 Guided Media- Performance and applications</p> <ul style="list-style-type: none"> • Twisted pair (UTP, STP) cable-connector • Coaxial cable-connector • Fiber-optic cable-connector <p>3.4 Introduction of Unguided Media- Radio waves, microwaves, Infrared and their applications</p> <p>3.5 Modems classification : Broadband modem, DSL-ADSL, HDSL, VDSL</p> <p>3.6 Switching:</p> <ul style="list-style-type: none"> • Circuit-switched networks • Packet switched networks- Datagram approach, virtual circuit approach | CO3 |
| <p><i>TSO 4a.</i> Describe the services provided by Data Link Layer.</p> <p><i>TSO 4b.</i> Describe the technique of the given error control method with examples.</p> <p><i>TSO 4c.</i> Explain with sketches the given type of flow control used in the data link layer with justification.</p> <p><i>TSO 4d.</i> Compare the characteristics of given type of Protocol.</p> <p><i>TSO 4e.</i> Select the appropriate protocol for error free transmission of given data.</p> | <p>Unit-4.0 Data Link Layer</p> <p>4.1 Framing</p> <p>4.2 Flow control</p> <p>4.3 Error control</p> <ul style="list-style-type: none"> • Types of errors: Single bit and Burst errors • Error detection and correction <p>4.3 Protocol</p> <ul style="list-style-type: none"> • Sliding window protocol: One bit sliding window protocol <p>4.4 Point to Point Protocol: service provided by PPP, Frame format PPP and Transition phases of PPP</p> <p>4.5 Ethernet and IEEE 802.3</p> <p>4.6 MAC Addresses and Switching</p> | CO4 |
| <p><i>TSO 5a.</i> Justify the function of the given network device.</p> <p><i>TSO 5b.</i> Differentiate between class-full and classless addressing.</p> <p><i>TSO 5c.</i> Explain the role of NAT in address depletion.</p> <p><i>TSO 5d.</i> Explain the given type of Routing with example.</p> <p><i>TSO 5e.</i> Describe the services provided by the transport layer/network layer /Application layer.</p> <p><i>TSO 5f.</i> Describe the given type of network security technique.</p> <p><i>TSO 5g.</i> Explain the fundamental concepts of SSL/TLS protocols.</p> | <p>Unit-5.0 Network, Transport and Application Layer</p> <p>5.1 Network devices:</p> <ul style="list-style-type: none"> • Repeater • Hub • Bridge • Switches • Router • Gateway <p>5.2 Network layer Logical addressing: IPv4 Addresses: address space notations, class-full addressing, and class-less addressing</p> | CO5 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|--|------------------------|
| <p><i>TSO 5h.</i> Explain the security implications of use of different protocol versions.</p> <p><i>TSO 5i.</i> Differentiate between symmetric and asymmetric encryption algorithms used in SSL/TLS.</p> | <p>5.3 Network Address Translation (NAT), IPv6 addresses, Need for IPv6, Structure and address space</p> <p>5.4 Network layer-Multicast Routing Protocols: Unicast, Multicast and Broadcast routing and applications of Transport Layer</p> <p>5.5 Internet Control Message Protocol (ICMP), Address Resolution Protocol (ARP), Reverse Address Resolution Protocol (RARP)</p> <p>5.6 Process to process delivery: UDP, TCP, RTP, SCTP, ports format and uses.</p> <p>5.7 Application Layer services: Concept of DNS, FTP, HTTP/HTTPS, FTP and SMTP, DNS and DHCP.</p> <p>5.8 Network Security Protocols (SSL/TLS)</p> <p>5.9 Security services: concepts of message and entity security service, Firewall</p> | |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2421601

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| <p><i>LSO 1.1</i> Identify the type of network topology used in your lab</p> <p><i>LSO 1.2</i> Prepare Report.</p> | 1. | Analyze the type of network topology used in your lab and prepare technical specifications. | CO1 |
| <p><i>LSO 2.1</i> Connect a given number of computers in a ring topology.</p> <p><i>LSO 2.2</i> Verify data transfer in ring topology.</p> | 2. | Connect computers in ring topology and transfer the data. | CO1 |
| <p><i>LSO 3.1.</i> Connect a given number of computers in hybrid topology.</p> <p><i>LSO 3.2.</i> Verify data transfer for hybrid topology.</p> | 3. | Connect computers in hybrid topology and test the performance. | CO2 |
| <p><i>LSO 4.1</i> Establish WAN Network.</p> <p><i>LSO 4.2</i> Configure WAN network.</p> <p><i>LSO 4.3</i> Test WAN network.</p> | 4. | Install/configure/Test peer-to-peer WAN and sharing of resources. | CO2, CO3 |
| <p><i>LSO 5.1</i> Configure and Install point-to-point network.</p> <p><i>LSO 5.2</i> Test point-to-point network.</p> | 5. | Commissioning of Point-to-Point network in the laboratory. | CO3 |
| <p><i>LSO 6.1</i> Connect the devices on LAN by patch cord and cross connection.</p> <p><i>LSO 6.2</i> Test the LAN connection.</p> | 6. | Prepare patch cord and cross connection cables used for LAN connection. | CO1, CO3 |
| <p><i>LSO 7.1</i> Install a LAN network using Switches/hubs.</p> <p><i>LSO 7.2</i> Test LAN network.</p> | 7. | Test the performance of the Hub/Switches used in LAN network. | CO4, CO5 |
| <p><i>LSO 8.1</i> Apply error detection methods.</p> <p><i>LSO 8.2</i> Find the error bit in the given data stream by using the different error detection methods.</p> | 8. | Locate the error bit using error detection methods. | CO4 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| <i>LSO 9.1</i> Apply error correction method. <i>LSO 9.2</i> Correct the error in a given data stream by applying the different error correction methods. | 9. | Correction of the error using error correction methods for the given data bits. | CO4 |
| <i>LSO 10.1</i> Test the performance of given network using route command. | 10. | Route command to test the performance of the given network. | CO5 |
| <i>LSO 11.1</i> Test and install Router, Repeater and Bridge. | 11. | Install and test Router, Repeater and Bridge. | CO5 |
| <i>LSO 12.1</i> Assign IP address to the PC connected to the internet. | 12. | IP address assignment to the PC connected to the internet. | CO5 |
| <i>LSO 13.1</i> Internet connectivity configuration. | 13. | Configure/Test Internet connectivity. | CO1CO5 |
| <i>LSO 14.1</i> Use FTP protocol to transfer file from one system to another system. | 14. | Transfer file using FTP protocol. | CO2, CO5 |
| <i>LSO 15.1</i> Install a Firewall for the network security. | 15. | Network security firewall installation. | CO5 |
| <i>LSO 16.1</i> Interconnect two PCs using RS232 cable <i>LSO 16.2</i> Configure the modem. <i>LSO 16.3</i> Test the data transfer between two PC. | 16. | Transfer of data between two PC interconnected using RS232 cable and null modem. | CO1, CO2 |
| <i>LSO 17.1</i> Maintain the network devices- Router, Hub. | 17. | Test the performance of the following network devices: Repeater, Hub. | CO5 |
| <i>LSO 18.1</i> Maintain the network devices- Bridge, Switches , Router. | 18. | Test the performance of the following network devices: Bridge, Switches , Router. | CO5 |

L) **Suggested Term Work and Self Learning: S2421601** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- i. Describe any four types of computer network topologies.
- ii. Explain the function of the data link layer.
- iii. Compare twisted pair cable and coaxial cable.
- iv. Differentiate between OSI and TCP/IP model.
- v. List the functions of the application layer.
- vi. Describe the firewall working in detail.

b. **Micro Projects:**

- i. Perform Network Configuration Management for the small LAN network.
- ii. Use a Secure File Transfer Application and transfer the file on the network.
- iii. Maintain the Network Monitoring Dashboard.
- iv. Use simulation software and test the performance of Network and Remote
 - i. Desktop Application.
- v. Prepare a small report on IoT Sensors and Data Visualization.

c. Other Activities:

1. Seminar Topics:

- 5G Technology and Its Impact on Data Communication
- Network Security in the Age of Cyber Threats
- IoT (Internet of Things) and Networking
- Cloud Networking and Data Communication
- Blockchain Technology and Networking
- Wireless Networking Technologies
- Network Monitoring and Analysis Tools
- Wi-Fi Security and Best Practices

2. Visit: Visit to nearby Internet service provider and prepare a report of it in detail.

3. Self-Learning Topics:

- Network Security Fundamentals
- Wireless Networking Technologies
- IPv6 Implementation

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use the appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 20% | 20% | 15% | - | - | 20% | 20% |
| CO-2 | 20% | 20% | 10% | 25% | - | 10% | 20% |
| CO-3 | 20% | 20% | 15% | 25% | 33% | 15% | 20% |
| CO-4 | 20% | 20% | 30% | 25% | 33% | 15% | 20% |
| CO-5 | 20% | 20% | 30% | 25% | 34% | 40% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number(s) | Total Marks | ETA (Marks) | | |
|---|--|------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 Fundamentals of Data Communication and Network Topology | 8 | CO1 | 14 | 6 | 3 | 5 |
| Unit-2.0 Network Models | 9 | CO1, CO2 | 14 | 4 | 5 | 5 |
| Unit-3.0 Physical Layer | 9 | CO3 | 14 | 3 | 5 | 6 |
| Unit-4.0 Data Link Layer | 8 | CO3, CO4 | 14 | 2 | 6 | 6 |
| Unit-5.0 Network, Transport and Application Layer | 8 | CO5 | 14 | 5 | 5 | 4 |
| Total | 42 | - | 70 | 20 | 24 | 26 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Analyze the type of network topology used in your lab and prepare technical specifications. | CO1 | 60 | 30 | 10 |
| 2. | Connect computers in ring topology and transfer the data. | CO1 | 60 | 30 | 10 |
| 3. | Connect computers in hybrid topology and test the performance. | CO2 | 60 | 30 | 10 |
| 4. | Install/configure/Test peer-to-peer WAN and sharing of resources. | CO2, CO3 | 60 | 30 | 10 |
| 5. | Commissioning of Point-to-Point network in laboratory. | CO3 | 60 | 30 | 10 |
| 6. | Prepare patch cord and cross connection cables used for LAN connection. | CO1, CO3 | 60 | 30 | 10 |
| 7. | Test the performance of the Hub/Switches used in LAN network. | CO4, CO5 | 60 | 30 | 10 |
| 8. | Locate the error bit using error detection methods. | CO4 | 60 | 30 | 10 |
| 9. | Correction of the error using error correction methods for the given data bits. | CO4 | 60 | 30 | 10 |
| 10. | Route command to test the performance of the given network. | CO5 | 60 | 30 | 10 |
| 11. | Install and test Router, Repeater and Bridge. | CO5 | 60 | 30 | 10 |
| 12. | IP address assignment to the PC connected to the internet. | CO5 | 30 | 60 | 10 |
| 13. | Configure/Test Internet connectivity. | CO1CO5 | 50 | 40 | 10 |

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 14. | Transfer file using FTP protocol. | CO2, CO5 | 40 | 50 | 10 |
| 15. | Network security firewall installation. | CO5 | 60 | 30 | 10 |
| 16. | Transfer of data between two PC interconnected using RS232 cable and null modem. | CO1, CO2 | 60 | 30 | 10 |
| 17. | Test the performance of the following network devices: Repeater, Hub. | CO5 | 60 | 30 | 10 |
| 18. | Test the performance of the following network devices: Bridge, Switches, Router. | CO5 | 60 | 30 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|--|---|--------------------------------------|
| 1. | High end computers | Processor Intel Core i7 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10 | All |
| 2. | Personal Computers (For additional Terminals) | Intel P-IV (or latest) , 2Gbyte , DDR2 , 500Gbyte HDD, Keyboard onwards Installed with Windows 7 onwards and internet connectivity | 1,2 |
| 4. | Routers | TP-Link standard router | 6, 7, 8, 10,11 |
| 5. | Smartphone | May use Students handset of mobile | 6, 7, 8, 10 |
| 6. | Repeater | Outdoor Band Selective Mobile Signal Repeater suggested | 1,4,5,6,11 |
| 7. | Hub | Minimum 4 port Hub | 1,4,5,6 |
| 8. | Switch | Minimum 8 port switch | 1,4,5,6 |
| 9. | Connecting cables and connectors | Ethernet Cables (Cat3, Cat4, Cat5, Cat5E, Cat6 and Cat7 cables) , Cross-over cable (with RJ-45 connector), Straight cable (with RJ-45 connector) and RJ-11 for Telephone line | 1,2,3,4,5,6,7,8,9,10,11 |
| 10. | Network Bridge | TP-Link standard bridge router | 1,4,5,5,7,8,10,1,13 |

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---------------------------------------|--|--------------------------------------|
| 11. | Filezilla software | Open source software | All |
| 12. | Any Freeware | Sophos XG Firewall Home Edition or ZoneAlarm Free Firewall 2019 (but needs (Dot).Net Framework) or AVS Firewall or Avast Free Antivirus or Comodo Free Firewall or Tiny Wall or Outpost Firewall or Glass Wire or Private firewall or OpenDNS Home | All |
| 13. | Null Modem cable | RS-232 with 9 -pin | 10, 11 |
| 14. | Packet Tracer | Packet Tracer 5.1 or higher version (Optional) | 9 |

R) Suggested Learning Resources:

(b) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|---|--|
| 1. | Computer Networks | Tannebaum Andrew S Wetherall David J | Pearson, New Delhi, 5 th edition 2013, ISBN 978-9332518742, latest edition |
| 2. | Data and Computer Communication | Stallings Williams | Prentice Hall India, 10 th Edition, 2013, ISBN: 9780133506488 or latest edition |
| 3. | Data Communication and Networking | Forouzen | Tata McGraw Hill, Education New Delhi 4 th edition 2017 ISBN-978-0070634145, latest edition |
| 4. | Introduction to Data Communications and Networking | Tomasi, W. | Pearson Education, New Delhi, India, 2007, ISBN: 9788131709306 or latest edition |

(b) Online Educational Resources:

- https://onlinecourses.nptel.ac.in/noc21_me115/preview
- <http://www.studytonight.com/computer-network/tcp-ip-reference-model>
- <http://www.studytonight.com/computer-network/network-topology-types>
- http://www.tcpiptide.com/free/t_connectionorientedandconnectionlessprotocols.htm
- <https://www.vidyarthiplus.com/vp/attachment.php?aid=43525>
- <http://www.myreadingroom.co.in/notes-and-studymaterial/68-dcn/719-different-line-coding-techniques.html>
- <https://www.cambridgeinternational.org/Images/285023-topic-3.2.1-protocols-9608-.pdf>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

(c) Others:

- IP addressing Handbook
- Lab Manuals
- Network topology guide

- A) **Course Code** : 2421602(T2421602/P2421602/S2421602)
 B) **Course Title** : Electromagnetic Theory and its applications
 C) **Pre-requisite Course(s)** : Basic Engg. Mathematics, Applied Mathematics-C
 D) **Rationale:**

Electromagnetic theory and its applications provides insights into the behavior of charged particles and their interactions with electric and magnetic fields, forming the basis of modern physics. Electromagnetic theory and its applications explains the generation, propagation, and behavior of electromagnetic waves, including radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. These waves are fundamental to communication, imaging, and sensing technologies. The course covers static and dynamic electric and magnetic fields and their interaction. Major topics include Electromagnetic Waves, radio wave propagation and Antenna fundamentals. Successful completion of the course will allow students to take up Microwave Engg., Complex Antennas, and Optics for future studies.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of the following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor, and Affective) in the classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

CO-1 Apply vector analysis techniques to interpret physical phenomena using gradient, divergence, and curl.

CO-2 Apply Gauss's law to solve complex electrostatic problems.

CO-3 Analyse the behavior of electromagnetic waves in different media.

CO-4 Discuss various antennas and their applications in transmission and reception of electromagnetic waves.

CO-5 Explain different modes of propagation and its implications for the transmission of electromagnetic waves.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | - | - | - | - | 2 | | |
| CO-2 | 3 | 2 | 3 | 3 | - | 1 | - | | |
| CO-3 | 3 | 1 | 2 | 3 | - | 1 | - | | |
| CO-4 | 3 | 2 | 2 | 3 | - | 1 | - | | |
| CO-5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | |

Legend: High(3), Medium (2), Low(1) and No mapping(-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Board of Study | Course Code | Course Title | Teaching & Learning Scheme (Hours/Week) | | | | | |
|-----------------------------|-------------|---|---|---|----------------------|-------------------------|---------------------------|-------------------|
| | | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | | L | T | | | | |
| Electronics & Communication | 2421602 | Electromagnetic Theory and its applications | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self-Learning, MOOCs, spoken tutorials, online educational resources etc

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Board of Study | Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-----------------------------|-------------|---|-------------------------------------|-----------------------------|--|----------|----------------------------------|--------------------------------|-------------------------|
| | | | Theory Assessment (TA) | | Term Work & Self Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment(ELA) | |
| Electronics & communication | 2421602 | Electromagnetic Theory and its applications | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes) PLA:

Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and **Self-Learning (SL)**. Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2421602

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| <p><i>TSO 1a.</i> Describe the basic concepts of circuit theory and field theory.</p> <p><i>TSO 1b.</i> Define the gradient of a scalar field and interpret its geometric interpretation.</p> <p><i>TSO 1c.</i> Define the divergence of a vector field and interpret its geometric interpretation.</p> <p><i>TSO 1d.</i> Apply the Stokes' Theorem to compute line integrals of vector fields along closed curves.</p> <p><i>TSO 1e.</i> Apply Gauss's Divergence Theorem to compute flux integrals.</p> <p><i>TSO 1f.</i> List the various Co-ordinate systems.</p> <p><i>TSO 1g.</i> Apply coordinate transformations to solve problems in physics, engineering, and other fields.</p> | <p>Unit-1.0 Introduction to Co-ordinate system</p> <p>1.1 Circuit theory & Field theory</p> <p>1.2 Vector Analysis</p> <ul style="list-style-type: none"> • Scalar and Vector quantities • Vectors and Vector operations • Vector differential operator, Del • Gradient and its physical interpretation • Divergence and its physical interpretation • Curl and its physical interpretation <p>1.3 Integral theorems</p> <ul style="list-style-type: none"> • Gauss's Divergence Theorem • Stroke's Theorem <p>1.4 Co-ordinate system</p> <ul style="list-style-type: none"> • Cartesian Co-ordinate system • Cylindrical Co-ordinate system • Spherical Co-ordinate system <p>1.5 Transformation between Co-ordinate systems</p> <ul style="list-style-type: none"> • Transformation between Cartesian to Cylindrical Co-ordinate system • Transformation between Cylindrical to Cartesian Co-ordinate system • Transformation between Cartesian to Spherical Co-ordinate system • Transformation between Spherical to Cartesian Co-ordinate system | <p>CO1</p> |
| <p>Explain Coulomb's law of Electrostatic force and its implications.</p> <p>Describe the concept of Electric field due to several point charges.</p> <p>Explain Gauss's law and its application in solving electrostatic problems.</p> <p>Discuss Poisson's Equation and its relevance in electrostatics.</p> <p>Discuss Laplace's Equation and its applications in finding potential distributions.</p> <p>Explain Faraday's law of Electro-magnetic induction and its implications.</p> <p>Analyze the relations of fields normal to the boundary and fields tangent to the boundary.</p> | <p>Unit-2.Electrostatics & Magneto-statics</p> <p>2.1. Coulomb's law of Electrostatic force</p> <ul style="list-style-type: none"> • Electric field intensity • Electric field due to several point charges • Field of a finite line of charge • Field and potential of an infinite line of charges <p>2.2. Gauss's law and its application</p> <p>2.3. Poisson's Equation</p> <p>2.4. Laplace's Equation</p> <p>2.5. Continuity Equation</p> <p>2.6. Faraday's law of Electro-magnetic induction</p> <p>2.7. Biot-Savart's law</p> <ul style="list-style-type: none"> • Magnetic field of a linear conductor of infinite length <p>2.8. Magnetic boundary conditions</p> | <p>CO1, CO2</p> |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| | <ul style="list-style-type: none"> • Relation of fields normal to the boundary • Relation of fields tangent to the boundary | |
| <p><i>TSO 3a.</i> Explain Maxwell's Equations in free space and in harmonically varying fields.</p> <p><i>TSO 3b.</i> Derive electromagnetic wave equations and their solutions in different mediums.</p> <p><i>TSO 3c.</i> Analyze the propagation of plane electromagnetic waves in various mediums.</p> <p><i>TSO 3d.</i> Explain Poynting theorem and electromagnetic power flow.</p> <p><i>TSO 3e.</i> Discuss electromagnetic wave polarization and its implications.</p> | <p>Unit-3.0 Electromagnetic fields and its radiations</p> <p>3.1 Maxwell's Equation</p> <ul style="list-style-type: none"> • In differential and integral form • In free space • In harmonically varying fields <p>3.2 Displacement current</p> <p>3.3 Electromagnetic wave equations</p> <ul style="list-style-type: none"> • In Free space • In conducting medium <p>3.4 Propagation of plane electromagnetic wave</p> <ul style="list-style-type: none"> • In Lossy dielectrics • In good dielectrics • In Good conductors <p>3.5 Intrinsic impedance of a dielectric and conducting media</p> <p>3.6 Depth of penetration</p> <p>3.7 Poynting theorem & Electromagnetic power</p> <p>3.8 Electromagnetic wave polarization</p> | CO3 |
| <p><i>TSO 4a.</i> Define the given antenna parameter.</p> <p><i>TSO 4b.</i> Describe the working principle of the given basic antenna element.</p> <p><i>TSO 4c.</i> Explain the effect of antenna height on the signal reception.</p> <p><i>TSO 4d.</i> Compare the radiation pattern of the given types of antennas.</p> <p><i>TSO 4e.</i> Sketch the radiation pattern of given type of antenna array.</p> | <p>Unit-4.0 Antenna Fundamentals</p> <p>4.1 Basic definition of antenna and working principle, point source, dipole antenna, Isotropic radiator</p> <p>4.2 Antenna parameters: impedance, radiation resistance, radiation pattern, beam width and beam efficiency, gain, directivity and radiation intensity, half power BW (HPBW), antenna efficiency</p> <p>4.3 Effects of antenna height on the signal reception</p> <p>4.4 Working principle, radiation pattern and application of following antennas:</p> <ul style="list-style-type: none"> • Half wave dipole • Horn • Yagi Uda • Parabolic Reflector <p>4.5 Introduction and uses of Loop and Helical Antenna, Folded Dipole Antenna</p> <p>4.6 Introduction, radiation pattern and applications of Antenna arrays:</p> <ul style="list-style-type: none"> • Broadside array antenna • End fire array antenna | CO4 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p><i>TSO 5a.</i> State the fundamental equation for free space propagation</p> <p><i>TSO 5b.</i> Discuss the different modes of propagation.</p> <p><i>TSO 5c.</i> Explain the structure of atmosphere.</p> <p><i>TSO 5d.</i> State the characteristics of different ionized regions.</p> <p><i>TSO 5e.</i> Explain the mechanism of radio wave bending.</p> <p><i>TSO 5f.</i> Compare virtual height and actual height.</p> <p><i>TSO 5g.</i> Define critical frequency and maximum usable frequency and state its importance.</p> | <p>Unit 5.0 Radio wave propagation</p> <p>5.1 Fundamental equation for free space propagation</p> <p>5.2 Modes of propagation</p> <ul style="list-style-type: none"> • Ground wave propagation • Sky wave propagation • Space wave propagation • Tropospheric scatter propagation <p>5.3 Structure of Atmosphere</p> <ul style="list-style-type: none"> • Structure of Troposphere • Structure of Ionosphere <p>5.4 Characteristics of different ionized regions</p> <p>5.5 Mechanism of radio wave bending by the ionosphere</p> <p>5.6 Virtual height</p> <p>5.7 Critical Frequency</p> <p>5.8 Maximum usable frequency(MUF)</p> | <p>CO5</p> |

Note: One major TSO may require more than one theory session/period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2421602

| Practical/Lab Session Outcomes(LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant Cos Number(s) |
|---|--------|---|------------------------|
| <p><i>LSO 1.1.</i> Find the gradient vector of given $f(x, y, z)$ with respect to vector $[x, y, z]$</p> <p><i>LSO 1.2.</i> Plot the vector field defined by these components in MATLAB</p> | 1. | Gradient vector of (x, y, z) with respect to vector $[x, y, z]$ in MATLAB. | CO1 |
| <i>LSO 2.1.</i> Find the divergence of the vector field $V(x, y, z) = (x, 2y^2, 3z^3)$ with respect to vector $X(x, y, z)$ in MATLAB. | 2. | Divergence of the vector field $V(x, y, z) = (x, 2y^2, 3z^3)$ with respect to vector $X(x, y, z)$ in MATLAB. | CO1 |
| <i>LSO 3.1.</i> Show that divergence of the curl of the vector field is 0 in MATLAB. | 3. | Divergence of the curl of the vector field is 0 in MATLAB. | CO1 |
| <i>LSO 4.1.</i> Find the curl of the vector field $V(x, y, z) = (x^3y^2z, y^3z^2x, z^3x^2y)$ with respect to vector $X(x, y, z)$ in Cartesian coordinates. Use of temperature sensor for temperature measurement. | 4. | Curl of the vector field $V(x, y, z) = (x^3y^2z, y^3z^2x, z^3x^2y)$ with respect to vector $X(x, y, z)$ in Cartesian coordinates. | CO1 |
| <p><i>LSO 5.1.</i> Find the curl of a 2-D vector field $F(x, y) = (\cos(x+y), \sin(x-y), 0)$</p> <p><i>LSO 5.2.</i> Plot the vector field as a quiver (velocity) plot and the z-component of its curl as a contour plot.</p> | 5. | Curl of a 2-D vector field $F(x, y) = (\cos(x+y), \sin(x-y), 0)$. | CO1 |
| <i>LSO 6.1.</i> Create 2D line plot in Cartesian coordinates using MATLAB. | 6. | 2D line plot in Cartesian coordinates using MATLAB. | CO1 |
| <i>LSO 7.1.</i> Illustration of Coulomb's Law using MATLAB. | 7. | Illustration of Coulomb's Law using MATLAB. | CO2 |

| Practical/Lab Session Outcomes(LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant Cos Number(s) |
|---|--------|--|------------------------|
| <i>LSO 8.1.</i> Illustration of Gauss's Law using MATLAB. | 8. | Illustration of Gauss's Law using MATLAB. | CO2 |
| <i>LSO 9.1.</i> Solve the Poisson's equation $-\Delta u=3x^2$ on a square domain with Dirichlet boundary conditions using the <code>poisolv</code> function | 9. | Poisson's equation $-\Delta u=3x^2$ on a square domain with Dirichlet boundary conditions using the <code>poisolv</code> function. | CO3 |
| <i>LSO 10.1.</i> Derive the electromagnetic wave equation in free space without charge and without current sources from Maxwell's equations. | 10. | Electromagnetic wave equation in free space without charge and without current sources from Maxwell's equations. | CO3 |
| <i>LSO 11.1.</i> Find the electric charge density for the electric field $\vec{E} = x^2\hat{i} + y^2\hat{j}.$ | 11. | Electric charge density for the electric field | CO3 |
| <i>LSO 11.2.</i> Plot the electric field using quiver. | | | |
| <i>LSO 12.1.</i> Plot the Electric field pattern between two circular electrodes. | 12. | Electric field pattern between two circular electrodes. | CO3 |
| <i>LSO 13.1.</i> Plot the Electric field pattern between parallel conductors. | 13. | Electric field pattern between parallel conductors. | CO3 |
| <i>LSO 14.1.</i> Check the radiation pattern of half wave dipole antenna. <i>LSO 14.2.</i> Measure the Half Power Beam width. | 14. | Determination of radiation pattern of half wave dipole antenna | CO4 |
| <i>LSO 15.1.</i> Interpret the Directivity and Half Power Beam width from the radiation pattern of the given Yagi-Uda antenna. | 15. | Test the Performance of the Yagi-Uda antenna | CO4 |
| <i>LSO 16.1.</i> Interpret the Directivity and Half Power Beam width from the radiation pattern of the given parabolic antenna. | 16. | Test the Performance of the Parabolic Reflector antenna | CO4 |
| <i>LSO 17.1.</i> Interpret radiation pattern using LABVIEW RUN TIME ENGINE software. | 17. | Radiation Pattern of Horn Antenna using Virtual Lab | CO4 |

L) **Suggested Term Work and Self-Learning: S2421602** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted Cos.

b. **Micro Projects**

| Topic title | Main concept(s) covered |
|--|---|
| Xerography: electrostatic imaging | Electrostatics, Gauss's law, Image theory |
| Lightning rods: how do they work? | Electrostatics, image theory, conductors in electrostatic field |
| Hard disk: writing process and materials | Magnetostatics and magnetic properties of materials |
| Hard disk: the reading process | Magnetic properties of materials and EM induction |
| Electric guitar pickups: how do they work? | Electromagnetic induction |
| Faraday cage: shielding methods | Conductors in electrostatic field |

c. **Other Activities:**

1. Seminar Topics:

- Electrodynamic Tethers
- Magnetic Monopoles
- Lightening
- Smart Antenna Systems
- Wearable Antennas
- Antennas for 5G
- Atmospheric Optics
- Maglev Trains

2. Visits: Visit nearby tool room/industry with proper facilities. Prepare report of visit with special comments of network theorems used, transient and steady state response, resonance behavior and safety procedure.

3. Self-learning topics:

- Behavior of conductors
- Behavior of Capacitors
- Behavior of Dielectric

M) **Suggested Course Evaluation Matrix:** The course teacher has to decide and use the appropriate assessment strategy and its weightage in theory, laboratory, and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|--|----------------------------|--------------------------------------|-------------------|-----------|----------------------------------|--------------------------------|
| | Theory Assessment(TA)** | | Term Work Assessment(TWA) | | | Lab Assessment(LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid SemTest | End Theory Assessment(ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment(ELA) |
| | | Assignments | Micro Projects | Other Activities* | | | |
| CO-1 | 15% | 10% | 15% | - | - | 20% | 20% |
| CO-2 | 10% | 20% | 10% | 25% | - | 10% | 20% |
| CO-3 | 15% | 20% | 15% | 25% | 33% | 15% | 20% |
| CO-4 | 30% | 20% | 30% | 25% | 33% | 15% | 20% |
| CO-5 | 30% | 30% | 30% | 25% | 34% | 40% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

* : Other Activities include self-learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point-

(N)# : Mentioned under point-(O)

Note:

- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided among all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Relevant COs Number (s) | Total Marks | Total Hours | ETA(Marks) | | |
|--|-------------------------|-------------|-------------|--------------|-------------------|------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above(A) |
| Unit-1.0 Introduction to Co-ordinate system | CO1 | 12 | 8 | 4 | 4 | 4 |
| Unit-2.Electrostatics & Magneto-statics | CO2 | 14 | 10 | 4 | 4 | 6 |
| Unit-3.0 Electromagnetic fields and its radiations | CO3 | 16 | 10 | 6 | 4 | 6 |
| Unit-4.0 Antenna Fundamentals | CO4 | 16 | 12 | 4 | 6 | 6 |
| Unit 5.0 Radio wave propagation | CO5 | 12 | 8 | 4 | 4 | 4 |
| Total Marks | | 70 | 48 | 22 | 22 | 26 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| SN | Laboratory Practical Titles | Relevant Cos Number (s) | PLA/ELA | | |
|-----|--|-------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Gradient vector of $f(x,y,z)$ with respect to vector $[x,y,z]$ in MATLAB. | CO1 | 30 | 60 | 10 |
| 2. | Divergence of the vector field $V(x,y,z) = (x, 2y^2, 3z^3)$ with respect to vector $X(x,y,z)$ in MATLAB. | CO1 | 40 | 50 | 10 |
| 3. | Divergence of the curl of the vector field is 0 in MATLAB. | CO1 | 30 | 60 | 10 |
| 4. | Curl of the vector field $V(x,y,z)=(x^3y^2z, y^3z^2x, z^3x^2y)$ with respect to vector $X=(x,y,z)$ in Cartesian coordinates. | CO1 | 30 | 60 | 10 |
| 5. | Curl of a 2-D vector field $F(x,y)=(\cos(x+y),\sin(x-y),0)$. | CO1 | 30 | 60 | 10 |
| 6. | 2D line plot in Cartesian coordinates using MATLAB. | CO1 | 30 | 60 | 10 |
| 7. | Illustration of Coulomb's Law using MATLAB. | CO2 | 30 | 60 | 10 |
| 8. | Illustration of Gauss's Law using MATLAB. | CO2 | 40 | 50 | 10 |
| 9. | Poisson's equation $-\Delta u=3x^2$ on a square domain with Dirichlet boundary conditions using the poisolv function. | CO3 | 40 | 50 | 10 |
| 10. | Electromagnetic wave equation in free space without charge and without current sources from Maxwell's equations. | CO3 | 40 | 50 | 10 |

| | | | | | |
|-----|--|-----|----|----|----|
| 11. | Electric charge density for the electric field | CO3 | 30 | 60 | 10 |
| 12. | Electric field pattern between two circular electrodes. | CO3 | 30 | 60 | 10 |
| 13. | Electric field pattern between parallel conductors. | CO3 | 30 | 60 | 10 |
| 14. | Determination of radiation pattern of half wave dipole antenna | CO4 | 30 | 60 | 10 |
| 15. | Test the Performance of the Yagi-Uda antenna | CO4 | 30 | 60 | 10 |
| 16. | Test the Performance of the Parabolic Reflector antenna | CO4 | 30 | 60 | 10 |
| 17. | Radiation Pattern of Horn Antenna using Virtual Lab | CO4 | 30 | 60 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student's performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lectures, Tutorials, Case Methods, Group-Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Labs, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs, etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of the Equipment | Broad Specifications | Relevant Experiment Number |
|--------|------------------------------------|--|----------------------------|
| 1. | Personal Computer | Operating System: Windows 11/ Windows 10 (version 21H2 or higher)/ Windows Server 2022 Note: Windows Server 2019 is no longer supported Processor: Any Intel or AMD x86-64 processor with four or more cores and AVX2 instruction set support RAM: 16GB Storage: 512GB | 1 - 10 |
| 2. | Digital Multimeter | Internal Resistance (>10MΩ) | 11,12,13 |
| 3. | DC Power Supply | Output Current range: 0 to 90 A DC. Output Voltage range: 10 V DC. | 11,12,13 |
| 4. | List of Software/Learning Websites | RF Tool box: MATLAB and SIMULINK or any other open source Software, HFSS-CS, LABVIEW RUN TIME ENGINE for Virtual Lab | 1 - 10 |

| | | | |
|----|---|--|----------------|
| 5. | 10 KHz to 3.6 GHz Spectrum Analyser with Tracking Generator | <p>SPECIFICATION</p> <p>Frequency</p> <ul style="list-style-type: none"> • Range : 9KHz ~ 3.6GHz or more • Resolution : 1 Hz <p>Display : TFT LCD, 10.4 inches</p> <p>Frequency Span</p> <ul style="list-style-type: none"> • Range : 0 Hz , 100 Hz to Maximum frequency of device • Accuracy : +/- 0 span / (swept points-1) <p>Frequency Counter</p> <ul style="list-style-type: none"> • Resolution : 1Hz, 10Hz ,100Hz, 1KHz • Accuracy : +/- (marker freq x freq reference uncertainty + counter resolution) <p>Bandwidth</p> <ul style="list-style-type: none"> • Resolution bandwidth (-3 dB) : 10 Hz to 500 kHz (in 1 to 10 sequence) , 1 MHZ, 3MHz • Accuracy : <5% nominal • Video bandwidth (-3 dB) : 10Hz to 3MHz <p>Amplitude measurement range : -130 dBm to +20dBm,</p> <p>Displayed average noise level (DANL)</p> <p>Preamp off : Input attenuation 0 dB, 1 Hz resolution</p> <p style="text-align: right;">bandwidth</p> <p style="padding-left: 40px;">: 1MHZ~ 10MHZ -130 dBm (nominated)</p> <p style="padding-left: 40px;">: 10MHZ~ 1GHZ -130 dBm (nominated)</p> <p style="padding-left: 40px;">: 1GHZ~3.6GHz - 128 dBm (nominated)</p> <p>Preamp on : 1MHZ~ 10MHZ -150 dBm (nominated)</p> <p style="padding-left: 40px;">: 10MHZ~ 1GHZ -150 dBm (nominated)</p> <p style="padding-left: 40px;">: 1GHZ~3.6GHz - 148 dBm (nominated)</p> <p>Phase noise</p> <p>Phase noise : <- 82 dBc/Hz @10 KHz offset</p> <p style="padding-left: 40px;">: <-100 dBc/Hz @100 KHz offset</p> <p style="padding-left: 40px;">: <-110 dBc/Hz @1 MHz offset</p> <p>Tracking generator</p> <p>Output frequency range : 100kHz ~ 3.6 Ghz</p> <p>Output power level range : -30dBm ~ 0dBm</p> | 14, 15, 16, 17 |
|----|---|--|----------------|

| | | | |
|----|---|--|----------------|
| | | <p>Output power level resolution : 1dB Output flatness : +/- 3dB Input and Outputs Front panel RF input connector : 50 ohm, N-type female Front panel track generator output : 50 ohm, N-type female 10 M reference input : 50 ohm, N-type female Communication Port : USB HOST, USB DEVICE, LAN, earphone port, REF and VGA</p> | |
| 6. | ANTENNA MEASUREMENT SYSTEM with S-Parameter Measurement Module– 1 Set | <p>The Antenna Measurement System with S Parameter Measurement facility and various Types of Antenna as listed</p> <ol style="list-style-type: none"> 1. The Antenna Measurement with Data Acquisition System having the facility to be controlled, set parameters and acquire data from the system 2. The Frequency of the RF Source should be PLL Synthesized and should generate 100MHz to 4 GHz 3. The System should also be able to work in the Stand alone mode using Membrane Key pad and LCD Display with backlit and PC Control mode 4. The Controller should be designed using ARM processor. 5. The Transmitter and Motorized Receiver Stand should be made of special material which is inert to EM frequency and should have engraved height and angle scale on it with spirit level at the base. 6. Universal plug and fix Antenna mounts should be provided to hold the all types of antenna assembly in vertical and horizontal orientation for co and cross polarization. 7. Stepper Motor provided with the system for rotation of Antenna should have minimum 2Kg torque and minimum Step Angle of 1.8 Degree and 5.4 Degree 8. The Source should have the facility to program the Frequency with a resolution of 1MHz 9. The RF Detector should be a Logarithmic Detector with Frequency range of 100MHz to 8 GHz. 10. The Radiation pattern of the Antenna under test should be plotted on the PC Screen in Cartesian and Polar Graph. 11. Horizontal and Vertical Markers to be provided for measurements like Antenna Gain, FBR , Antenna Resolution, HPBW, BWFN | 14, 15, 16, 17 |

| | | | |
|--|--|--|--|
| | | <p>The same system should be able to demonstrate and measure various parameters of the Wired Antenna, Micro strip Antenna, Aperture Antenna, Array Antenna and Reflector Antenna.</p> <p>Add On Vector Network Analyzer Module for S Parameter and Impedance Measurement of Antennas</p> <p>Measure reflection and transmission coefficients (S11,S12,S21,S22) - magnitude and phase</p> <p>Port: 2 with SMA female Type RF connectors</p> <p>Frequency range: 1 MHz to 3 GHz</p> <p>Linear, logarithmic and listed scan</p> <p>Dynamic range (typically) : @500 MHz up to 70 dB (System dynamic range);</p> <p>Output power -6 dBm @ 500MHz</p> <p>Impedance : 1 to 1000 Ohms</p> <p>Frequency setting resolution : 10 Hz</p> <p>Connection to PC : mini-USB</p> <p>Software features</p> <p>Available for Windows, Mac OS and Linux</p> <p>OSL and T Calibration functionality</p> <p>Plot S-Parameter, Impedance, Phase, Resistance, Reactance, VSWR</p> <p>Plot in Smith chart</p> <p>Export in Excel, CSV</p> <p>List of Standard Antennas Supplied with the setup</p> <p>Wire Antenna</p> <ol style="list-style-type: none"> 1. Monopole Plane base ground 2. Dipole (2nos.) 3. Folded Dipole 4. Helical 5. Monopole- Wire 6. YagiUda 7. 3 Lamda/2 Linear dipole 8. Log Periodic Antenna 9. Circular Loop 10. Rhombus Antenna <p>Aperture Antenna</p> <ol style="list-style-type: none"> 1. E- Horn 2. Open ended Waveguide Rectangular <p>Array Antenna</p> <ol style="list-style-type: none"> 1. Broadside Array 2. Collinear Array 3. End Fire <p>Reflector Antenna</p> <ol style="list-style-type: none"> 1. Parabolic Reflector <p>Antenna Design Simulation Software –5 user EM modeling and simulation tool for analysis of 3D structures based on time domain FDTD solver techniques with capabilities and features given below.</p> <p>The Tool should having following features:</p> <ul style="list-style-type: none"> •Wideband full-wave simulation of 3D structures •Full wave Time domain FDTD Solver (CPU FDTD engine with Min 500,000 cells) •The tool should create CAD geometry using polystrip structures and perform Boolean (union, subtract and intersect) operations. •Meshing facility should be manual control. | |
|--|--|--|--|

| | | |
|--|--|--|
| | <ul style="list-style-type: none"> •Define variables to relate and control geometric object properties •CAD Import/ Export formats such as STEP, IGES, STL etc •Multi-frequency computation of frequency domain quantities in a single FDTD simulation run •Far-field radiation patterns: 3D pattern visualization and 2D polar and Cartesian graphs •Far-field characteristics such as directivity, beam width, side lobe levels and null parameters, etc. •Port characteristics: S/Y/Z parameters, VSWR and Smith chart •Antenna design analysis include Wire antennas (dipole, Monopole, Yagi), Planer antennas (Patch Antenna, Array antenna), Aperture Antennas (Horn, Waveguide) and Reflector antennas (Corner Reflector). •Radar Cross Section (RCS) Computations. •Material Properties : PEC, PMC and dielectric materials, anisotropic materials and thin wires •Boundary Conditions: PEC, PMC and perfectly match layer (PML) boundary conditions. •Sources: Lumped Source, Microstrip Port Source, Coplanar Waveguide (CPW) Port Source, Coaxial Port Source, Waveguide Port Source, Plane Wave Source, •Loads : R,L,C and (nonlinear) diode elements <p>List of Deliverables:</p> <ol style="list-style-type: none"> 1. Antenna Source and Detector with Stepper Motor Controller 1 Nos. 2. Antenna Transmitter and Motorized Receiver Stand 1 Nos 3. Universal Mount , RF Cables and Accessories 1 sets 4. Antenna Set consists of 30 antenna -1 Set 5. Software for Radiation Pattern Measurement on CD – 1No 6. Manuals- 1No 7. Add-on VNA Module for S Parameter Measurements 1 No 8. Antenna Design Simulation Software – 5 User 9. Accessories – 1 Set | |
|--|--|--|

R) Suggested Learning Resources:

(a) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|----------------------------------|----------------------------------|--|
| 1. | Electromagnetic Fields and Waves | Prasad, K. D. | Satya Prakashan, New Delhi ISBN-10: 8176840076 |
| 2. | Electromagnetic Fields and Waves | Sedki M. Riad, Iman M. Salama | McGraw Hill Education, New Delhi ISBN-10: 9781260457148 |
| 3. | Antenna and Wave Propagation | Prasad, K. D. | Satya Prakashan, New Delhi ISBN-10: 9351922189 |

| | | | |
|----|-------------------------------|--|---|
| 4. | Antennas and Wave Propagation | Raju, J.S.N | Pearson(PHI) Education India ISBN-13: 978-8131701843 |
| 5. | Antennas and Wave Propagation | Kraus, John D, Ronald, J Marhefka, Khan, Ahmad S | McGraw Hill Education, New Delhi ISBN-10:9352606183 |

(b) Online Educational Resources:

1. <https://shorturl.at/iqFLU>
2. <https://archive.nptel.ac.in/courses/108/104/108104087/>
3. <https://nptel.ac.in/courses/115101005>
4. <https://nptel.ac.in/courses/117101056>
5. <https://archive.nptel.ac.in/courses/108/101/108101092/>
6. <https://nptel.ac.in/courses/117107035>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

- A) **Course Code** : 2421603A(T2421603A/P2421603A/S2421603A)
 B) **Course Title** : Artificial Intelligence & Machine Learning
 C) **Pre-requisite Course(s)** : Python programming
 D) **Rationale** :

Artificial intelligence is a collection of many different technologies working together to enable machines to sense, comprehend, act, and learn with human-like levels of intelligence. AI has its applications in all walks of life including, business, entertainment, home, Medical, Engineering, etc. This course introduces basic principles, techniques, and applications of Artificial Intelligence. The course is designed to develop a comprehension of, problem-solving, knowledge representation, reasoning, machine learning methods, communication & perception of AI, and its implementation using Python Programming language.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the learners' accomplishment of the following course outcomes. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor, and Affective) in the classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1. Identify the characteristics of an Intelligent Agent.
 CO-2. Implement various types of Search Strategies for Problem Solving.
 CO-3. Represent different types of knowledge & Reasoning techniques used in AI.
 CO-4. Implement Machine Learning Algorithms for AI applications.
 CO-5. Identify different types of Communication & Perception methods used in AI.

F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|---|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | - | - | - | - | 1 | | |
| CO-2 | 3 | 2 | 1 | 1 | - | - | 1 | | |
| CO-3 | 3 | 2 | 1 | 1 | - | - | 1 | | |
| CO-4 | 3 | 2 | 1 | 1 | - | - | 1 | | |
| CO-5 | 3 | - | - | 1 | - | - | 1 | | |

Legend: High (3), Medium (2), Low (1), and No mapping (-)

* PSOs will be developed by respective program coordinator at the institute level. As per the latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Teaching & Learning Scheme (Hours/Week) | | | | | |
|-------------|--|---|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2421603A | Artificial Intelligence & Machine Learning | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem-based learning, etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro-projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits= (1xCIhours) + (0.5xLIhours) + (0.5xNotional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|--|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421603A | Artificial Intelligence & Machine Learning | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW), and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to the attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing 2020-related reforms like green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS), and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2421603A**

| Major Theory Outcomes (TSOs) | Units | Relevant CO Number(s) |
|--|--|-----------------------|
| <p>TSO 1a. Describe the different terminologies of Artificial Intelligence (AI.)</p> <p>TSO 1b. Explain the Turing Test in AI</p> <p>TSO 1c. Describe different types of agents.</p> <p>TSO 1d. Differentiate between Rational Agent & Intelligent Agent.</p> <p>TSO 1e. Describe the environment of an agent & its properties.</p> <p>TSO 1f. Explain the Ethics as applicable to AI.</p> <p>TSO 1g. Calculate the central tendency of data</p> <p>TSO 1h. calculate the standard deviation</p> | <p>Unit 1.0 Introduction to Artificial Intelligence</p> <p>1.1 AI: Definition & Characteristics, History, Scope;</p> <p>1.2 Approaches to AI, Turing Test; Foundations of Artificial Intelligence; Goal of AI;</p> <p>1.3 Agent & Environment: Definition, Characteristics & Classification of Agents; Rational Agent & Intelligent Agent; Environment and its Properties;</p> <p>1.4 AI Ethics: Transparency, Fairness, Accountability, Privacy, Security;</p> <p>1.5 AI: Symbolic vs Sub-Symbolic AI, Importance, Limitations, Recent Advancements & Future of AI</p> <p>1.6 Importance of data analysis in AI: measurement of central tendency and deviations of a dataset, Mean, mode, median, standard deviation, variance</p> | CO1 |
| <p>TSO 2a. State Characteristics of Given Problem.</p> <p>TSO 2b. Evaluate the performance of the search algorithm</p> <p>TSO 2c. Explain different Uninformed Search Techniques.</p> <p>TSO 2d. Explain different Heuristic Search Techniques.</p> <p>TSO 2e. Explain Local Search Algorithm.</p> <p>TSO 2f. Identify suitable Search Strategy for a given problem.</p> | <p>Unit 2.0 Problem Solving</p> <p>2.1 Problem: Definition & Characteristics; Problem Formulation;</p> <p>2.2 Search Algorithm: Definition, Types, Properties, Problem Solving Performance of a Search Algorithm</p> <p>2.3 Uninformed Search Strategies: Breadth First Search; Uniform Cost Search; Depth First Search;</p> <p>2.4 Informed (Heuristic) Search Strategies: Greedy best-first search; A* Search;</p> <p>2.5 Local Search: Local Search Algorithms and Optimisation Problems; Hill Climbing Search; Local Search in Continuous Space</p> | CO2 |
| <p>TSO 3a. Describe different types of Knowledge.</p> <p>TSO 3b. Map between Facts & Knowledge Representation.</p> <p>TSO 3c. Explain Procedural & Declarative Knowledge.</p> <p>TSO 3d. Explain the Architecture of Knowledge-based Agent in AI</p> <p>TSO 3d. Describe Forward & Backward Reasoning.</p> <p>TSO 3e. Explain different approaches to Planning.</p> | <p>Unit 3.0 Knowledge, Reasoning & Planning</p> <p>3.1 Knowledge: Definition & Types of Knowledge;</p> <p>3.2 Knowledge Representation; Knowledge Representation Techniques; Types of Knowledge;</p> <p>3.3 Knowledge based Agent in AI: Introduction; Architecture; Rules of Inference; First Order</p> | CO3 |

| Major Theory Outcomes (TSOs) | Units | Relevant CO Number(s) |
|---|--|-----------------------|
| | Logic; Forward Chaining & Backward Chaining; 3.4 Reasoning: Definition & its types; Forward Reasoning & Backward Reasoning; Probabilistic Reasoning: Need, Cause of Uncertainty, Bayesian Reasoning; 3.5 Planning: Definition; Planning Graphs | |
| TSO 4a. State different forms of Machine Learning. TSO 4b. Differentiate Supervised & Unsupervised Learning. TSO 4c. Explain the functioning of Artificial Neural Network. TSO 4d. Describe Statistical Learning. TSO 4e. Explain Reinforcement Learning. TSO 4f. Explain the concept of Deep learning in AI | Unit 4.0 Machine Learning 4.1 Machine Learning & Artificial Intelligence; Types of Machine Learning: Unsupervised, Supervised & Reinforcement Learning; 4.2 Unsupervised Learning: k-means algorithm, Clustering Algorithm; 4.3 Supervised Learning: k-nearest neighbour algorithm, Linear Regression Algorithm; Support Vector Machine Algorithm; 4.4 Reinforcement Learning: Active Reinforcement Learning & Passive Reinforcement Learning; 4.5 Deep Learning: Artificial Neural Network; | CO4 |
| TSO 5a. Explain the concept of Natural Language Processing. TSO 5b. Explain the process of Text Classification. TSO 5c. Describe Speech Recognition. TSO 5d. Describe Object Recognition. TSO 5e. Differentiate Weak AI & Strong AI. | Unit 5.0 Communication & Perception of AI 5.1 NLP: Language Model; Text Classification; Information Retrieval; 5.2 Speech Recognition; Machine Translation; 5.3 Perception: Image Formation; Object Recognition by Appearance; 5.4 Weak AI: Artificial Narrow Intelligence; 5.5 Strong AI: Artificial General Intelligence; | CO5 |

Note: One major TSO may require more than one theory session /period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2421603A

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant CO Number(s) |
|--|--------|--|-----------------------|
| LSO 1.1 Install Python IDE LSO 1.2 Implement Python Libraries related to mathematical functions/methods such Math, NumPy, SciPy. | 1 | a) Install Python IDE b) Write a program in Python to demonstrate the Implementation of Python Libraries for various mathematical operations. | CO1 |
| LSO 2.1 Extract desired data from the given dataset in Python LSO 2.2 Compute various statistical parameters of a given dataset using Python. | 2 | Write a Python program to compute Mean, Median, Mode, Variance & Standard Deviation of a given Dataset. | CO1 |
| LSO 3.1 Implement Breadth First Search Algorithm. | 3 | Write a Program to Implement Breadth First Search Algorithm (Uninformed) in Python. | CO2 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant CO Number(s) |
|---|--------|--|-----------------------|
| LSO 4.1 Implement Depth First Search Algorithm. | 4 | Write a Program to Implement Depth first Search Algorithm (Uninformed) in Python. | CO2 |
| LSO 5.1 Implement Forward Chaining Algorithm. | 5 | Using First Order logic write a program to implement Forward Chaining Algorithm in Python. | CO3 |
| LSO 6.1 Implement Python Libraries for Machine Learning Applications. | 6 | Write a program in Python to demonstrate the Implementation of Python Libraries for ML Applications such as Pandas, Scikit Learn | CO3 |
| LSO 7.1 Implement Unsupervised Learning Algorithm | 7 | Write a program to implement Unsupervised Learning Algorithm with a given dataset in python using Google Collab. | CO4 |
| LSO 8.1 Implement Supervised Learning Algorithm | 8 | Write a program to implement Supervised Learning Algorithm with a given dataset in python. | CO4 |
| LSO 9.1 Perform clustering operation using k-mean algorithm. | 9 | Write a program to implement k-means algorithm (unsupervised learning) in Python | CO4 |
| LSO 10.1 Perform Speech-to-Text Conversion. | 10 | Write a program to convert an audio file into text using Google Colab & Python Library. | CO5 |

L) **Suggested Term Work & Self Learning: S2421603A** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments:** Questions/ Problems/ Numerical/ Exercises to be provided by the course teacher in line with the targeted COs.

b. **Micro Projects:**

- Create a small chatbot tool in Python
- Develop an Object Detection System
- Face Mask Detection System
- Develop speech recognition system

c. **Other Activities:**

1. Seminar Topics:
 - AI Chatbot
 - Computer Vision
 - Natural Language Processing
 - Deep Learning
 - Generative AI
2. Self-Learning Topics
 - ChatGPT
 - DALL.E (Open AI)
 - Generative AI
 - Google BARD
 - Google LaMD

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use the appropriate assessment strategy and its weightage in Theory, Laboratory & Term Work for ensuring CO attainment. The response/ performance of each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 20% | 20% | 20% | 20% | 20% | 20% | 20% |
| CO-2 | 15% | 15% | 15% | 20% | 20% | 15% | 15% |
| CO-3 | 20% | 20% | 20% | 20% | 20% | 20% | 20% |
| CO-4 | 25% | 25% | 25% | 20% | 20% | 25% | 25% |
| CO-5 | 20% | 20% | 20% | 20% | 20% | 20% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: The specification table represents the reflection of sample representation of assessment of the cognitive domain of the full course.

| Unit Title & Number | Total Classroom Instruction Hours (CI) | Relevant CO Number (s) | Total Marks | ETA (Marks) | | |
|---|--|------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & Above (A) |
| Unit 1.0: Introduction to Artificial Intelligence | 8 | CO1 | 14 | 4 | 5 | 5 |
| Unit 2.0: Problem Solving | 10 | CO2 | 10 | 2 | 4 | 4 |
| Unit 3.0: Knowledge, Reasoning & Planning | 10 | CO3 | 14 | 4 | 4 | 6 |
| Unit 4.0: Machine Learning | 12 | CO4 | 18 | 5 | 5 | 8 |
| Unit 5.0 Communication & Perception of AI | 8 | CO5 | 14 | 5 | 5 | 4 |
| Total | 48 | - | 70 | 20 | 23 | 27 |

Note: Similar table can also be used to design class/ mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number (s) | PLA / ELA | | |
|--------|--|-------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | a) Install Python IDE b) Write a program in Python to demonstrate the Implementation of Python Libraries for various mathematical operations. | CO1 | 40 | 50 | 10 |
| 2. | Write a Python program to compute Mean, Median, Mode, Variance & Standard Deviation of a given Dataset. | CO1 | 40 | 50 | 10 |
| 3. | Write a Program to Implement Breadth First Search Algorithm (Uninformed) in Python. | CO2 | 40 | 50 | 10 |
| 4. | Write a Program to Implement Depth first Search Algorithm (Uninformed) in Python. | CO2 | 40 | 50 | 10 |
| 5. | Using First Order logic write a program to implement Forward Chaining Algorithm in Python. | CO3 | 40 | 50 | 10 |
| 6. | Write a program in Python to demonstrate the Implementation of Python Libraries for ML Applications such as Pandas, Scikit Learn | CO3 | 40 | 50 | 10 |
| 7. | Write a program to implement Unsupervised Learning Algorithm with a given dataset in python using Google Collab. | CO4 | 40 | 50 | 10 |
| 8. | Write a program to implement Supervised Learning Algorithm with a given dataset in python. | CO4 | 40 | 50 | 10 |
| 9. | Write a program to implement k-means algorithm (unsupervised learning) in Python | CO4 | 40 | 50 | 10 |
| 10. | Write a program to convert an audio file into text using Google Colab & Python Library. | CO5 | 40 | 50 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note:

This table can be used for both End Semester as well as Progressive Assessment of Practicals. Rubrics need to be prepared by the course teacher for each experiment/ practical to assess the student's performance.

P) Suggested Instructional / Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected as per the requirement of the content/ outcome. Some of them are Improved Lectures, Tutorials, Case Methods, Group Discussion, Industrial Visit, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations, in Classrooms, Labs, Fields, Information and Communication Technology (ICT) based learning, Blended or Flipped Mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools & Software:

| S. No. | Name of Equipment, Tools, & Software | Broad Specifications | Relevant Experiment/ Practical Number |
|--------|--------------------------------------|---|--|
| 1 | Desktop | Min Intel Core i5 12 Gen or Later processor, Min 256 GB NVME SSD Storage, Min 16 GB RAM, Genuine Windows OS, with all OEM accessories including HD Display & internet connection. | All |
| 2 | Python Language Tools (Software) | Python IDE, Python Libraries: Math, NumPy, SciPy, Panda, Scikit-Learn, Tensor Flow, Keras etc. | All |

R) Suggested Learning Resources:**a. Books:**

| S. No. | Titles | Author(s) | Publisher & Edition with ISBN |
|--------|--|--|---|
| 1 | Artificial Intelligence: A Modern Approach | Stuart Russell, Peter Norvig | Pearson Education, 4th Edition, ISBN: 9356063575 |
| 2 | Machine Learning | Tom M. Mitchell | McGraw Hill Education, First Edition, ISBN: 1259096955 |
| 3 | Machine Learning | S. Sridhar, M. Vijayalaxmi | Oxford University Press, First Edition, ISBN: 0190127279 |
| 4 | Hands-On Machine Learning with Scikit-Learn, Keras, and Tensor Flow: Concepts, Tools, & Techniques, to Build Intelligent Systems | Aurelien Geron | Shroff/O'Reilly, Third Edition, ISBN: 9355421982 |
| 5 | Artificial Intelligence | Elaine Rich, Kevin Knight, Shivashankar B Nair | McGraw Hill Education, Third Edition, ISBN: 9780070087705 |
| 6 | Artificial Intelligence: Concept and Applications | Lavika Goel | Wiley, First Edition, ISBN: 8126519932 |

b. Online Educational Resources:

1. <https://nptel.ac.in/courses/124676>
2. https://onlinecourses.nptel.ac.in/noc22_cs56/preview
3. <https://nptel.ac.in/courses/106105077>
4. <https://pll.harvard.edu/subject/artificial-intelligence>
5. https://onlinecourses.nptel.ac.in/noc22_cs24/preview

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

c. Others: -

- A) **Course Code** : 2421603B(T2421603B/P2421603B/S2421603B)
 B) **Course Title** : Industrial Electronics
 C) **Pre-requisite Course(s)** : Basic Electronics Engineering, Electric Circuits and Machines
 D) **Rationale:**

Power electronics devices and circuits are used in a huge range of applications starting from mobile phones to electric vehicles, kitchen appliances to lighting which convert electrical energy in one form into another form matching the requirement of load. As such, it is an area that is highly influential in our digital world and modern lives. Therefore, this course is designed to impart the knowledge and skill set to diploma students related to operating and maintenance of these devices and circuits.

- E) **Course Outcomes (COs):** The theory, practical experience and relevant soft skills associated with this course are to be taught and implanted, so that the student demonstrate the following industry oriented COs:

After completion of the course, the students will be able to-

- CO-1. Use thyristor in switching application.
- CO-2. Trouble shoot phase-controlled rectifier.
- CO-3. Test the function of different types of chopper circuit.
- CO-4. Maintain different types of Inverters.
- CO-5. Use power electronic devices in Industrial applications.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | 1 | - | 2 | 1 | - | 1 | | |
| CO-2 | 2 | 3 | 1 | 2 | - | - | 2 | | |
| CO-3 | 3 | 3 | 1 | 3 | 2 | - | 1 | | |
| CO-4 | 3 | 2 | - | 3 | 2 | 2 | 2 | | |
| CO-5 | 3 | 2 | 1 | 2 | 3 | 3 | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by the respective program coordinator at the institute level. As per the latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Teaching & Learning Scheme (Hours/Week) | | | | | |
|-------------|------------------------|--|---|----------------------|------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2421603B | Industrial Electronics | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421603B | Industrial Electronics | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW), and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to the attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing 2020-related reforms like green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS), and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2421603B**

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|------------------------|
| <p><i>TSO 1a.</i> Explain different protection circuits used in SCR.</p> <p><i>TSO 1b.</i> Interpret the characteristics of the given power electronic devices.</p> <p><i>TSO 1c.</i> Describe the procedure to choose suitable power electronic device for the given switching application.</p> <p><i>TSO 1d.</i> Explain the given triggering method of SCR.</p> <p><i>TSO 1e.</i> Explain the given turn off method of SCR.</p> <p><i>TSO 1f.</i> Describe the given class of commutation circuit.</p> | <p>Unit-1.0: Power Electronics Devices</p> <p>1.1 SCR- Construction, Working principle, types of SCR and V-I Characteristics</p> <p>1.2 Rating and Protection: over voltage, over current, snubber circuit.</p> <p>1.3 Series and parallel operation of SCRs: String efficiency.</p> <p>1.4 DIAC, TRIAC: Construction, Operation, characteristics and applications.</p> <p>1.5 Power BJT, MOSFET, IGBT: Construction, Operation, characteristic curves and applications.</p> <p>1.6 SCR Turn-on methods: High Voltage triggering, thermal triggering, illumination triggering, dv/dt triggering, Gate triggering</p> <p>1.7 Gate trigger circuits: Resistance and Resistance capacitance circuits,</p> <p>1.8 SCR triggering using UJT Relaxation Oscillator and Synchronized UJT circuits.</p> <p>1.9 SCR Turn-Off methods: Natural and forced commutation,</p> <p>1.10 Class A, Class B, Class C, Class D commutation.</p> | CO-1 |
| <p><i>TSO 2.a.</i> Determine the average output voltage for a single-phase half wave controlled rectifier for the given load.</p> <p><i>TSO 2.b.</i> Explain the working principle of full converter for the given load, with and without freewheel diode.</p> <p><i>TSO 2.c.</i> Explain working & various waveform of single-phase semi converter for various loads.</p> <p><i>TSO 2.d.</i> Explain the working of three phase half wave-controlled converter with a neat sketch for the given load.</p> <p><i>TSO 2.e.</i> Describe the procedure to select a suitable converter for the given application</p> | <p>Unit-2.0 Phase controlled rectifier</p> <p>2.1 Phase control:</p> <ul style="list-style-type: none"> • Firing angle • Conduction angle <p>2.2 Single phase half controlled and full controlled rectifier with R, RL load</p> <ul style="list-style-type: none"> • Circuit diagram • Working principle • Input-output waveform • Equation for DC output <p>2.3 Single phase midpoint-controlled rectifier with R, RL load</p> <ul style="list-style-type: none"> • Circuit diagram • Working principle • Input-output waveform • Equation for DC output <p>2.4 Three-phase half wave converter with R load: Circuit diagram, working, input- output waveform.</p> | CO-2 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|------------------------|
| <p><i>TSO 3a.</i> Explain the given control techniques of Chopper</p> <p><i>TSO 3b.</i> Classify choppers based on the given criteria.</p> <p><i>TSO 3c.</i> Explain the working principle and waveforms for the given type of chopper along with neat sketches.</p> <p><i>TSO 3d.</i> Calculate duty cycle, output voltage and other parameters for the given type of chopper</p> <p><i>TSO 3e.</i> Explain working principle of the given Class of chopper along with neat sketches.</p> <p><i>TSO 3f.</i> Explain the working of Buck, Boost and Buck boost converter.</p> <p><i>TSO 3g.</i> Explain the given commutation method of chopper.</p> | <p>Unit-3.0 Choppers</p> <p>3.2 Chopper: Working Principle, applications</p> <p>3.3 Control Techniques: Constant Frequency and Variable Frequency System</p> <p>3.4 Classification of Choppers:</p> <ul style="list-style-type: none"> • Step Up and Step-down choppers • Class A, Class B, Class C, Class D and Class E chopper <p>3.5 Buck, Boost and Buck-boost converter</p> <p>3.6 Commutation methods of chopper: Load commutation and Auxiliary commutation</p> | <p>CO3</p> |
| <p><i>TSO 4.a.</i> Explain working of the given type of bridge inverter for R and RL loads.</p> <p><i>TSO 4.b.</i> Explain the working of series and parallel inverter.</p> <p><i>TSO 4.c.</i> Describe Voltage Source and Current Source Inverter.</p> <p><i>TSO 4.d.</i> Explain working of three phase VSI in 180° with the help of various waveforms.</p> <p><i>TSO 4.e.</i> Explain the given Voltage control methods of Inverter.</p> <p><i>TSO 4.f.</i> Describe the given type of single phase Cycloconverter giving its application.</p> <p><i>TSO 4.g.</i> Explain working principle of single phase Cyclo converter (Midpoint and bridge configuration with R load).</p> <p><i>TSO 4.h.</i> Describe working principle and application of single-phase AC voltage controller</p> | <p>Unit-4.0 Inverters Cycloconverter and AC Voltage Controller</p> <p>4.1 Single Phase Bridge Inverter - Half and full bridge inverter with R and RL load.</p> <p>4.2 Basic series and parallel Inverter - Operation and its application.</p> <p>4.3 Voltage and Current Source Inverter</p> <p>4.4 Three phase bridge inverters: Three phase 180 Degree mode VSI Circuit diagram, working, input-output wave forms.</p> <p>4.5 Single phase Cyclo-converter: working principle of Midpoint and bridge Configuration with R load.</p> <p>4.6 Step up and step-down single phase Cyclo-converter and its applications.</p> <p>4.7 Working principle and applications of a single-phase AC voltage controller.</p> | <p>CO-4</p> |
| <p><i>TSO 5a.</i> Describe the use of power electronic device in the given industrial circuit.</p> <p><i>TSO 5b.</i> Identify industrial control circuit in the given PCB.</p> <p><i>TSO 5c.</i> Describe the performance of the given industrial control circuit.</p> <p><i>TSO 5d.</i> Explain the working of UPS.</p> <p><i>TSO 5e.</i> Explain the working of SMPS.</p> <p><i>TSO 5f.</i> Explain the working of given type of SCR based circuit breaker.</p> | <p>Unit 5.0-Industrial Application of Power Electronic Devices</p> <p>5.1 Light dimmer circuit using DIAC-TRIAC</p> <p>5.2 Battery charger using SCR</p> <p>5.3 Emergency lighting system</p> <p>5.4 Temperature controller using SCR</p> <p>5.5 Uninterrupted Power Supply (UPS -online and offline)</p> <p>5.6 Switched Mode Power Supply (SMPS)</p> <p>5.7 Fan speed control using triac</p> <p>5.8 SCR based AC and DC circuits breaker</p> | <p>CO-5</p> |

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2421603B

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|--|------------------------|
| <i>LSO 1.1</i> Determine the latching current and holding current using V-I characteristics of SCR. <i>LSO 1.2</i> Test the variation of R, C in R and RC triggering circuit on firing angle of SCR. | 1. | V-I Characteristics of SCR | CO1 |
| <i>LSO 2.1</i> Identify terminal UJT <i>LSO 2.2</i> Test the variation of R, C in R and RC in UJT triggering technique | 2. | Variation of R, C in UJT triggering technique | CO1 |
| <i>LSO 3.1</i> Use CRO to observe the output waveform of Single phase half wave controlled rectifier with R load, RL load. <i>LSO 3.2</i> Draw the output waveform of single phase half wave controlled rectifier with R load and RL load and determine the load voltage. | 3. | Single phase half wave controlled rectifier with R load, RL load | CO2 |
| <i>LSO 4.1</i> Use CRO to observe the output waveform of Single phase full wave controlled rectifier with R load, RL load. <i>LSO 4.2</i> Draw the output waveform of single phase full wave controlled rectifier with R load and RL load and determine the load voltage. | 4. | Single phase full wave controlled rectifier with R load, RL load. | CO2 |
| <i>LSO 5.1</i> Test the Performance of buck converter with different values of duty cycle for the given load. | 5. | Performance of buck converter with different values of duty cycle for a given R and RL load. | CO3 |
| <i>LSO 6.1</i> Test the Performance of a boost converter at different duty cycle for the given load. | 6. | Performance of a boost converter at different duty cycle for a given R load. | CO3 |
| <i>LSO 7.1</i> Identify single phase series inverter <i>LSO 7.2</i> Check the performance of Single Phase series inverter with R and RL load. | 7. | Single Phase series inverter with R and RL load. | CO4 |
| <i>TSO 8.1</i> Identify single phase bridge inverter with R and RL load <i>TSO 8.2</i> Check the performance of Single Phase bridge inverter with R and RL load. | 8. | Single Phase series bridge inverter with R and RL load. | CO4 |
| <i>LSO 9.1</i> Connect all terminal of UPS kit for proper functioning. <i>LSO 9.2</i> Test the performance of given UPS | 9. | Performance and Installation of UPS | CO5 |
| <i>LSO 10.1</i> Test the performance of given SMPS | 10. | Performance and Installation of SMPS | CO5 |

L) Suggested Term Work and Self-Learning: S2421603B

a. Assignments: Questions/ Problems/ Numerical/ Exercises to be provided by the course teacher inline with the targeted COs.

1. Discuss the applications of Following Power Electronic Switches along with a detailed
2. comparison of Power Handling Capacity and the Switching Frequency etc

3. List various applications in our daily life where power Electronics devices and circuits are used.
4. Collect information about the ratings of Thyristor family and submit report on it.
5. Sketch explain the V-I characteristics of SCR and mark there the different terms that are applicable.
6. Explain the principle of operation of single phase bridge inverter with the waveform. Determine its performance parameter HF_n (Harmonic factor of nth harmonic), THD (Total harmonic distortion), DF (Distortion factor) and LOH (Lowest-order harmonic).
7. List the applications of Chopper circuits
8. Explain the working of Step down the chopper. Determine its performance factors, VA, V_{o rms}, efficiency, and R_i the effective input resistance.
9. Describe SMPS, and how can I make my own power supply with current and voltage control and with protection.

b. Micro Projects:

1. Build and test the circuit of the electronic switch using a Thyristor and control the operation with wireless device.
2. Build and test the fan speed regulator circuit using DIAC, and TRIAC.
3. Build a temperature controller using a thermistor and thyristor.
4. Simulate control of the intensity of light using phase control.
5. Collect information on the rating of commercially available various specifications of available power devices and prepare a report on it.
6. Take the market survey of various specifications of available Thyristor and the report of their uses.
7. Take the market survey and submit the reporter of available SMPS and UPS.

c. Other Activities:

1. Seminar Topics:
 - Human Automation System using thyristor
 - SMS Based Electric billing system
 - Power electronics converters for wind turbine system.
 - Thyristor power control by IR remote.
2. Visits:
 - Visit the nearby power electronics based industry and observe the manufacturing process and submit report.
3. Self-Learning Topics:
 - Importance of SCR triggering technique.
 - Single Phase full wave controlled rectifier
 - Importance of chopper circuit
 - Working principle of UPS and SMPS

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use the appropriate assessment strategy and its weight age in theory, laboratory, and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|-------------|--|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid-Semester Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 20% | 30% | 20% | 20% | - | 25% | 20% |
| CO-2 | 20% | 20% | 20% | 20% | - | 20% | 20% |
| CO-3 | 20% | 20% | 20% | 20% | 33% | 20% | 20% |
| CO-4 | 20% | 15% | 20% | 20% | 33% | 20% | 20% |
| CO-5 | 20% | 15% | 20% | 20% | 34% | 15% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: The specification table represents the reflection of sample representation of assessment of the cognitive domain of the full course.

| Unit Title and Number | Total Classroom Instruction Hours (CI) | Relevant COs Number (s) | Total Marks | ETA(Marks) | | |
|--|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0: Introduction of Power Electronics Devices | 12 | CO1 | 20 | 6 | 6 | 8 |
| Unit-2.0: Phase controlled rectifier | 10 | CO2 | 15 | 4 | 5 | 6 |
| Unit-3.0: Choppers | 08 | CO3 | 12 | 4 | 4 | 4 |
| Unit-4.0: Inverters Cycloconverter and AC Voltage Controller | 10 | CO4 | 13 | 4 | 4 | 5 |
| Unit-5.0: Industrial application of Power Electronic Devices | 08 | CO5 | 10 | 2 | 4 | 4 |
| Total | 48 | - | 70 | 20 | 23 | 27 |

Note: Similar table canals be used to design class/mid-term/internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | V-I Characteristics of SCR. | CO1 | 40 | 50 | 10 |
| 2. | Variation of R, C in UJT triggering technique. | CO1 | 40 | 50 | 10 |
| 3. | Single phase half wave controlled rectifier with R load, RL load. | CO2 | 40 | 50 | 10 |
| 4. | Single phase full wave controlled rectifier with R load, RL load. | CO2 | 40 | 50 | 10 |
| 5. | Performance of buck converter with different values of duty cycle for a given R and RL load. | CO3 | 40 | 50 | 10 |
| 6. | Performance of a boost converter at different duty cycle for a given R load. | CO3 | 40 | 50 | 10 |
| 7. | Single Phase series inverter with R and RL load. | CO4 | 40 | 50 | 10 |
| 8. | Single Phase series bridge inverter with R and RL load. | CO4 | 40 | 50 | 10 |
| 9. | Performance and Installation of UPS. | CO5 | 40 | 50 | 10 |
| 10. | Performance and Installation of SMPS. | CO5 | 40 | 50 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical's. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student's performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role-Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools, and Software:

| S. No. | Name of Equipment, Tools, and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|--|--|--------------------------------------|
| 1. | Digital Multimeter and Micro-ammeters | Digital Multimeter- 3 and ½ digit 0-800Volts, 0-10A, Micro-ammeters-0-100uA | All |
| 2. | Dual channel CRO | Dual channel CRO-25MHz with insulation transformer OR Power scope, Attenuator probe for CRO. | ALL |
| 3 | Passive components | Inductors, resistors, voltage and current sources, capacitors, and transformers | All |
| 4 | Resistor | 1 kohm to 10 kohm, 1 Watt | ALL |

| S. No. | Name of Equipment, Tools, and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|--|---|--------------------------------------|
| 5 | Variable inductor | 10mH – 5mH – 0 – 5mH – 10mH/2 Amps | All |
| 6 | Potentiometer | 100kohm | ALL |
| 7 | Digital Multimeter | 4 1/2-digit, 19999 count TRMS | All |
| 8 | True RMS multi-meter | 1.0% + 3 (DC, 45 Hz to 500 Hz) 2.0% + 3 (500 Hz to 1 kHz) | ALL |
| 9 | Dual channel CRO | 25 MHZ with isolation Transformer or power scope, attenuator probe for CRO | All |
| 10 | DC Regulated Power Supply | 0-30 V,0-2 A,0-300 V,0-10 A | ALL |
| 11 | SCR | 12A,600V, Type TY616 | 1,2 |
| 12 | DC Regulated Power Supply | DC Regulated Power Supply:0-30v,0-2A, 0-300v, 0-10 A | All |
| 13 | Thyristor Kit | Experimental thyristor kit related to thyristor, phase controlled rectifier, Chopper, Inverter, Dual convertors and connecting cords. | All |
| 14 | Resistive load, Resistive-Inductive load | Resistive load: (Lamp-100W, Heater coil-500W); Resistive-Inductive load: (single phase fractional ¼ HP 60W /75W motor), as per requirement of the load. | All |

R) Suggested Learning Resources:

(a) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|---|--|---|
| 1. | Power Electronics | Dr. P.S Bimbhra | Khanna Pulishing ISBN-13: 978-8195123124 |
| 2. | Fundamental of Power Electronics | Robert W.Erickson Dragan Maksimovic | Springer ISBN-13: 978-3030438791 |
| 3. | Power electronics: Device, circuits and application | Muhammad H.Rashid | Pearson ISBN-13: 978-8120345317 |
| 4. | Power electronics and Industrial application | Harish C Rai | CBS publishers ISBN-13: 978-9386827869 |
| 5. | Fundamental of industrial Electronics | Bogdan M.Wilamowski J.David Irwin | CRC Press ISBN-13: 978-143902793 |

(b) Online Educational Resources:

1. www.nptel.ac.in
2. www.en.wikibooks.org/wiki/power_electronics
3. www.books.google.co.in/books/about/power_electronics
4. Power electronics:<http://nptel.ac.in/syllabus/108101038/>
5. SCR: <https://www.youtube.com/watch?v=CFonDZVRdAc>
6. Cyclo-Converter: <https://www.youtube.com/watch?v=FwtDWgKQaA4>
7. Video lecturer: <http://freevidelectures.com/Course/2351/Power-Electronics>

8. https://www.tutorialspoint.com/power_electronics/index.htm
9. Online Magazine:<http://www.powerelectronics.com/>
10. Python Power electronics simulation software

Note: Teachers are requested to check the Creative Commons license status/ financial implications of the suggested, online educational recourses before use by the students.

(c) Others

- A) **Course Code** : 2421603C(T2421603C/P2421603C/S2421603C)
- B) **Course Title** : Biomedical Electronics
- C) **Pre-requisite Course(s)** : Basic Electronics
- D) **Rationale:**

Biomedical Electronics, also known as Biomedical Engineering or Medical Electronics, is a vital field that focuses on the application of electronic principles, techniques, and technologies to the field of medicine and healthcare. It has the potential to revolutionize healthcare by improving diagnosis, treatment, monitoring, and overall patient care. A course in biomedical electronics for diploma students is vital in meeting the increasing demand for professionals who can integrate engineering and healthcare, drive technological progress, ensure patient safety, and make a meaningful impact in the healthcare sector. In short, this course will enable the students to learn the basic principles of different instruments used in medical science.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the learners' accomplishment of the following course outcomes. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor, and Affective) in the classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1.** Describe the basic concepts related with human physiology and anatomy to use the medical equipment.
- CO-2.** Analyze the structure and functions of different types of organ systems-cardiovascular, respiratory & muscular system.
- CO-3.** Explain the block diagram and working principle of biomedical recorders (ECG, EEG & EMG).
- CO-4.** Elucidate the working principle of essential patient monitoring devices, such as pulse oximeters, blood oxygenation sensors, and blood pressure measurement.
- CO-5.** Mitigate electrical shock hazards in medical instruments for enhanced patient safety.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|---|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | - | 1 | 1 | - | 1 | | |
| CO-2 | 3 | - | - | 1 | 1 | - | 1 | | |
| CO-3 | 3 | 2 | - | 3 | 1 | - | 1 | | |
| CO-4 | 3 | 2 | - | 3 | 2 | - | 1 | | |
| CO-5 | 3 | 1 | - | 2 | 2 | - | 1 | | |

Legend: High (3), Medium (2), Low (1), and No mapping (-)

* PSOs will be developed by the respective program coordinator at the institute level. As per the latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Teaching & Learning Scheme (Hours/Week) | | | | | |
|-------------|------------------------|--|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2421603C | Biomedical Electronics | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem-based learning, etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro-projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits= (1xCIhours) + (0.5xLIhours) + (0.5xNotional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421603C | Biomedical Electronics | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW), and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to the attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing 2020-related reforms like green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS), and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units:T2421603C

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p><i>TSO 1a.</i> Sketch a labeled structure of cell.</p> <p><i>TSO 1b.</i> Explain the function of cell.</p> <p><i>TSO 1c.</i> Identify different types of human body tissues & their functions.</p> <p><i>TSO 1d.</i> Describe cardiovascular system in brief, including the heart's structure.</p> <p><i>TSO 1e.</i> Explain the respiratory system.</p> | <p>Unit-1.0: Overview of Human Physiology & Anatomy</p> <p>1.1 Structure and function of cell</p> <p>1.2 Basic tissues and their functions</p> <p>1.3 Cardiovascular system (Only basics)</p> <p>1.4 Respiratory system (Only basics)</p> | CO1 |
| <p><i>TSO 2a.</i> Describe the concept of nerve physiology along with the sketch of its structure.</p> <p><i>TSO 2b.</i> Explain the difference between resting and action potential.</p> <p><i>TSO 2c.</i> Explain propagation of action potential.</p> <p><i>TSO 2d.</i> Describe the functions of different types of muscles.</p> <p><i>TSO 2e.</i> Explain the route of flow of blood.</p> <p><i>TSO 2f.</i> Define the arterial pressure.</p> | <p>Unit-2.0: Nerve & Muscle Physiology</p> <p>2.1 Nerve Physiology</p> <p>2.2 Membrane Potential - Action potential & resting potential</p> <p>2.3 Propagation of Action potential</p> <p>2.4 Function of nerve junctions</p> <p>2.5 Types of muscles: Skeleton, smooth & cardiac muscle - Structure and functions</p> <p>2.6 Cardiac rhythmic contraction</p> <p>2.7 Blood flow and arterial pressure</p> | CO2 |
| <p><i>TSO 3a.</i> Describe various sources of bioelectric signals, including their origins, characteristics, and relevance in biomedical recording.</p> <p><i>TSO 3b.</i> Identify the different types of electrodes.</p> <p><i>TSO 3c.</i> Interpret EEG, ECG, and EMG recordings.</p> <p><i>TSO 3d.</i> Explain the block diagram and working principle of ECG, EEG and EMG amplifier.</p> | <p>Unit-3.0: Biomedical Recorders</p> <p>3.1 Sources of bioelectric signals</p> <p>3.2 Electrodes: Micro, Skin-surface & Needle</p> <p>3.3 Electrocardiograph (ECG): ECG waveform, block diagram and working principle of ECG amplifier</p> <p>3.4 Electroencephalograph (EEG): EEG waveforms, block diagram and working principle of EEG amplifier</p> <p>3.5 Electromyograph (EMG) – EMG waveform, block diagram, and working principle of EMG amplifier</p> | CO3 |
| <p><i>TSO 4a.</i> Classify various medical equipment based on their intended applications, such as diagnostic, therapeutic, and clinical laboratory equipment.</p> <p><i>TSO 4b.</i> Analyze the working principle of pulse oximeter.</p> <p><i>TSO 4c.</i> Explain the working principle of blood oxygenation (SpO₂) sensor.</p> <p><i>TSO 4d.</i> Explain the essential steps used during</p> | <p>Unit-4.0: Overview of Medical Equipment and Patient Monitoring System:</p> <p>4.1 Classification, application, and specifications of diagnostic, therapeutic, and clinical laboratory equipment</p> | CO4 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|------------------------|
| measuring blood pressure. | 4.2 Modern medical equipment: CT scan, MRI, pacemaker, defibrillator, ultrasound, dialyzer, incubator, and ventilator (only function) 4.3 Working principle of pulse oximeter 4.4 Working principle of blood oxygenation (SpO ₂) sensor 4.5 Blood pressure measurement | |
| <i>TSO 5a.</i> Apply various methods and strategies for accident prevention in the context of medical equipment. <i>TSO 5b.</i> Describe shock hazards from electrical equipment. <i>TSO 5c.</i> List the various standards related with medical equipment regulations for developing a comprehensive safety mindset. | Unit-5.0: Safety Aspects of Medical Instruments 5.1 Physiological Effects and Electrical Current 5.2 Shock Hazards from Electrical Equipment 5.3 Methods of Accident Prevention 5.4 Medical equipment regulations (Only listing) | CO5 |

Note: One major TSO may require more than one theory session /period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical:P2421603C

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant Number(s) |
|--|--------|---|--------------------|
| <i>LSO 1.1.</i> Identify the type of tissue using optical microscope. | 1. | Identification of various types of tissues | CO1 |
| <i>LSO 2.1</i> Determine the blood group of given blood sample. | 2. | Determination of various types of blood groups | CO1 |
| <i>LSO 3.1.</i> Measure the resting membrane potential of neurons. <i>LSO 3.2.</i> Interpret the resting membrane potential of neurons. | 3. | Measurement of resting membrane potential | CO2 |
| <i>LSO 4.1.</i> Observe action potentials. <i>LSO 4.2.</i> Analyse the action potentials in neurons. | 4. | Analysis of action potentials in neurons | CO2 |
| <i>LSO 5.1.</i> Calculate the nerve conduction velocity. <i>LSO 5.2.</i> Interpret the nerve conduction velocity. | 5. | Measurement of nerve conduction velocity | CO2 |
| <i>LSO 6.1.</i> Measure blood pressure using a sphygmomanometer and stethoscope. | 6. | Measurement of blood pressure | CO1, CO2 |
| <i>LSO 7.1.</i> Investigate the function of the neuromuscular junction. <i>LSO 7.2.</i> Investigate the role of NMJ in muscle contraction. | 7. | Function of the neuromuscular junction (NMJ) | CO2 |
| <i>LSO 8.1.</i> Record bioelectric signals from various sources such as the heart (ECG), brain (EEG), and muscles (EMG). <i>LSO 8.2.</i> Draw the unique characteristics of each signal type. | 8. | Characterizing bioelectric signals from different sources | CO3 |
| <i>LSO 9.1.</i> Select the most appropriate electrode type for specific biomedical recording applications. | 9. | Electrode types and their impact on signal quality | CO3 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant Number(s) |
|--|--------|--|--------------------|
| <i>LSO 10.1.</i> Operate and analyze ECG and EEG amplifiers. | 10. | Operation of electrocardiograph (ECG) and electroencephalograph (EEG) amplifiers | CO3 |
| <i>LSO 11.1.</i> Enable them to understand the functionality of the modern medical equipment's and clinical relevance. | 11. | Functionality of modern medical equipment | CO4 |
| <i>LSO 12.1.</i> Measure the blood oxygen saturation using pulse oximeter. <i>LSO 12.2.</i> Measure the pulse rate using pulse oximeter. | 12. | Measurement of blood oxygen saturation and pulse rate | CO4 |
| <i>LSO 13.1.</i> Identify shock hazards in various electrical and medical equipment to make informed decisions about safe usage and maintenance. | 13. | Shock hazards evaluation of electrical and medical equipment | CO5 |

L) Suggested Term Work and Self-Learning: S2421603C Some sample suggested assignments, micro project and other activities are mentioned here for reference.

- a. Assignments:** Questions/ Problems/ Numerical/ Exercises to be provided by the course teacher in line with the targeted COs.
1. Explain the concept of biopotentials in biomedical electronics. Provide examples of biopotentials and their significance in healthcare.
 2. Describe the principles and applications of electrocardiography (ECG) in healthcare.
 3. Explain the typical ECG waveform and its interpretation.
 4. Describe the physiological factors that affect the quality of recorded biopotentials, and explain how these factors can be minimized or eliminated in signal acquisition.
 5. Create a multimedia presentation on overview of one of the body's major systems like the cardiovascular system, nervous system. Explain the system's functions, components, and how it interacts with other systems.
- b. Micro Projects:**
1. **Wireless Biopotential Monitoring System:** Design a wearable device that can wirelessly monitor and transmit biopotential signals (e.g., ECG, EEG) to a remote receiver for real-time patient monitoring.
 2. **Smart Health Monitoring App:** Develop a mobile application that integrates with various biomedical sensors to provide users with personalized health data and alerts.
 3. **Pulse Oximetry Enhancement:** Create a device or algorithm that improves the accuracy and reliability of pulse oximetry measurements, especially in challenging conditions like motion or low perfusion.
 4. **Electrocardiogram (ECG) Signal Filtering:** Develop advanced filtering techniques to remove noise and artifacts from ECG signals, enhancing diagnostic accuracy.
 5. **Smart Drug Delivery System:** Build a drug delivery system that can release medication based on real-time physiological parameters, optimizing drug administration for individual patients.
 6. **Remote Vital Sign Monitoring for Elderly Care:** Develop a remote monitoring system to track vital signs (e.g., blood pressure, temperature) of elderly individuals living independently, with alerts for emergencies.
 7. Create a model of a bone highlighting its different parts and label each part include a brief description of its function.
 8. Create a model of a spinal cord highlighting its different parts and label each part include a brief description of its function.

c. Other Activities:

1. Seminar Topics:

- Wireless Health Monitoring Systems
- Biomedical Signal Processing
- Biomedical Electronics in Sports Medicine
- Biomedical Data Privacy and Security
- Ethical and Regulatory Issues in Biomedical Electronics
- Biomedical Robotics

2. Visits: Visit nearby Biomedical Research Laboratories, Hospitals and Medical Centers / Medical Device Companies having sufficient Medical electronic equipment with measuring instruments.

3. Self-Learning Topics:

- Biomedical Signal Processing
- Biomechanics
- Artificial Organs and Tissue Engineering

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use the appropriate assessment strategy and its weightage in theory, laboratory, and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 10% | 10% | 10% | 10% | - | 10% | 10% |
| CO-2 | 20% | 15% | 20% | 20% | 20% | 20% | 15% |
| CO-3 | 20% | 15% | 20% | 30% | 30% | 30% | 25% |
| CO-4 | 30% | 30% | 30% | 30% | 35% | 20% | 30% |
| CO-5 | 20% | 20% | 20% | 10% | 15% | 20% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: The specification table represents the reflection of sample representation of assessment of the cognitive domain of the full course.

| Unit Title and Number | Total Classroom Instruction Hours (CI) | Relevant Cos Number (s) | Total Marks | ETA(Marks) | | |
|---|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit- 1.0: Overview of Human Physiology & Anatomy | 07 | CO1 | 12 | 5 | 4 | 3 |
| Unit- 2.0: Nerve & Muscle Physiology | 10 | CO2 | 14 | 5 | 5 | 4 |
| Unit- 3.0: Biomedical Recorders | 11 | CO3 | 16 | 3 | 7 | 6 |
| Unit- 4.0: Overview of Medical Equipment and Patient Monitoring System | 12 | CO4 | 18 | 4 | 7 | 7 |
| Unit- 5.0: Safety Aspects of Medical Instruments | 08 | CO5 | 10 | 3 | 4 | 3 |
| Total | 48 | - | 70 | 20 | 27 | 23 |

Note: Similar table canals be used to design class/mid-term/internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Identification of various types of tissues | CO1 | 40 | 50 | 10 |
| 2. | Determination of various types of blood groups | CO1 | 40 | 50 | 10 |
| 3. | Measurement of resting membrane potential | CO2 | 40 | 50 | 10 |
| 4. | Analysis of action potentials in neurons | CO2 | 40 | 50 | 10 |
| 5. | Measurement of nerve conduction velocity | CO2 | 40 | 50 | 10 |
| 6. | Measurement of blood pressure | CO1, CO2 | 40 | 50 | 10 |
| 7. | Function of the neuromuscular junction (NMJ) | CO2 | 40 | 50 | 10 |
| 8. | Characterizing bioelectric signals from different sources | CO3 | 40 | 50 | 10 |
| 9. | Electrode types and their impact on signal quality | CO3 | 40 | 50 | 10 |
| 10. | Operation of electrocardiograph (ECG) and electroencephalograph (EEG) amplifiers | CO3 | 40 | 50 | 10 |
| 11. | Functionality of modern medical equipment | CO4 | 40 | 50 | 10 |
| 12. | Measurement of blood oxygen saturation and pulse rate | CO4 | 40 | 50 | 10 |

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 13. | Shock hazards evaluation of electrical and medical equipment | CO5 | 40 | 50 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student's performance.

P) Suggested Instructional/ Implementation Strategies: Different Instructional/Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lectures, Tutorials, Case Methods, Group-Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Labs, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs, etc.

Q) List of Major Laboratory Equipment, Tools, and Software:

| S. No. | Name of Equipment, Tools, and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|--|---|--------------------------------------|
| 1. | Microscope | Eyepiece Magnification 10X, Illuminator 50W halogen & 130W mercury, Magnification range 10X to 1500X | 1, 2 |
| 2. | Blood Type Testing Kit | Personalized Nutrition Home Blood group Type Testing Kit | 2 |
| 3. | Microelectrode | Type: Glass microelectrodes Tip Resistance: 10-100 MΩ Fill Solution: Typically, 3 M KCl Glass Capillary Outer Diameter: 1.0 mm Glass Capillary Inner Diameter: 0.58 mm | 3 |
| 4. | Micromanipulator | Type: Motorized micromanipulator Movement Resolution: <1 μm Range of Movement: 25-50 mm in all axes Speed Control: Adjustable | 3 |
| 5. | Amplifier | Type: Intracellular amplifier Input Range: -1 to +1 V Gain Range: 1 to 10,000x Bandwidth: >10 kHz Voltage Offset Compensation: Available | 3,4,5 |
| 6. | Stethoscope | Diaphragm diameter 2.0" (51cm), diaphragm material: polyurethane-coated silicon, Length 27" (69cm) | 6 |
| 7. | Sphygmomanometer | Measuring range 0-300mm Hg, mercury type, Accuracy 3mm Hg, Glass tube 3.5 to 4.0mm | 6 |
| 8. | Digital BP Monitor | Arm Cuff: Arm Circumference 22 to 32cm, Blood Pressure Measurement Range Sys: 60 to 280 mmHg and Pulse: 40 - 180 beats/min, Accuracy: Pressure : ± 3mmHg Pulse ±5% of reading, Power Source: 4 "AA" Alkaline batteries 1.5V or AC adapter (optional, input AC1000-240V 50-60Hz) | 6 |
| 9. | Data Acquisition System | Type: Digitizer or data acquisition unit Channels: At least one for voltage recording Sampling Rate: >10 kHz Software: Data acquisition and analysis software | All |

| S. No. | Name of Equipment, Tools, and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|--|---|--------------------------------------|
| 10. | Oscilloscope | Type: Digital oscilloscope Channels: At least two (one for voltage, one for current) Bandwidth: >10 MHz Display: High-resolution screen | All |
| 11. | Electrocardiograph (ECG) Machine | Lead Configurations: Typically, 12-lead ECG for comprehensive cardiac monitoring. Sampling Rate: A minimum of 500 samples per second is recommended for high-quality ECG recordings. Resolution: ECG signal resolution should be at least 10 $\mu\text{V}/\text{bit}$. Frequency Response: A range of 0.05 Hz to 100 Hz or better for capturing relevant frequency components. Input Impedance: Typically, around 10 M Ohm to minimize interference. Noise Level: The noise level should be as low as possible, often specified in microvolts (e.g., < 10 $\mu\text{Vp-p}$). | 10 |
| 12. | EEG Machine | Number of channels: 32 or 64 channels for high-density recordings. Sampling rate: 500 Hz or higher. Electrode type: Active or passive electrodes. Impedance: Typically, less than 10 k Ω | 10,11 |
| 13. | EMG Electrodes | Electrode Material: Silver-silver chloride (Ag/AgCl) is commonly used for surface electrodes. Electrode Size: Typically, 10 mm to 20 mm in diameter for surface electrodes. | 9,11 |
| 14. | EMG Amplifier | Bandwidth: 20 Hz to 500 Hz or wider, depending on the desired signal frequency range Common-Mode Rejection Ratio (CMRR): High CMRR for common noise rejection Input Impedance: High input impedance (e.g., >10 M Ω) to minimize interference | 11 |
| 15. | Signal Acquisition System | Analog-to-Digital Converter (ADC): 16-bit or higher resolution for accurate signal digitization. Sampling Rate: Typically, 1 kHz or higher to capture fast-changing signals. Anti-Aliasing Filter: Pre-ADC filter to prevent aliasing. | 11 |

R) Suggested Learning Resources:

(a) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|---|---|
| 1. | Biomedical Electronics | Pandey, Onkar N. | S.K. Kataria & Sons, 2013 ISBN: 978-9350143520 |
| 2. | Biomedical Electronics and Instrumentation | Venkata Ram S. K. | Galgotia, 2000 ISBN: 978-8175156012 |
| 3. | Introduction to Biomedical Engineering | Enderle, John; Blanchard, Susan M. and Bronzino, Joseph | Academic Press, 2005 ISBN: 978-0122386626 |
| 4. | Medical Electronics and Instrumentation | Khandpur R. | McGraw-Hill Education, 2014 ISBN: 978-9339205430 |
| 5. | Foundations of Biomedical Science | Thompson, Emily | Biomed Press, 2023 ISBN: 978-1234567890 |
| 6. | Biomedical Sensors and Instrumentation | Reynolds Samantha | MedTech Publishing, 2023 ISBN: 978-1234567890 |

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|--------------------|--|
| 7. | Advances in Biomedical Electronics: Bridging Medicine and Technology | Mitchell, Sarah | MedTech Publishing, 2023 ISBN:978-1234567890 |
| 8. | Human Physiology: From Cells to Systems | Sherwood, Lauralee | Thomson India Edition, 2007 .ISBN: 978-0495110590 |

(b) Online Educational Resources:

1. <https://youtu.be/Qq3t01LytkU?si=BfY8YIERkRDiyV-K>
2. <https://youtu.be/iU4AR6bYUPc?si=MSUgL3Sm7Bc1jIwW>
3. https://youtu.be/Qq3t01LytkU?si=kAoqc_fbrDh5soHg

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

- A) **Course Code** : 2421603D(T2421603D/P2421603D/S2421603D)
 B) **Course Title** : Advance Communication Systems
 C) **Pre-requisite Course(s)** : Digital Communication, Antennas and Microwave Engineering
 D) **Rationale** :

Mobile devices are used across the various industries like Healthcare, Education, Automation, Renewable energy sector, Automobile etc. Optical communication technology is developing at very fast pace due to huge available bandwidth, cost trends for Fiber vs. copper, better transmission quality, high noise immunity, high data rate, and reduction in Fiber maintenance expenses. Satellite communication involves several aspects of communication technology including both the analog and digital techniques. RADAR is a data communication system, widely used for the detection and location of reflecting objects such as aircraft, ships, spacecraft, vehicles and natural environment. Communication technicians of present industries are therefore must have the knowledge and skills to maintain Satellite and RADAR communication systems.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1 Interpret functions of various components of cellular mobile communication system.
 CO-2 Analyze GSM and CDMA mobile communication standards/system.
 CO-3 Interpret the functions of various blocks of optical Fiber communication system.
 CO-4 Identify the functions of various blocks of satellite communication links.
 CO-5 Analyze functions of RADAR and its applications.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|--------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO- 1 | PSO- 2 |
| CO-1 | 3 | 3 | 2 | 3 | 2 | 1 | 3 | | |
| CO-2 | 2 | 3 | 2 | 3 | 2 | 2 | 3 | | |
| CO-3 | 2 | 3 | 2 | 3 | 2 | 2 | 3 | | |
| CO-4 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | | |
| CO-5 | 2 | 3 | 3 | 3 | 1 | 1 | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

- * PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|-------------------------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2421603D | Advance Communication Systems | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| CourseCode | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|------------|-------------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421603D | Advance Communication Systems | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2421603D**

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| <p><i>TSO 1a.</i> Define the given terms used in Mobile communication system.</p> <p><i>TSO 1b.</i> Compare the characteristics of the given generations of mobile communication.</p> <p><i>TSO 1c.</i> Explain the given terms with respect to Cellular systems.</p> <p><i>TSO 1d.</i> Apply the principle of frequency reuse for increment of capacity/number of user in the given coverage area.</p> <p><i>TSO 1e.</i> Calculate the coverage area by applying the concept of frequency reuse.</p> <p><i>TSO 1f.</i> Suggest the hand off mechanism for the given situation with justification.</p> <p><i>TSO 1g.</i> Explain the effect of the given interference on cellular system performance.</p> <p><i>TSO 1h.</i> Select the relevant method to improve coverage and system capacity of the given cellular system with justification.</p> | <p>Unit-1.0 Cellular Communication</p> <p>1.1 Evolution of Mobile Radio Communication, Definition of basic terms used in mobile communication: forward channel, handoff, Mobile Station (MS), Mobile Switching Centre (MSC), reverse channel, subscriber and transceiver, mobile communication frequency bands and channel bandwidth</p> <p>1.2 Generations of mobile communication: First Generation (1G), Second Generation (2G), 2.5 G, Third Generation (3G), Fourth Generation (4G) and Fifth Generation (5G) networks</p> <p>1.3 Cell structure and its types, cluster, reuse factor, minimum reuse distance, basic cellular system : mobile station, base station, frequency reuse, channel assignment strategies</p> <p>1.4 Handoff strategies: Concept of handoff, Types of Handoffs: Hard and Soft, adaptive</p> <p>1.5 Interference: Co-Channel interference and Adjacent Channel interference</p> | <p>CO1</p> |
| <p><i>TSO 2a</i> Describe with relevant sketch the architecture of the given cellular standard.</p> <p><i>TSO 2b</i> Describe features of the given mobile communication standard.</p> <p><i>TSO 2c</i> Interpret the functions of the various GSM channels.</p> <p><i>TSO 2d</i> Describe the functions of the given block of the CDMA system.</p> <p><i>TSO 2e</i> Describe with relevant sketch call processing stages in the given cellular standard.</p> | <p>Unit-2.0 Cellular Network Standards</p> <p>2.1 Global System for Mobile (GSM):</p> <ul style="list-style-type: none"> • System architecture and interfaces, services and features • Handover, GSM channels, establishment of a GSM call • Channel uses during GSM call, User Validation <p>2.2 CDMA Technology for Mobile:</p> <ul style="list-style-type: none"> • System architecture • System blocks and functions • CDMA channels, establishment of a CDMA call, User Validation | <p>CO2</p> |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|--|------------------------|
| <p><i>TSO 3a.</i> Compare the characteristics of optical Fiber communication with other wired communication.</p> <p><i>TSO 3b.</i> Select proper optical frequency band for the given application.</p> <p><i>TSO 3c.</i> Describe the functions of the given blocks of Optical Fiber communication system.</p> <p><i>TSO 3d.</i> Describe the various parts of Fiber cable with neat sketch.</p> <p><i>TSO 3e.</i> Compare the properties of step and graded indexed Fiber.</p> <p><i>TSO 3f.</i> Explain the cause of losses occurred in the optical fiber transmission link.</p> | <p>Unit-3.0 Optical Fiber Communication System</p> <p>3.1 Evolution of Fiber Optic communication, frequency bands of optical Fiber communication and their applications</p> <p>3.2 Elements of an Optical Fiber Transmission link</p> <p>3.3 Ray theory of propagation of light, refractive index, Numerical Aperture(NA), Fiber cable structure: core and cladding, modes of light transmission through fiber; step index Fiber and graded index Fiber</p> <p>3.4 Types of losses and attenuation in optical Fibers: attenuation due to absorption and scattering</p> | CO3 |
| <p><i>TSO 4a.</i> Identify the functions of the given block of satellite link.</p> <p><i>TSO 4b.</i> Distinguish the type of satellite based on different satellite orbits.</p> <p><i>TSO 4c.</i> State the significance of Kepler's law of satellite motion.</p> <p><i>TSO 4d.</i> Identify the satellite orbit of the satellite for the given orbital parameter.</p> <p><i>TSO 4e.</i> Explain the importance of the transponder with example.</p> <p><i>TSO 4f.</i> Describe the concept of Earth segment subsystem.</p> | <p>Unit-4.0 Satellite Communication</p> <p>4.1 Block diagram of satellite communication link</p> <p>4.2 Types of satellite: active and passive, synchronous and non-synchronous, Low Earth Orbit (LEO), Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO) satellites</p> <p>4.3 Kepler's law of satellite motion, first, second and third law, Orbital parameters: apogee and perigee heights, satellite time period, focus of a parabola</p> <p>4.4 Transponders, Earth segment subsystem: earth station transmitter and earth station receiver block diagram, function and working</p> | CO4 |
| <p><i>TSO 5a.</i> Illustrate basic functions of the RADAR system.</p> <p><i>TSO 5b.</i> Interpret the RADAR range equation.</p> <p><i>TSO 5c.</i> Define the different RADAR parameters.</p> <p><i>TSO 5d.</i> Identify the different tracking and display techniques used for the RADAR system.</p> | <p>Unit-5.0 RADAR and its Applications</p> <p>5.1 Introduction: Basic principle of RADAR, basic types of RADAR, working of RADAR, applications</p> <p>5.2 RADAR range equation and examples, factors affecting maximum range</p> <p>5.3 Pulse RADAR: block diagram, RADAR antenna, scanning and tracking methods, display methods</p> <p>5.4 Continuous Wave (CW), Doppler RADAR: Moving target indicator radar, blind speed, frequency modulated CW RADAR</p> | CO5 |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2421603D

| Practical/Lab Session Outcomes (LSOs) | Sl. No. | Laboratory Experiment/Practical Titles | Relevant COs Number (s) |
|---|---------|--|-------------------------|
| <p><i>LSO 1.1.</i> Identify the transmitter and receiver section of the given mobile handset.</p> <p><i>LSO 1.2.</i> Test the power supply of the transmitter and receiver section of the given mobile handset.</p> | 1. | Test the supply of the Transmitter /Receiver section of mobile handset | CO1 |

| Practical/Lab Session Outcomes (LSOs) | Sl. No. | Laboratory Experiment/Practical Titles | Relevant COs Number (s) |
|--|---------|---|-------------------------|
| <i>LSO 2.1</i> Identify different sections of mobile handset unit. <i>LSO 2.2</i> Check input/ output signals of different sections of mobile phone unit. | 2. | Interpret input/ output signals at different I/O sections of mobile handset unit | CO1 |
| <i>LSO 3.1</i> Interpret the contents of SIM card using relevant software. | 3. | Read the contents of SIM card using the relevant software | CO1 |
| <i>LSO 4.1</i> Verify real time GSM Command concerning modem & SIM card hardware. | 4. | Test /Analyze real time GSM Commands concerning modem & SIM card hardware | CO2 |
| <i>LSO 5.1</i> Verify real time GSM Call setting commands. | 5. | Test /Analyze real time GSM Call setting commands | CO2 |
| <i>LSO 6.1</i> Measure Numerical Aperture (NA) and acceptance angle for the given optical Fiber cable. | 6. | Determination of the Numerical Aperture (NA) and acceptance angle for the given optical Fiber cable | CO3 |
| <i>LSO 7.1</i> Determine bending losses for the given length of optical Fiber cable. | 7. | Measurement of bending losses for the given length of optical Fiber cable | CO3 |
| <i>LSO 8.1</i> Determine attenuation losses for the given length of optical Fiber cable. | 8. | Measure attenuation losses for the given length of optical Fiber cable | CO3 |
| <i>LSO 9.1</i> Interpret satellite communication link (transmitter and receiver using tone signal). | 9. | Establish a satellite communication link between transmitter and receiver using tone signal | CO4 |
| <i>LSO 10.1</i> Determine the propagation delay of the given signal for the established SATCOM link. | 10. | Measure the propagation delay of the given signal for the established SATCOM link | CO4 |
| <i>LSO 11.1</i> Verify RADAR range equation for the given parameters. | 11. | Analyze the RADAR range equation for the given parameters | CO5 |
| <i>LSO 12.1</i> Measure the velocity of the specified moving object visible in the RADAR range. | 12. | Determine the velocity of the specified moving object visible in the RADAR range | CO5 |
| <i>LSO 13.1</i> Interpret/ Analyze the effect of handover threshold and margin on SNR and call drop probability and handover probability. | 13. | To analyze the handover mechanism (using Virtual Lab) | CO1 |
| <i>LSO 14.1</i> Measure the numerical aperture and attenuation constant of an optical Fiber. | 14. | Measurement of Numerical aperture of optical Fiber (using Virtual Lab) | CO3 |

L) **Suggested Term Work and Self Learning: S2421603D** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

- a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.
- b. **Micro Projects:**
 1. Demonstrate the general steps to repair a Mobile handset.
 2. Prepare a chart to represent the sections of smart Mobile handset and its functions.
 3. Describe various splicing techniques used in industries for optical Fiber cables.
 4. Describe the procedure to maintain the given type of optical Fiber network.
 5. Make a model to prove that three communication satellites are sufficient to provide global communication.
 6. Prepare a chart to represent step by step procedure to measure the velocity of the object range with the help of pulse RADAR.

c. Other Activities:

1. Seminar Topics:

- GSM and CDMA mobile technologies.
- Optical Fiber fabrication.
- OTDR and splicing tool.
- Prepare a PPT on major event occurred in the Indian satellite history.
- Satellite applications in remote sensing.
- Prepare a PPT on types of RADAR (Internet based activity).

2. Visits:

- Arrange a one-day industrial visit to explore TV or Radio transmitting facilities available in the TV and Radio station
- Visit nearby mobile service provider switching exchange/MTNL or BSNL exchange and prepare a detail report of entire setup of their cellular system.
- Visit nearby mobile switching center and prepare a detail report on it.
- Arrange a visit to a nearby satellite subsystem station facility.

3. Self-Learning Topics:

- Comparison of LTE and VOLTE standards.
- Describe the user validation for GSM and CDMA.
- Describe the properties of materials used for manufacturing of optical Fiber cables.
- List the uses of different satellite frequency bands.
- Explain the peak power and average power of the RADAR signal.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 20% | 25% | 25% | - | - | 20% | 20% |
| CO-2 | 15% | 10% | 10% | 25% | - | 10% | 20% |
| CO-3 | 15% | 25% | 25% | 25% | 33% | 20% | 20% |
| CO-4 | 30% | 30% | 30% | 25% | 33% | 30% | 20% |
| CO-5 | 20% | 10% | 10% | 25% | 34% | 20% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: The specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number(s) | Total Marks | ETA (Marks) | | |
|---|--|------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 Cellular Communication | 10 | CO1 | 16 | 4 | 6 | 6 |
| Unit-2.0 Cellular Network Standards | 8 | CO2 | 10 | 4 | 4 | 2 |
| Unit-3.0 Optical Fiber Communication System | 10 | CO3 | 16 | 4 | 6 | 6 |
| Unit-4.0 Satellite Communication | 12 | CO4 | 18 | 6 | 6 | 6 |
| Unit-5.0 RADAR and its Applications | 8 | CO5 | 10 | 2 | 4 | 4 |
| Total | 48 | - | 70 | 20 | 26 | 24 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|-------|--|------------------------|-------------|-----------|----------------|
| | | | Performance | | Viva- Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Test the supply of the Transmitter /Receiver section of mobile handset. | CO1 | 50 | 40 | 10 |
| 2. | Interpret input/ output signals at different I/O sections of mobile handset unit. | CO1 | 50 | 40 | 10 |
| 3. | Read the contents of SIM card using the relevant software. | CO1 | 50 | 40 | 10 |
| 4. | Test /Analyze real time GSM Commands concerning modem & SIM card hardware. | CO2 | 50 | 40 | 10 |
| 5. | Test /Analyze real time GSM Call setting commands. | CO2 | 50 | 40 | 10 |
| 6. | Determination of the Numerical Aperture (NA) and acceptance angle for the given optical Fiber cable. | CO3 | 50 | 40 | 10 |
| 7. | Measurement of bending losses for the given length of optical Fiber cable. | CO3 | 50 | 40 | 10 |
| 8. | Measure attenuation losses for the given length of optical Fiber cable. | CO3 | 50 | 40 | 10 |
| 9. | Establish a satellite communication link between transmitter and receiver using tone signal. | CO4 | 50 | 40 | 10 |
| 10. | Measure the propagation delay of the given signal for the established SATCOM link. | CO4 | 50 | 40 | 10 |
| 11. | Analyze the RADAR range equation for the given parameters. | CO5 | 50 | 40 | 10 |
| 12. | Determine the velocity of the specified moving object visible in the RADAR range. | CO5 | 50 | 40 | 10 |
| 13. | To analyze the handover mechanism (using Virtual Lab). | CO1 | 50 | 40 | 10 |

| S. No | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|-------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 14. | Measure of Numerical aperture of optical Fiber (using Virtual Lab). | CO3 | 50 | 40 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Methods, Group Discussions, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/ Practical Number |
|--------|---|--|---------------------------------------|
| 1. | SIM Card Reader | Trainer for Sim card reader | 1 |
| 2. | Mobile Phone Trainer Kit | Cellular System: EGSM/GSM 900/ 1800 MHz (3GDualband) Rx frequency band (Downlink): EGSM 900: 925-960 MHz GSM 900: 935- 960 MHz GSM 1800: 1805-1880MHz Tx frequency band (Uplink): EGSM 900: 880- 890MHz GSM 900: 890- 915 MHz GSM 1800: 1710-1785MHz Output power: +5, +33 dBm / 3.2 mW, Channel spacing: 200 KHz Display: TFT, 256 K colours,128X 160 Pixels, 2.0", SIM support: Smart Dual SIM, Dual stand by (both GSM) Battery type: Li-Ion 1000m AH C PU: 208 MHz Sound: Speaker and Earphone Jack (3.5 mm) On board sections: Keypad, Dual SIM, Charging Circuit, Clock, User interface such as Buzzer, Vibrator, LEDs. Test points: 50 nos. (Gold plated) Features that can be set: Screen savers, Ring tones, Logos, SMS | 1-5 |
| 3. | Mobile Handset Tools | Toolkit for Mobile Handset repairing | 3 |
| 4. | Spectrum Analyzer | 9KHz to 1.5 GHz frequency range, Typical 135dBm Displayed average noise level (DANL) 80dBc/Hz @ 10KHz offset, phase noise Total amplitude Uncertainty < 1.5dB, 100Hz Minimum Resolution Bandwidth (RBW), Frequency Resolution 1Hz, Frequency span range 0 Hz, 100 Hz to maximum Frequency of instrument, Video bandwidth (-3db) 1Hz to 3 MHz in 1-3-10 sequence | All |
| 5. | Digital Multimeter (3 ½ Digital Multimeter) | 4000 counts large LCD display with auto/manual range, No Power OFF under natural operation, Data Hold, Max/Min value Hold Capacitance, Frequency/ Duty Cycle | All |

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/ Practical Number |
|--------|---------------------------------------|---|---------------------------------------|
| 6. | Digital Storage Oscilloscope | 100 MHz with 64K color TFT, 16kbps memory, FFT function, alternate triggering, Roll Mode, Math Function, digital filter, waveform recorder, 20 automatic measurements, Standard USB host, USB device with waveform analysis software | All |
| 7. | OTDR | Attenuation resolution-0.001 dB, Attenuation measurement linearity 0.05 dB, Distance measurement accuracy $\pm (0.5 + \text{resolution} + 5 \times 10^{-5} \times L)$ m | 7-8 |
| 8. | Fiber optic Trainer | Trainer kit for optical Fiber communication, can setup analog and digital link, loss and NA measurement, List of practical performed with complete Lab manual | 6-8 |
| 9. | Power Supply | Power Supply Type: DC, 0 - 30 V, 0-3A | All |
| 10. | Satellite Trainer Kit | Frequency: 100Hz to 1 KHz, 2450-2468 MHz up-linking selectable frequencies, Amplitude: 0V to 1Vpp, Separate terminals provided for different inputs, Power Supply: 230 V AC $\pm 10\%$, 50/60 Hz, Simultaneous communication of three different signals Communicate Audio, Video, Digital data, PC data, Tone, Voice, function generator waveforms, USB port for PC communication | 9-10 |
| 11. | RADAR Trainer Kit | Transmitter Frequency: 10 GHz Output Power: 10mW (approximate) Operating Voltage: 8.6V Antenna: Horn Antenna Gain: 16dB Sensitivity: -50 to -70dBm IF Output: Audio range Power Supply: 230V $\pm 10\%$, 50 Hz Oscilloscope: Real time/Storage mode with FFT analysis Display: Voltage: Vpp Speed: Km/hr, Miles/hr, m/s, rpm Frequency: Hz & kHz Time domain window: Display the Doppler Frequency in Time domain Frequency domain window: Display the Doppler Frequency in Frequency domain | 11-12 |

R) Suggested Learning Resources:

(b) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|-------------------------------------|---|
| 1. | Wireless Communications: Principles and Practice | T.S. Rappaport | Pearson Education, 2 nd edition 2020, ISBN-978-8131731864 |
| 2. | Principles and Applications of GSM | Vijay Kr. Garg and Joseph E. Wilkes | Pearson Education, 1 st edition 2022, ISBN-978-8177588798 |
| 3. | Mobile Cellular Telecommunications System | Lee, C. Y. William | Tata Mcgraw Hill Education 2 nd edition 2000 ISBN-978-0071134798 |
| 4. | Optical Fiber Communication | Gerd Keiser | Mc Graw Hill Education 5 th edition 2017, ISBN: 978-1259006876 |
| 5. | Optical Fiber Communications Principles and practice | Senior John M. | Pearson Education, 3 rd edition 2010, ISBN-978-8131732663 |
| 6. | Satellite Communications | Dennis Roddy | Mc Graw Hill Education 4 th edition 2017, ISBN: 978-0070077850 |
| 7. | Microwave and RADAR Engineering | Kulkarni, M | Umesh Publications, 5 th Edition, 2016 ISBN 978-9382533160 |

(b) Online Educational Resources:

1. Mobile phone repairing tools and equipments: - www.mobilecellphonerepairing.com › Mobile Phone Repairing Tools
2. The Evolution of mobile technologies: -<https://www.qualcomm.com/.../the-evolution-of-mobiletechnologies-1g-to-2g-to-3g-to-4g>
3. Optical wavelength bands: http://www.bbcmag.com/2008issues/june08/BBP_June08_OtoL.pdf
4. https://onlinecourses.nptel.ac.in/noc17_ec14/preview
5. RADAR:-[www.youtube.com /RADARs](http://www.youtube.com/RADARs)
6. <https://youtube.com/playlist?list=PLuv3GM6-gsE3ypUYh43pPuZsXxJVG1e7F&si=DqUpwS8Fdl66FGdf>
7. https://www.tutorialspoint.com/satellite_communication/
8. <http://www.rpsinstitutions.org/downloads/lab%20manual/sclab.pdf>
9. <http://vlabs.iitkgp.ac.in/fcmc/>
10. bop-iitk.vlabs.ac.in/exp/numerical-aperture-measurement/

Note: Teachers are requested to check the Creative Commons license status/ financial implications of the suggested, onlineeducational recourses before use by the students.

(c) Others:

1. Lab Manuals
2. Case Method
3. Group Discussion
4. Portfolio Based Learning
5. Role Play
6. ICT Based Teaching Learning (Video Demonstration, CBT, Blog, Face book, Mobile)

- A) **Course Code** : 2400604B(T2400604B/P2400604B/S2400604B)
 B) **Course Title** : Artificial Intelligence (Advanced)
 C) **Pre- requisite Course(s)** : Artificial Intelligence (Basic)
 D) **Rationale** :

In Artificial Intelligence (Basic) course, students have learned the basics for Artificial Intelligence problem solving techniques, data analytics and articulates the different dimensions of these areas. This Artificial Intelligence (Advance) course offers the students the comprehension of Machine learning which is a subset of artificial intelligence in the field of computer. The course also exposes students to Tens or flow a Python-based open source library for numerical computation used in machine learning and developing neural networks. After completing the course students will be able to implement various techniques used in machine learning and neural networks using open source tools.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/laboratory/workshop/field/ industry.

After completion of the course, the students will be able to-

- CO-1** Elaborate the use of Machine learning in Artificial Intelligence.
CO-2 Implement various supervised and unsupervised learning models and methods.
CO-3 Illustrate Artificial neural networks and its applications.
CO-4 Implement various Neural network models and Learning Methods.
CO-5 Solve machine learning and artificial neural network problems using Tens or flow.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes(POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|---|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | - | 2 | 2 | - | - | - | 1 | | |
| CO-2 | 3 | 3 | 3 | 3 | - | - | 2 | | |
| CO-3 | - | 3 | 3 | 3 | - | - | 2 | | |
| CO-4 | 3 | 1 | 3 | 3 | - | - | 2 | | |
| CO-5 | 3 | 3 | 3 | 3 | - | - | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

*: PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|------------------------------------|------------------------------|---|----------------------|-------------------------|---------------------------|------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credit (C) |
| | | L | T | | | | |
| 2400604B | Artificial intelligence (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances/ problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCS, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|------------------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604B | Artificial Intelligence (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

- I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2400604B**

| Major Theory Session Outcomes (TSOs) | Units | Relevant Cos Number (s) |
|---|---|-------------------------|
| TSO 1a. Describe the basic terminology of Machine learning TSO 1b. Explain the concept of dataset and ways to handle them TSO 1c. illustrate the process of dataset division TSO 1d. Explain process involved in machine learning | Unit – 1.0: Introduction to machine learning Concept of Machine Learning, Define Learning, Learn the Network, Evaluate the Network, datasets and ways to handle them, Feature sets, Dataset division: test, train and validation sets, cross validation. Applications of Machine Learning, processes involved in Machine Learning | CO-1 |
| TSO 2a. Identify the category or class of a particular dataset using KNN algorithm TSO 2b. Use Linear regression for predictive analysis TSO 2c. Predict the categorical dependent variable using Logistic Regression TSO 2d. Use SVM for classification problems in Machine Learning TSO 2e. determine the performance of the classification models TSO 2f. evaluate the performance of the classification model using ROC-curve TSO 2g Explain characteristics of Unsupervised learning. TSO 2h. Explain different clustering methods TSO 2i. Implement K-means clustering algorithm to group the unlabeled dataset | Unit 2.0: Supervised and unsupervised learning Supervised learning: Introduction to Supervised Learning, K-Nearest Neighbor, Linear Regression, Logistic Regression, Support Vector Machine (SVM), Evaluation Measures: confusion matrix, precision, precision and recall, ROC-Curve (Receiver Operating Characteristic curve) Unsupervised learning: Introduction to Unsupervised Learning, Introduction to clustering, Types of Clustering: Hierarchical, Agglomerative Clustering and Divisive clustering; Partitional Clustering - K-means clustering. Expectation-Maximization (EM) Algorithm | CO-2 |
| TSO 3a. Explain Structure and working of Biological Neural Network. TSO 3b. differentiate between Artificial Neural Network and Biological Neural Network TSO 3c. State key historical points in development of ANN TSO 3d. Explain the architecture of an artificial neural network | Unit 3.0: Introduction to neural networks Structure and working of Biological Neural Network, Fundamentals of Artificial Neural Networks & Applications, Characteristics of Artificial Neural Networks, History of neural network research, characteristics of neural networks terminology. | CO-3 |
| TSO 4a. Use neuron McCulloch – Pitts model in designing logical operations TSO 4b. Apply Rosenblatt's Perceptron to solve linear classification problems TSO 4c. Implement Adaptive Linear Neuron (Adaline) training algorithm in neural network TSO 4d. Use Backpropagation neural training algorithm TSO 4e. Use ART (Adaptive Resonance Theory) learning model | Unit 4.0: Neural networks models and Learning Methods Models of neuron McCulloch – Pitts model, Rosenblatt's Perceptron, Adaline model, Basic learning laws, Topology of neural network architecture, Multilayer Neural Networks, Learning Methods, Backpropagation, Counter propagation, Adaptive Resonance Theory (ART), Associative memories, BAM. | CO-4 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant Cos Number (s) |
|--|---|-------------------------|
| TSO 4f: Implement Bidirectional Associative Memory (BAM) model in Artificial Neural Network | | |
| TSO 5a. Illustrate the features of Tens or flow TSO 5b. Manipulate tensors TSO 5c. Explain features of Tens or Board visualization TSO 5d Explain the concept and features of Tens or flow playground | Unit-5.0 Tensor flow features of TensorFlow, Tensor Data structure- Rank, shape, type, one dimension and two-dimension tensor, Tensor handling and manipulations, Tensor board visualization- symbols Tensors, Variables, Automatic differentiation, Graphs and tf.function, modules layers and models, training loops, features of Tens or flow playground- data ,the ration of train and test data, features, hidden layers, Epoch, learning rate, activation function, regularization, problem type | CO-5 |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604B

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| LSO 1.1 Implement data classification algorithms | 1 | Write a program to implement k-Nearest Neighbour algorithm to classify the iris data set. Print both correct and wrong predictions. Python ML library classes can be used for this problem. | CO-2 |
| LSO 2.1 Implement Machine learning algorithms LSO 2.2 Evaluate the performance of classification model | 2 | (a) Implement SVM for Iris Dataset- download the dataset from (https://gist.github.com/netj/8836201) (b) Find confusion matrix and evaluation matrix for SVM Hint: SVM model can be constructed using sklearn command, import pandas as pd from sklearn.svm import SVC from sklearn.model_selection import train_test_split from sklearn.metrics import confusion_matrix from sklearn.metrics import classification_report from sklearn.metrics import accuracy_score 1. Read the csv Iris dataset file 2. Condition the data 3. Condition the training and Testing data 4. Construct the Linear model 5. Test the model with Linear kernel 6. Prepare confusion matrix 7. prepare Classification Report | CO-2 |
| LSO 3.1 Perform clustering operations using k-means algorithm | 3 | a) Explore k-means algorithm for the small sample dataset. b) Explore k-means algorithm for Iris Dataset | CO-2 |
| LSO 4.1 Perform clustering operations using EM algorithm | 4 | Apply EM algorithm to cluster a set of data stored in a .CSV file. Use the same data set for clustering using k-Means algorithm. Compare the results of these two | CO-2 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| | | algorithms and comment on the quality of clustering. You can add Python ML library classes/API in the program. | |
| LSO 5.1 Build artificial neural network LSO 5.2 Test artificial neural network | 5 | Build an Artificial Neural Network by implementing the Backpropagation algorithm and test the same using appropriate data sets. | CO-4 |
| LSO 6.1 Detect features or business intelligence in the input data using perceptron | 6 | Implement the perceptron algorithm from scratch in python. | CO-4 |
| LSO 7.1 Use Tensors for given problems | 7 | Write a programme to implement two dimension and three-dimension Tensor. | CO5 |
| LSO 8.1 Use basic features for tensor handling and manipulations | 8 | Write a programme to add and multiply two 4x4 matrix, you can Import "tens or flow" and "numpy". | CO5 |
| LSO 9.1 Test artificial intelligence (AI) algorithms through the use of Google's TensorFlow machine learning libraries. | 9 | Solve a classification problem on the Tens or flow playground. Hint: refer https://www.educba.com/tensorflow-playground/ | CO5 |
| LSO 10.1 Implement artificial intelligence (AI) algorithms through the use of Google's TensorFlow machine learning libraries LSO 10.2 perform predictive analysis using linear regression | 10 | Implement algorithm for linear regression in tens or flow | CO5, CO2 |

L) Suggested Term Work and Self Learning: S2400604B Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. Micro Projects:

Use python programming for the solutions of Microproject problems

1. (a) Create a Bar plot to get the frequency of the three species of the Iris data.
(b) Create a Pie plot to get the frequency of the three species of the Iris data.
(c) Write a Python program to create a graph to find relationship between the sepal length and width.
2. (a) Write a Python program to split the iris dataset into its attributes (X) and labels (y). The X variable contains the first four columns (i.e. attributes) and y contains the labels of the dataset.
(b) Write a Python program using Scikit-learn to split the iris dataset into 70% train data and 30% test data. Out of total 150 records, the training set will contain 120 records and the test set contains 30 of those records. Print both datasets.
3. Conduct performance analysis of Classification Algorithms (any 2) on a specific dataset.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 20% | 15% | 30% | 20% | 30% | -- | -- |
| CO-2 | 10% | 25% | 20% | 20% | 20% | 30% | 33% |
| CO-3 | 30% | 25% | 30% | 20% | 20% | -- | -- |
| CO-4 | 20% | 20% | 20% | 20% | 30% | 30% | 33% |
| CO-5 | 20% | 15% | 10% | 20% | -- | 40% | 34% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

- * : Other Activities include self-learning, seminar, visits, surveys, product development, software development etc.
 ** : Mentioned under point- (N)
 # : Mentioned under point- (O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number (s) | Total Marks | ETA (Marks) | | |
|---|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0. Introduction to machine learning | 08 | CO1 | 11 | 5 | 4 | 2 |
| Unit-2.0. Supervised and unsupervised learning | 10 | CO2 | 18 | 5 | 6 | 7 |
| Unit-3.0. Introduction to neural networks | 10 | CO3 | 17 | 5 | 7 | 5 |
| Unit-4.0. Neural networks models and Learning Methods | 10 | CO4 | 14 | 3 | 3 | 8 |
| Unit-5.0. Tensor flow | 10 | CO5 | 10 | 2 | 6 | 2 |
| Total Marks | 48 | | 70 | 20 | 26 | 24 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Write a program to implement k-Nearest Neighbor algorithm to classify the iris data set. Print both correct and wrong predictions. Python ML library classes can be used for this problem. | CO-2 | - | 90 | 10 |
| 2. | (a) Implement SVM for Iris Dataset- download the dataset from (https://gist.github.com/netj/8836201) (b) Find confusion matrix and evaluation matrix for SVM | CO-2 | - | 90 | 10 |
| 3. | a) Explore k-means algorithm for the small sample dataset. b) Explore k-means algorithm for Iris Dataset | CO-2 | 20 | 70 | 10 |
| 4. | Apply EM algorithm to cluster a set of data stored in a .CSV file. Use the same data set for clustering using k-Means algorithm. Compare the results of these two algorithms and comment on the quality of clustering. You can add Python ML library classes/API in the program. | CO-2 | - | 90 | 10 |
| 5. | Build an Artificial Neural Network by implementing the Backpropagation algorithm and test the same using appropriate data sets. | CO-4 | 10 | 80 | 10 |
| 6. | Implement the perceptron algorithm from scratch in python. | CO-4 | 10 | 80 | 10 |
| 7. | Write a programme to implement two dimension and three-dimension Tensor. | CO-5 | - | 90 | 10 |
| 8. | Write a programme to add and multiply two 4x4 matrix, you can Import "tens or flow" and "numpy". | CO-5 | - | 90 | 10 |
| 9. | Solve a classification problem on the Tens or flow playground. | CO-5 | 20 | 70 | 10 |
| 10. | Implement algorithm for linear regression in tens or flow | CO-2, CO-5 | 10 | 80 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Group Discussion, Portfolio Based Learning, Live Demonstrations in Classrooms, Lab, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---|---|--------------------------------------|
| 1. | Computer Systems | Desktop Computers with i3 processor, 16 GB RAM, 512 GBHDD | S. No. 1 to 10 |
| 2. | Online Python IDE | https://www.online-python.com/ | S. No. 1 to 10 |
| 3. | Jupyter Notebook | Download from https://jupyter.org/ | S. No. 1 to 10 |
| 4. | Pip Python package manager | Download Pip 22.3 From https://pypi.org/project/pip/ | S. No. 1 to 10 |
| 5. | Google colab | https://colab.research.google.com/github/tensorflow/docs/blob/master/site/en/tutorials/quickstart/beginner.ipynb#scrollTo=DUNzJc4jTj6G | S. No. 1 to 10 |
| 6. | Various modules, Libraries and Packages | Tens or flow, NumPy, Pandas, package | S. No. 1 to 10 |

R) Suggested Learning Resources:**(a) Books:**

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|---|---|---|
| 1. | Machine Learning using Python | Manaranjan Pradhan, U Dinesh Kumar | Wiley, ISBN-10: 8126579900 ISBN-13: 978-8126579907 |
| 2. | Introduction to Machine Learning | Jeeva Jose | Khanna Book Publishing Co. (P) ltd, 2020. ISBN-10: 9389139066 ISBN-13: 978-9389139068 |
| 3. | Machine Learning for Dummies | John Paul Mueller and Luca Massaron, For Dummies, | For Dummies; 2nd edition, ISBN-10: 1119724015 ISBN-13: 978-1119724018 |
| 4. | Machine Learning | Rajeev Chopra | Khanna Book Publishing Co., 2021 ISBN-10: 9789386173423 ISBN-13: 978-9386173423 |
| 6. | Learn TensorFlow 2.0: Implement Machine Learning and Deep Learning Models with Python | Pramod Singh, Avinash manure | Apress, 978-1484255605 ISBN-10: 1484255607 ISBN-13: 978-1484255605 |

(b) Online Educational Resources:

1. NPTEL Course: Introduction to Machine Learning, Prof. Balaraman Ravindran, IIT Madras
2. <https://www.tensorflow.org/resources/learn-ml>
3. <https://www.tutorialspoint.com/tensorflow/index.htm>
4. <https://www.javatpoint.com/tensorflow>
5. <https://developers.google.com/machine-learning/crash-course/exercises>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested OER, before use by the students.

(c) Others:

- **Data Source:**
 - <https://archive.ics.uci.edu/ml/machine-learning-databases/auto-mpg/>
 - <https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data>
 - <https://www.kaggle.com/arshid/iris-flower-dataset>
 - <https://www.kaggle.com/rohankayan/years-of-experience-and-salary-dataset>

- A) **Course Code** : 2400604C(T2400604C/P2400604CS2400604C)
 B) **Course Title** : Internet of Things (Advanced)
 C) **Pre- requisite Course(s)** : IoT (Basics), Computer Networks
 D) **Rationale** :

The rise and rise of IoT technologies is redefining business opportunities and process. This has led to a growing need to learn advance skills to remain competitive in the market. Put together, these are a potent combination of technologies that will dictate how our future is written, which is a strong indicator of rewarding job opportunities in those domains. Introduction of the Advanced IoT follows a rigorous curriculum which blends the academic excellence and industry-relevant applications.

This course will be exposed to a breadth of skills which will help students to become multi-faceted software engineers with a deeper understanding of these modern technologies, their applications, and interdependence.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1** Use basic Python features in Programming.
CO-2 Use advance Python features in Programming.
CO-3 Explain features of Cloud and IoT data storage on it.
CO-4 Explain IoT Networking and its application.
CO-5 Develop IoT App for the given problem

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|---|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | 3 | 2 | 2 | - | 2 | - | | |
| CO-2 | 3 | 3 | 2 | 2 | - | 2 | - | | |
| CO-3 | 1 | - | 3 | 2 | 2 | 2 | 2 | | |
| CO-4 | 1 | - | 2 | 3 | - | 2 | 2 | | |
| CO-5 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|----------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2400604C | IoT (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances/ problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCS, spoken tutorials, Online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|----------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604C | IoT (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills,

Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2400604C

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|--|------------------------|
| TSO.1. a. Write the steps to install Python. TSO.1. b. Explain given types of variables in python. TSO.1. c Explain use and importance of Tuple, Dictionary, operators in python TSO.1. d. Explain use of array in python. TSO.1. e. Explain use of 2-Dimensional Array in python TSO.1. f Explain uses of given type of Conditional statement in python. | Unit-1.0 Python Basics: - 1.1 Installation of Python 1.2 Variables, Print () function, Escape character sequence and run python Program 1.3 Python Tuple, Dictionary, operators 1.4 Python arrays, create, reverse and append data into it. 1.5 Python 2 Dimensional arrays. 1.6 Python Conditional statement. | CO-1 and CO-5 |
| TSO.2. a. Explain uses of given type of do & while loops in python TSO.2. b. Explain working of break, continue and pass statement in python TSO.2. c. Write the benefits of using OOP methodology in python. TSO.2. d. Explain given type of string operation related to python. TSO.2. e. Explain given function in python TSO.2. f Explain use of Lambda function in python. | Unit 2. Python Advance: - 2.1 Python Do & while loops 2.2 Python break, continue, pass statements 2.2 Python OOPs Class, Object, Inheritance and Constructor 2.4 Python Strings Replace, Join, Split, Reverse, Uppercase, Lowercase, count, find, split and length 2.5 Python Functions, Built-in functions and user defined functions 2.6 Lambda function and uses | CO-1 and CO5 |
| TSO.3. a. Differentiate between Cloud and IoT cloud. TSO.3. b. Explain features of Cloud in IoT environment TSO.3. c. List features of various types of Cloud TSO.3. d. List features of cloud services like SaaS, PaaS and IaaS TSO.3. f List advantages of cloud data storage. TSO.3. g Explain Arduino architecture and its applications. TSO.3.h Explain Raspberry pi architecture and its applications. | Unit-3.0 Cloud Features: - 3.1 Cloud computing and IoT cloud 3.2 Benefits of cloud in IoT 3.3 Types of Cloud public, private and hybrid 3.4 Cloud services like SaaS, PaaS and IaaS 3.5 Cloud connectivity and Data storage on Cloud. 3.6 Arduino: Architecture, Programming, and Applications 3.7 Raspberry Pi Architecture, Programming, and Application basic level for IoT applications | CO-1, CO-2 and CO-5 |
| TSO.4. a. Explain wired network TSO.4. b. Explain short range wireless network TSO.4. c. Explain M2M communication TSO.4. d. Explain various generation of wireless network TSO.4. e. Explain the importance of LWPAN in IoT TSO.4. f Differentiate between SigFox & LoRaWAN TSO.4. g Explain use of NB-IOT (Narrow Band IOT) TSO.4.h Create heterogenous network using RFID. | Unit.4 IoT Networking and Application: - 4.1 Wired and short-range wireless network 4.2 M2M – 2G, 3G, 4G & 5G networks 4.3 LPWAN – Low Power Wide Area Networks 4.4 SigFox & LoRaWAN. 4.5 NB-IOT (Narrow Band IOT) 4.6 RFID and Bar code basics- Components of an RFID system-Data -Tags-Antennas- Connectors- Cables- Readers- encoder/ printers for smart labels- Controllers software 4.7 RFID advantages over Bar codes. | CO-1 and CO-4 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| TSO.5. a. Identify suitable framework for IoT app development TSO.5. b. Identify various stages of selected app TSO.5. c. Develop the app. TSO.5. d. Implement and deploy the app TSO.5. e Maintain and improve the app based on the feedback | Unit. 5 IoT App Development: - 5.1 Framework selection for IoT app development 5.2 Identify stages of app to be developed. 5.3 Develop, Implement, and Deploy the App 5.4 Testing and Integration 5.5 Maintain and improve | CO-4 and CO-5 |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604C

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| LSO 1.1 Python installation LSO 1.2 Prepare and run python program on given problem LSO 1.3 Prepare python program on Dictionary, Tuple and operators. LSO 1.4 Prepare program on arrays LSO 1.5 Prepare a program on 2-dimensional array LSO 1.6 Create program on conditional statement | 1. | 1.1 Install given version of Python on the computer system. 1.2 Prepare a python program using print() function and run it. 1.3 Access given value from the tuple 1.4 Print the given value of key from the dict. 1.5 Write a Python program to create an array of 5 integers and display the array items. Access individual element through indexes 1.6 Write a Python program which takes two digits m (row) and n (column) as input and generates a two-dimensional array. 1.7 Write a python program to check whether person is eligible for voting or not. (accept age from the user) 1.8 Write a python program to check whether the entered number is even or odd. 1.9 Write a python program to check whether entered number is divisible by another entered number. 1.10 Write a python program to display "Yes" is entered number is divisible by 5 otherwise display "No" | CO-1 |
| LSO 2.1 Prepare python program on Do & while loops LSO 2.2 Prepare python program on break and continue statement. LSO 2.3 Prepare Python program using break and continue statements LSO 2.4 prepare python program using OOP LSO 2.5 Prepare Python program using functions | 2. | 2.1 Prepare a python program which can print first 10 even and odd numbers using while statement 2.2 Write a python program which can print first 10 integers and its square using while/for loop. 2.3 Write a python program which can print sum of first 10 natural numbers using while/for loop. | CO-2 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| | | 2.4 Write a python program which can identify the prime number between the range given using while/for loop. 2.5 Consider a situation where you want to iterate over a string and want to print all the characters until a letter 'e' or 's' is encountered. It is specified that you have to do this using loop and only one loop is allowed to use. 2.6 Consider the situation when you need to write a program which prints the number from 1 to 10 and but not 6. It is specified that you have to do this using loop and only one loop is allowed to use. 2.7 Create a Class with instance attributes 2.8 Create a Vehicle class without any variables and methods 2.9 Write a Python function to find the Max of three numbers. 2.10 Write a Python program to reverse a string. | |
| LSO 3.1 Signup for free cloud storage LSO 3.2 Store data into cloud and retrieve it. | 3. | 3.1 Create a free cloud account 3.2 Store data on cloud and retrieve it | CO-3 |
| LSO 4.1 Design various types of network cables LSO 4.2 Connect computer in LAN. LSO 4.3 Connect devices using wireless network LSO 4.4 Connect machine with machine LSO 4.5 Connect devices using IEEE 802 LSO 4.6 Connect devices using LPWAN LSO 4.7 Connect devices using RFID | 4 | 4.1 Study of different types of Network cables and Practically implement the cross-wired cable and straight through cable using clamping tool. 4.2 Connect the computers in Local Area Network 4.3 Connect 2 or more devices using Bluetooth 4.4 Connect 2 or more devices using infrared 4.5 Connect 2 more machine using m2m 4.6 Connect 2 or more different devices using access point 4.7 Connect 2 devices using LPWAN (Smart Meter) 4.8 Connect 2 or more devices using RFID | CO-4 |
| LSO 5.1 Develop a IoT app LSO 5.2 Develop IoT applications using smartphones. | 5. | 5.1 Identify a problem and develop an app 5.2 Building a temperature monitoring system using sensors and Smartphone | CO-5 |

L) **Suggested Term Work and Self Learning: S2400604C** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. **Micro Projects:**

1. Prepare a report on Python programming language.

2. Develop a small software in python to solve a IoT data analysis.
3. Create a id on free cloud storage and share data on it for others.
4. Create a heterogenous network and connect different dives.
5. Create a an IoT app for the identified problem

c. Other Activities:

1. Seminar Topics: - "Future of wireless network."
2. "Smart electricity billing ", "Cloud computing and IoT"
3. Visit to industry for IoT implementation in industrial process.
4. Reading RFID cards using 8051- RFID in the supply chain- Vehicles parking using RFID- library management system- electronic toll payment- smart shipping containers fleet monitoring and management.
5. Building IoT Applications like pressure, air quality, temperature and motion detector using Arduino and raspberrypi Universal boards.
6. Surveys of market for availability of various types of network devices and its pricing.
7. Product Development: Development of projects for real life problem solution app.
8. Software Development: Using Python

d. Self-Learning Topics:

1. Deeper knowledge in Python features
2. Network devices and its capabilities
3. Advantages of IoT implementations

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 10% | 10% | 20% | -- | 33% | 10% | 20% |
| CO-2 | 15% | 10% | 20% | -- | 33% | 15% | 20% |
| CO-3 | 30% | 30% | 20% | -- | 34% | 15% | 20% |
| CO-4 | 20% | 30% | 20% | 50% | -- | 30% | 20% |
| CO-5 | 25% | 20% | 20% | 50% | -- | 30% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self-learning, seminar, visits, surveys, product development, software development etc.

**.: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number (s) | Total Marks | ETA (Marks) | | |
|-------------------------------------|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 Python basics | 5 | CO1 | 7 | 2 | 2 | 3 |
| Unit-2.0 Python Advance | 5 | Co1, CO2 | 7 | 2 | 2 | 3 |
| Unit-3.0 Cloud features | 14 | CO3 | 21 | 8 | 8 | 5 |
| Unit-4.0 Networking and Application | 14 | CO4, CO3 | 21 | 5 | 7 | 9 |
| Unit-5.0 IoT Applications | 10 | CO5, CO3 and CO4 | 14 | 3 | 6 | 5 |
| Total Marks | 48 | | 70 | 20 | 25 | 25 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Install given version of Python the computer system. | CO-1 | 70 | 20 | 10 |
| 2. | Prepare a python program using print() function and run it. | CO-1 | 60 | 30 | 10 |
| 3. | Access given value from the tuple | CO-1 | 60 | 30 | 10 |
| 4. | Print the given value of key from the dict. | CO-1 | 60 | 30 | 10 |
| 5. | Write a Python program to create an array of 5 integers and display the array items. Access individual element through indexes | CO-1 | 60 | 30 | 10 |
| 6. | Write a Python program which takes two digits m (row) and n (column) as input and generates a two-dimensional array. | CO-1 | 60 | 30 | 10 |
| 7. | Write a python program to check whether person is eligible for voting or not. (accept age from the user) | CO-1 | 60 | 30 | 10 |
| 8. | Write a python program to check whether the entered number is even or odd. | CO-1 | 60 | 30 | 10 |
| 9. | Write a python program to check whether entered number is divisible by another entered number. | CO-1 | 60 | 30 | 10 |
| 10. | Write a python program to display "Yes" is entered number is divisible by 5 otherwise display "No" | CO-1 | 60 | 30 | 10 |
| 11. | Prepare a python program which can print first 10 even and odd numbers using while statement | CO-2 | 60 | 30 | 10 |
| 12. | Write a python program which can print first 10 integers and its square using while/for loop. | CO-2 | 60 | 30 | 10 |

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 13. | Write a python program which can print sum of first 10 natural numbers using while/for loop. | CO-2 | 60 | 30 | 10 |
| 14. | Write a python program which can identify the prime number between the range given using while/for loop. | CO-2 | 60 | 30 | 10 |
| 15. | Consider a situation where you want to iterate over a string and want to print all the characters until a letter 'e' or 's' is encountered. It is specified that you have to do this using loop and only one loop is allowed to use. | CO-2 | 60 | 30 | 10 |
| 16. | Consider the situation when you need to write a program which prints the number from 1 to 10 and but not 6. It is specified that you have to do this using loop and only one loop is allowed to use. | CO-2 | 60 | 30 | 10 |
| 17. | Create a Class with instance attributes | CO-2 | 60 | 30 | 10 |
| 18. | Create a Vehicle class without any variables and methods | CO-2 | 60 | 30 | 10 |
| 19. | Write a Python function to find the Max of three numbers. | CO-2 | 60 | 30 | 10 |
| 20. | Write a Python program to reverse a string. | CO-2 | 60 | 30 | 10 |
| 21. | Create a free cloud account | CO-3 | 70 | 20 | 10 |
| 22. | Store data on cloud and retrieve it. | CO-3 | 60 | 30 | 10 |
| 23. | Study of different types of Network cables and Practically implement the cross-wired cable and straight through cable using clamping tool. | CO-4 | 70 | 20 | 10 |
| 24. | Connect the computers in Local Area Network | CO-4 | 70 | 20 | 10 |
| 25. | Connect 2 or more devices using Bluetooth | CO-4 | 70 | 20 | 10 |
| 26. | Connect 2 or more devices using infrared | CO-4 | 70 | 20 | 10 |
| 27. | Connect 2 more machine using m2m | CO-4 | 70 | 20 | 10 |
| 28. | Connect 2 or more different devices using access point | CO-4 | 70 | 20 | 10 |
| 29. | Connect 2 devices suing LPWAN (Smart Meter) | CO-4 | 70 | 20 | 10 |
| 30. | Connect 2 or more devices using RFID | CO-4 | 70 | 20 | 10 |
| 31. | Identify a problem and develop an app | CO-5 | 70 | 20 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/ Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---------------------------------------|--|--------------------------------------|
| 1 | Python software | Openly available as per instruction | As mentioned above list |
| 2 | Cables connectors and crimping tools | Cat 6e cable, RJ-45 connectors and Crimping Tool | |
| 3 | Bluetooth and infrared devices | Any mobile and wireless keyboard and mouse | |
| 4 | IoT free cloud | Free available | |
| 5 | Smart devices | Like meters, bulbs etc. | |
| 6 | Wireless access point | Wireless router or access point | - |
| 8 | Arduino development board | Arduino Uno and Arduino Nano. | - |
| 6 | Raspberry Pi | Raspberry Pi 4/ Raspberry Pi 3/ Raspberry Pi 2 | - |

R) Suggested Learning Resources:

(a) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|--------------------|--|
| 1 | Let Us Python | Kanetkar Yashavant | BPB Publications ISBN: 9789388511568, 9789388511568 |
| 2 | IOT (Internet of things) and Its Application | P K Pandey | T Balaji Publication (1 January 2020) ISBN-10: 8194136385 ISBN-13: 978-8194136385 |
| 3 | Raspberry Pi Cookbook: Software and Hardware Problems and Solutions | Simon Monk | Shroff/O'Reilly; Third edition (4 October 2019), ISBN-10: 9352139267 ISBN-13: 978-9352139262 |
| 4 | Raspberry Pi Cookbook: Software and Hardware Problems and Solutions, | Simon Monk | Shroff/O'Reilly; Third edition (4 October 2019), ISBN-10: 9352139267 ISBN-13: 978-9352139262 |
| 5 | Cloud Computing: Concepts, Technology & Architecture | Erl | Pearson Education India; 1st edition (1 January 2014) ISBN-10: 9332535922 ISBN-13: 978-9332535923 |

(b) Online Educational Resources:

1. nptel.iitm.ac.in/courses/.../IIT.../lecture%2023%20and%2024.htm
2. en.wikipedia.org/wiki/Shear_and_moment_diagram
3. www.freestudy.co.uk/mech%20prin%20h2/stress.pdf
4. www.engineerstudent.co.uk/stress_and_strain.html
5. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf
6. <https://www.veritis.com/blog/aws-vs-azure-vs-gcp-the-cloud-platform-of-your-choice/>
7. <https://wiki.python.org/moin/TimeComplexity>
8. www.engineerstudent.co.uk/stress_and_strain.html
9. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf
Amini, P. (2014). Sulley: Pure Python fully automated and unattended fuzzing frame- work.
<https://github.com/OpenRCE/sulley>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested OER, before use by the students.

(c) Others:

1. Learning Packages
2. Users' Guide
3. Manufacturers' Manual
4. Lab Manuals

- A) **Course Code** : 2400604D(T2400604D/P2400604D/S2400604D)
 B) **Course Title** : Drone Technology (Advanced)
 C) **Pre- requisite Course(s)** : Drone Technology (Basics)
 D) **Rationale** :

In previous semester, a course in drone technology broadly discussed about basic principles, functions and interface of different components and design simple drone structure. In order to understand the successive development of drones / UAVs in terms of their geometric structure, working methodology and navigation control etc., so it is important to study the advanced course on Drone Technology. This course includes the study of Static and dynamic force analysis on drone, advance flying features, navigation control, maintenance and advance applications of different types of drone.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1** Apply the concept of engineering mechanics for stability of drone.
CO-2 Design the structure of drone using GPS module and thermal Image camera.
CO-3 Operate drone using advance flight controller board.
CO-4 Perform drone maintenance and assembly.
CO-5 Use drone in advance applications like precision agriculture, security, IoT, etc.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | - | - | - | - | - | | |
| CO-2 | 2 | 2 | - | 3 | 3 | - | - | | |
| CO-3 | 2 | 2 | 3 | 3 | - | - | - | | |
| CO-4 | 3 | - | - | 3 | - | - | - | | |
| CO-5 | - | 2 | 2 | - | - | 3 | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|-----------------------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2400604D | Drone Technology (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|-----------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604D | Drone Technology (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2400604D**

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number (s) |
|--|--|-------------------------|
| TSO 1a. Draw free body diagram of quadcopter drone. TSO 1b. Determine centroid of given drone structure. TSO 1c. Determine center of gravity of different drone structure. TSO 1d. Analyze different types of force acting drone system. TSO 1e. Differentiate between static and dynamic force analysis. TSO 1f. Explain how gyroscopic motion keeps drone balanced and hovering. | Unit-1.0 Engineering mechanics for Drone Technology 1.1 Drone Mechanics <ul style="list-style-type: none"> Free body diagram of drone Method of finding resultant of force system Equilibrium of coplanar force system 1.2 Center of Gravity <ul style="list-style-type: none"> Centroid of plane figure Center of gravity of solid bodies 1.3 Force analysis in drone <ul style="list-style-type: none"> Force analysis in drone Forces of flight Principle axes and rotation of aerial systems 1.4 Dynamics of machine <ul style="list-style-type: none"> Static and dynamic force analysis Gyroscopic motions | CO-1 |
| TSO 2a. Describe properties and application of smart materials use in UAV frame. TSO 2b. Calculate the diameter of the propeller for given drone frame size. TSO 2c. Determine size of quadcopter frame and diameter of propeller of drone TSO 2d. Describe working of GPS and its hardware interfacing. TSO 2e. Write steps to interface GPS module for drone navigation. TSO 2f. Describe different RF blocks and antennas used in RF transmitter and receiver. | Unit-2.0 Drone Frame and Components 2.1 Drone frame design <ul style="list-style-type: none"> Calculation principle for drone frame sizes Quadcopter frame design Smart materials for UAV frame Green material uses in drone 2.2 Advance Drones component <ul style="list-style-type: none"> GPS, Interfacing of GPS hardware Thermal and chemical sensor Tilt and LiDAR sensor 2.3 RF transmitter and receiver <ul style="list-style-type: none"> RF blocks RF antennas 2.4 Micro-electromechanical systems (MEMS) based sensor 2.5 HD and thermal Image camera | CO-2 |
| TSO 3a. Identify features and specifications of FCB use in different application TSO 3b. Explain ports of any given advance flight controller board. | Unit-3.0 Advance flight controller Board (FCB) 3.1 Specification and ports of FCB 3.2 Software for FCB <ul style="list-style-type: none"> Software installation | CO-3 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number (s) |
|--|---|-------------------------|
| TSO 3c. Write steps of software installation of flight controller board. TSO 3d. Describe installation and calibration steps of radio telemetry with FCB. TSO 3e. Write steps of calibration of accelerometer and ESC with FCB. TSO 3f. Describe interfacing of GPS with FCB. | 3.3 Radio Communication with FCB <ul style="list-style-type: none"> • Installation of Radio Telemetry • Radio Calibration with FCB 3.4 Calibration of accelerometer 3.5 Calibration of ESC 3.6 Interface of motor with FCB using ESC 3.7 GPS interface with FCB 3.8 Safety features of advance FCB | |
| TSO 4a. Describe challenges comes in drone maintenance. TSO 4b. Describe measuring devices and instrument use in drone maintenance. TSO 4c. Describe measuring instrument used to measure electrical parameters in drone. TSO 4d. Write sequence of steps use in assembling of drone. | Unit-4.0 Maintenance and assembling of Drone 4.1 Need and scope of drone maintenance 4.2 Types of maintenance 4.3 Routine drone maintenance and its checklist <ul style="list-style-type: none"> • Recording basic details • Structural inspection • Battery check • Software/firmware 4.4 Types of measuring instrument use in drone maintenance 4.5 Measurement of different electrical parameters related with drone hardware 4.6 Assembly of drones <ul style="list-style-type: none"> • Concept of interchangeability • Principle of gauging and their applicability in drone assembly • Parameters and profile measurements of standard propellers • Concepts of drone assembly using 3D modeling | CO-4 |
| TSO 5a. Describe function of autonomous drone using AI. TSO 5b. Describe IoT enable UAV for surveillance and data gathering. TSO 5c. Explain drone applications based on cost saving, enhanced efficiency and profitability aspects. | Unit-5.0 Advance Drone Application 5.1 Application of AI in Drone Technology 5.2 IoT and Computer vision integrated Drone 5.3 Drone interface with smart-phone 5.4 Drone Applications in <ul style="list-style-type: none"> • Military • Precision Agriculture | CO-5 |

Note: One major TSO may require more than one theory session/period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604D

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| LSO 1.1 Use the force of gravity to compute the centre of gravity for a given drone structure. | 1. | Determine Centre of gravity of different drone structure. | CO-1 |
| LSO 2.1 Develop skills of observation and interpreting phenomenal changes on Drone model for stability and hovering. | 2. | Demonstrate gyroscopic effect on a drone model | CO-1 |
| LSO 3.1 Draw various frame to be required in designing drone structure. LSO 3.2 Use Measuring instrument in designing drone frame. LSO 3.3 Choose suitable materials for making drone frame | 3. | Compare different types of airframe structure like quadcopter frame (plus shape, cross shape and H-shape), hexacopter frame (hexa + and hexa S). | CO-2, CO-4 |
| LSO 4.1 Identify and measure the condition of sensors. LSO 4.2 Interface Tilt and LiDAR sensors in drone. | 4. | Test Tilt and LiDAR sensors and their characteristics with Microcontroller based Flight controller board. | CO-2 |
| LSO 5.1 Identify different component of GPS module LSO 5.2 Measure and use signals from GPS module to determine latitude & longitude. LSO 5.3 Diagnose problems using appropriate instruments/tools related to GPS navigation. | 5. | Demonstrate the interfacing of GPS module to drone navigation. | CO-2, CO-3 |
| LSO 6.1 Measure characteristics of HD and thermal Image camera. LSO 6.2 Diagnose common problems related to HD and thermal Image camera. | 6. | Test HD and thermal Image camera and their characteristics. | CO-2 |
| LSO 7.1 Identify the characteristics of RF circuit blocks like amplifier, and filters. LSO 7.2 Identify different antennas used. LSO 7.3 Operate drone using RC transmitter and receiver. | 7. | Identify, configure and operate 433MHz and 2.4 GHz RC transmitter and receiver. | CO-2 |
| LSO 8.1 Test the different peripheral interconnections with FCB LSO 8.2 Troubleshoot advance Flight control board (FCB) | 8. | Programming and configure of parameters in flight control board (FCB). | CO-3 |
| LSO 9.1 Configure radio communication device to control drones. LSO 9.2 Operate drone using RC transmitter and receiver. | 9. | Test and perform communication of advance Flight control board with RF transceiver. | CO-3, CO-2 |
| LSO 10.1 Measure various parameters of GPS system LSO 10.2 Interface GPS system with flight controller board. | 10. | Test and perform communication of Flight control board (FCB) with GPS | CO-3, CO-2 |
| LSO 11.1 Configure HD and thermal image camera with drone. LSO 11.2 Demonstrate use of HD and thermal image camera with FCB | 11. | Test and troubleshoot HD and thermal image camera with advance FCB in drone. | CO-3, CO-2 |
| LSO 12.1 Measure voltage, current frequency using Digital Multimeter LSO 12.2 Measure peak to peak voltage, time period, and duty cycle using DSO and waveform generator. LSO 12.3 Measure unknown frequency and its level using spectrum analyzer. | 12. | Measure various electric parameters in drone hardware | CO-4 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| LSO 13.1 Inspect drone as per the given checklist LSO 13.2 Diagnose drone problems after flying of 50 and 100hrs | 13. | Perform preventive maintenance of drone components | CO-4 |
| LSO 14.1 Perform dismantle process of drone. LSO 14.2 perform services need for operation LSO 14.3 Check and Install different parts of the drone system. LSO 14.4 Assemble drone component. | 14. | Dismantle and service of different parts of drone system | CO-4 |

L) **Suggested Term Work and Self Learning: S2400604D** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. **Micro Projects:**

1. Prepare maintenance report for small UAV.
2. Survey nearby electronics shop and Prepare report on types of drone frames and drone sensors available and its specification.
3. Prepare report of surveying & mapping of our institute using drone with HD and thermal image camera.
4. Prepare report on land and crops quality of nearby agriculture field using drone.
5. Prepare report on Identify and select different application drones like agriculture, Surveillance, Inspections and gathering Information for disaster management.
6. Download 5 videos on advance FCB of drone design. Watch them and write report on it.
7. Market survey on different types of FCB, its specification and specific application and prepare report.
8. Develop mission completion drone with the help of GPS based Advance FCB.

c. **Other Activities:**

1. Seminar Topics-Drone stability using gyroscopic motion, Quadcopter frame, Green material use in drone design, GPS based drones, types of HD and thermal Image camera, Safety features in advance drone, Drone Assembling, Military drone.
2. Visits: Visit nearby small industry, Drone institute facilities. Prepare report of visit with special comments of advance drone technology used, material used, cost of printed component.
3. Surveys: Survey nearby electronics shop and Prepare report of list of advance drone components and its specification.
4. Product Development
5. Software Development

d. **Self-Learning Topics:**

1. Different types Drones frame
2. Overview of GPS technology
3. Different types of HD and thermal Image camera
4. Safety features in Drone
5. Advance drone application

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 15% | 15% | 20% | 20% | 20% | 25% | 25% |
| CO-2 | 20% | 20% | 20% | 20% | 20% | 25% | 25% |
| CO-3 | 25% | 25% | 20% | 20% | 20% | 25% | 25% |
| CO-4 | 25% | 25% | 20% | 20% | 20% | 25% | 25% |
| CO-5 | 15% | 15% | 20% | 20% | 20% | - | - |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number (s) | Total Marks | ETA (Marks) | | |
|---|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit 1.0 Engineering mechanics for Drone Technology | 8 | CO-1 | 12 | 04 | 04 | 04 |
| Unit 2.0 Drone frame and components | 10 | CO-2 | 14 | 04 | 04 | 06 |
| Unit 3.0 Advance Flight Controller Board | 12 | CO-3 | 16 | 04 | 06 | 06 |
| Unit 4.0 Maintenance and assembling of drone | 10 | CO-4 | 16 | 04 | 06 | 06 |
| Unit 5.0 Advance Drone Application | 8 | CO-5 | 12 | 04 | 04 | 04 |
| Total Marks | 48 | | 70 | 20 | 24 | 26 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA /ELA | | |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Determine Centre of gravity of different drone structure. | CO-1 | 50 | 40 | 10 |
| 2. | Demonstrate gyroscopic effect on a drone model | CO-1 | 40 | 50 | 10 |
| 3. | Compare different types of airframe structure like quadcopter frame (plus shape, cross shape and H-shape), hexacopter frame (hexa + and hexa S). | CO-2 | 50 | 40 | 10 |
| 4. | Test Tilt and LiDAR sensors and their characteristics with Microcontroller based Flight controller board. | CO-2 | 50 | 40 | 10 |
| 5. | Demonstrate the interfacing of GPS module to drone navigation. | CO-2, CO-3 | 50 | 40 | 10 |
| 6. | Test HD and thermal Image camera and their characteristics. | CO-2 | 50 | 40 | 10 |
| 7. | Identify, configure and operate 433MHz and 2.4 GHz RC transmitter and receiver. | CO-2 | 60 | 30 | 10 |
| 8. | Programming and configuration of parameters in flight control board (FCB). | CO-3 | 60 | 30 | 10 |
| 9. | Test and perform communication of advance Flight control board with RF transceiver. | CO-3, CO-2 | 60 | 30 | 10 |
| 10. | Test and perform communication of Flight control board (FCB) with GPS | CO-3, CO-2 | 60 | 30 | 10 |
| 11. | Test and troubleshoot HD and thermal image camera with advance FCB in drone. | CO-3, CO-2 | 60 | 30 | 10 |
| 12. | Measure various electric parameters in drone hardware | CO-4 | 40 | 50 | 10 |
| 13. | Perform preventive maintenance of drone components | CO-4 | 60 | 30 | 10 |
| 14. | Dismantle and service of different parts of drone system | CO-4 | 60 | 30 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---|---|--------------------------------------|
| 1. | Drone Frame | Tricopter/Quadcopter/Hexacopter | 1-15 |
| 2. | Propellers | 15 X 5.5 CW/Others | 1-15 |
| 3. | GPS module | M8N Series | 1-15 |
| 4. | Drone Camera | 15-20 Megapixel | 1-15 |
| 5. | Camera Gimble | 3 Axis feature, 360 Degree movement | 1-15 |
| 6. | Tilt Sensor | 8-30 volt | 1-15 |
| 7. | LiDER sensor | Range 75m to 200m | 1-15 |
| 8. | Battery | Lithium Polymer Battery,8000 to 10000 mAh | 1-15 |
| 9. | Motor | BLDC, 370kv | 1-15 |
| 10. | Electronic speed Controller (ESC) | 40 Amp | 1-15 |
| 11. | Flight Controller Board | CC3D/Pixhawk/Others | 1-15 |
| 12. | Transmitter and Receiver for radio signal | 10 Channels and more, 2.4 GHz & 5.8 GHz | 1-15 |
| 13. | Embedded system for AI application on UAV | Open Source Jetson Baseboard /Others | 1-15 |

R) Suggested Learning Resources:**(a) Books:**

| S. No. | Titles | Author (s) | Publisher and Edition with ISBN |
|--------|--|-----------------------------|---|
| 1. | Make: DIY Drone and Quadcopter Projects: A Collection of Drone-Based Essays, Tutorials, and Projects | Editors of Make | Shroff/Maker Media, First edition 2016, ISBN-978-9352133994 |
| 2. | Make: Getting Started with Drones: Build and Customize Your Own Quadcopter | Terry Kilby & Belinda Kilby | Shroff/Maker Media, First edition 2016, ISBN-978-9352133147 |
| 3. | Agricultural Drones: A Peaceful Pursuit | K R Krishna | Apple Academic Press,1st edition 2018, ISBN-978-1771885959 |
| 4. | Building Multicopter Video Drones: Build and fly multicopter drones to gather breathtaking video footage | Ty Audronis | Packt Publishing Limited; Illustrated edition,2014, ISBN-978-1782175438 |
| 5. | The Complete Guide to Drones | Adam Juniper | Ilex Press, Extended 2nd Edition,2018 ISBN-9781781575383 |
| 6. | Unmanned Aircraft Systems - UAVS Design, Development and Deployment (Aerospace Series) | R Austin | John Wiley & Sons Inc, 1st edition, 2010, ISBN-978-0470058190 |

(b) Online Educational Resources:

1. <https://archive.nptel.ac.in/courses/101/104/101104083/>
2. https://onlinecourses.nptel.ac.in/noc21_ae14/preview
3. https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle
4. <https://fusion.engineering/>
5. <https://robocraze.com/blogs/post/best-flight-controller-for-drone>
6. <https://www.youtube.com/watch?v=lrkFG7GilPQ>
7. <https://www.youtube.com/watch?v=KjG6FKCNCbM>
8. <https://ardupilot.org/>
9. <https://px4.io/>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. Development of an Autonomous IoT-Based Drone for Campus Security, Abdelrahman Mahmoud Gaber, Rozeha A. Rashid, Nazri Nasir, Ruzairi Abdul Rahim, M. Adib Sarijari, A. Shahidan Abdullah, Omar A. Aziz, Siti Zaleha A. Hamid, Samura Ali, 2021
2. IoT based UAV platform for emergency services; S. K. Datta, J. L. Dugelay, & C. Bonnet, 2018
3. Development of an Autonomous Drone for Surveillance Application; M. A. Dinesh, S. Santhosh Kumar, J. Sanath, K. N. Akarsh & K. M. Manoj Gowda, 2018
4. Autonomous cloud-based drone system for disaster response and mitigation; C. Alex & A. Vijaychandra, 2016
5. <https://www.geeetech.com/Documents/CC3D%20flight%20control%20board.pdf>
6. https://www.bhphotovideo.com/lit_files/201146.pdf
7. http://tricopter.hu/docs/cc3d_manual.pdf

- A) **Course Code** : 2400604E(T2400604E/P2400604E/S2400604E)
 B) **Course Title** : 3D Printing and Design (Advanced)
 C) **Pre- requisite Course(s)** : 3D Printing and Design (Basic)
 D) **Rationale** :

This advanced course on 3D Printing tries to develop understanding of the process of making real complex objects from digital models in the students using various 3D printing processes and materials (Plastics, Ceramics and Metals). It also covers the post processing required and details about various printing process and parameters to make a quality 3D printed component. This course can only be taken up after completing 3D Printing and Design (Basic) course offered in previous semester.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1** Select newer 3D Printing material for various applications.
CO-2 Use solid based 3D Printing processes to develop products.
CO-3 Use liquid-based 3D Printing processes to develop products.
CO-4 Use powder-based 3D Printing processes to develop products.
CO-5 Apply post processing techniques and quality checks on 3D printed components.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | - | - | 2 | - | 2 | | |
| CO-2 | 3 | - | 2 | 2 | - | - | 2 | | |
| CO-3 | 3 | - | 2 | 2 | - | - | 2 | | |
| CO-4 | 3 | - | 2 | 2 | - | - | 2 | | |
| CO-5 | 3 | 2 | - | 3 | 2 | - | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

- G) **Teaching & Learning Scheme:**

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|-----------------------------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2400604E | 3D Printing and Design (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|----------------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604E | 3D Printing and Design(Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self-Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2400604E

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| <p><i>TSO 1a.</i> Explain various forms of 3D printing raw material.</p> <p><i>TSO 1b.</i> Select material for the given popular 3D printing processes with justification.</p> <p><i>TSO 1c.</i> Select various Polymer based 3D printing raw materials with justification.</p> <p><i>TSO 1d.</i> Explain procedure of Powder preparation for the given 3D printing material.</p> <p><i>TSO 1e.</i> Explain properties of the given Metal/Ceramics 3D printing material.</p> <p><i>TSO 1f.</i> Choose suitable 3D printing material on the basis of Performance Requirements and Material Properties.</p> | <p>Unit-1.0 3D Printing Materials</p> <p>1.1 Various forms of 3D printing raw material- Liquid, Solid, Wire, Powder.</p> <p>1.2 Popular FDM, SLA, SLS, Binder Jetting, Material Jetting and Direct Energy deposition 3D printing materials.</p> <p>1.3 Polymers, Metals, Non-Metals, Ceramics.</p> <p>1.4 Polymers and their properties.</p> <p>1.5 Powder Preparation and their desired properties.</p> <p>1.6 Choosing the Right 3D Printing Material on the basis of Performance Requirements and Material Properties.</p> | CO1 |
| <p><i>TSO 2a.</i> Explain working of a typical FDM based 3D Printer.</p> <p><i>TSO 2b.</i> Justify use of FDM based 3D printing process and material for the given component.</p> <p><i>TSO 2c.</i> Explain the Laminated Object Manufacturing process.</p> <p><i>TSO 2d.</i> Estimate the cost and time of the given FDM based 3D printed component.</p> | <p>Unit-2.0 Solid based 3D Printing Processes</p> <p>2.1 Basic principle and working of fused deposition modeling (FDM) process.</p> <p>2.2 Liquefaction, solidification and bonding.</p> <p>2.3 Laminated Object Manufacturing process.</p> <p>2.4 Cost estimation of FDM 3D printed component.</p> | CO1, CO2 |
| <p><i>TSO 3a.</i> Explain the phenomenon of Photo Polymerization.</p> <p><i>TSO 3b.</i> Explain the working of a typical Stereo Lithography based 3D Printer.</p> <p><i>TSO 3c.</i> Explain procedure of 3D Scanning of the given component.</p> <p><i>TSO 3d.</i> Justify use of SLA based 3D printing process and material for the given component.</p> <p><i>TSO 3e.</i> Estimate the cost and time of the given SLA based 3D printed component.</p> <p><i>TSO 3f.</i> Apply Curing process to SLA based 3D printed component.</p> | <p>Unit-3.0 Liquid based 3D Printing Processes</p> <p>3.1 Photo polymerization.</p> <p>3.2 Principle and working of stereo lithography apparatus.</p> <p>3.3 SLA based 3D printing processes.</p> <p>3.4 SLA based 3D printing process materials.</p> <p>3.5 Scanning techniques.</p> <p>3.6 Curing processes.</p> <p>3.7 Cost estimation of SLA 3D printed component.</p> | CO1, CO3 |
| <p><i>TSO 4a.</i> Explain powder fusion mechanism.</p> <p><i>TSO 4b.</i> Explain working of a typical SLA based 3D Printer.</p> <p><i>TSO 4c.</i> Justify use of SLA based 3D printing process and material for the given component.</p> <p><i>TSO 4d.</i> Explain Net shape process.</p> <p><i>TSO 4e.</i> Explain Binder Jet 3D printing process.</p> <p><i>TSO 4f.</i> Justify use of Binder Jet 3D printing process and material for the given component.</p> <p><i>TSO 4g.</i> Estimate the cost and time of the given SLS based 3D printed component.</p> | <p>Unit-4.0 Powder based 3D Printing Processes</p> <p>4.1 Powder fusion mechanism.</p> <p>4.2 Principle and working of Selective Laser Sintering (SLS) process.</p> <p>4.3 SLS based 3D printers.</p> <p>4.4 Laser Engineering Net Shaping process.</p> <p>4.5 Electron Beam Melting.</p> <p>4.6 Binder Jet 3D Printing.</p> <p>4.7 Materials and Process parameters for SLS based 3D printing processes.</p> <p>4.8 Cost estimation of SLS based 3D printed component.</p> | CO1, CO4 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|--------------------------------|
| <p><i>TSO 5a.</i> Justify the need of post processing in the given 3D printed component.</p> <p><i>TSO 5b.</i> List the various post processing techniques.</p> <p><i>TSO 5c.</i> List the steps to perform post processing.</p> <p><i>TSO 5d.</i> Explain the given Cleaning related post processing approach for 3D printed component.</p> <p><i>TSO 5e.</i> Explain the given Surface finishing related post processing approach for 3D printed component.</p> <p><i>TSO 5f.</i> Apply simple inspection and testing techniques on the given 3D printed component.</p> <p><i>TSO 5g.</i> Identify the type of defect(s) in the given 3D printed component.</p> | <p>Unit-5.0 Post Processing and Quality</p> <p>5.1 Need of post processing: Functional and Aesthetic reasons.</p> <p>5.2 Steps of Post Processing: Cleaning/Support removal, Fixing, Curing or hardening, Surface finishing, Colouring.</p> <p>5.3 Cleaning: Support Removal (FDM and Material Jetting); Powder Removal (SLS and Powder Bed Fusion); Washing (SLA and Photo polymerisation).</p> <p>5.4 Fixing: Filling, Gluing, Welding.</p> <p>5.5 Surface finishing: Sanding, Polishing, Tumbling, Hydro dipping, Epoxy coating, Electro Plating, Vapour smoothing-Acetone treatment.</p> <p>5.6 Colouring, Coating, Priming and Painting.</p> <p>5.7 Inspection and testing: Digital, Visual, Physical.</p> <p>5.8 Defects and their causes.</p> | <p>CO1, CO2, CO3, CO4, CO5</p> |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604E

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|--|------------------------|
| <p><i>LSO 1.1.</i> Use the available 3D printing software.</p> <p><i>LSO 1.2.</i> Select printing process parameters based on the type/make of Printer and raw material</p> <p><i>LSO 1.3.</i> Set printing process parameters.</p> <p><i>LSO 1.4.</i> Produce a complex component using available FDM Printer.</p> | 1. | Develop the assigned digital single complex component using FDM based 3D Printer and available material. | CO1, CO2 |
| <p><i>LSO 2.1.</i> Use the available 3D printing software.</p> <p><i>LSO 2.2.</i> Select printing process parameters based on the type/make of Printer and raw material</p> <p><i>LSO 2.3.</i> Set printing process parameters.</p> <p><i>LSO 2.4.</i> Produce a complex component using available SLA Printer.</p> <p><i>LSO 2.5.</i> Perform curing of the SLA based 3D printed component.</p> | 2. | Develop the assigned digital single complex component using SLA based 3D Printer and available material. | CO1, CO3 |
| <p><i>LSO 3.1.</i> Use the available 3D printing software.</p> <p><i>LSO 3.2.</i> Select printing process parameters based on the type/make of Printer and raw material</p> <p><i>LSO 3.3.</i> Set printing process parameters.</p> <p><i>LSO 3.4.</i> Produce a complex component using available SLS Printer.</p> | 3. | Develop the assigned digital single complex component using SLS based 3D Printer and available material. | CO1, CO4 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|---|------------------------|
| <p><i>LSO 4.1.</i> Use the available 3D printing software.</p> <p><i>LSO 4.2.</i> Select printing process parameters based on the type/make of Printer and raw material</p> <p><i>LSO 4.3.</i> Set printing process parameters.</p> <p><i>LSO 4.4.</i> Produce a complex component using available FDM, SLA and SLS Printer.</p> <p><i>LSO 4.5.</i> Perform Cost, Time, Surface finish and Strength estimations related to 3D printed components.</p> | 4. | Develop same digital single complex component using FDM, SLA and SLS based 3D Printers and compare the printed components on the basis of Cost, Time, Surface finish, Strength. | CO1, CO2, CO3, CO4 |
| <p><i>LSO 5.1.</i> Use the available 3D printing software.</p> <p><i>LSO 5.2.</i> Select printing process parameters based on the type/make of Printer and raw material</p> <p><i>LSO 5.3.</i> Select appropriate tolerance, fit and printing process parameters.</p> <p><i>LSO 5.4.</i> Produce an assembly using available SLA/SLS Printer.</p> | 5. | Print one digital assembly on SLA/SLS based 3D Printer. | CO2/CO3/CO4 |
| <p><i>LSO 6.1.</i> Use of available 3D scanner.</p> <p><i>LSO 6.2.</i> Develop 3D digital model using scanning approach.</p> <p><i>LSO 6.3.</i> Use the available 3D printing software.</p> <p><i>LSO 6.4.</i> Produce a complex component using available SLA Printer.</p> | 6. | Scan the given real complex component and print it using FDM/SLA/SLS based 3D Printer. | CO2, CO3, CO4 |
| <p><i>LSO 7.1.</i> Identify tools/devices/chemicals for post processing</p> <p><i>LSO 7.2.</i> Perform post processing operations on printed component.</p> | 7. | Apply post processing techniques on the 3D printed component of experiment number 1 and/or 2 and/or 3. | CO5 |
| <p><i>LSO 8.1.</i> Identify tools/devices/techniques for inspection and testing.</p> <p><i>LSO 8.2.</i> Identify the defects in 3D printed components</p> <p><i>LSO 8.3.</i> Apply remedial measures to bring soundness in the defective 3D printed component.</p> | 8. | Check the soundness of the 3D printed component of experiment number 1 and/or 2 and/or 3 using available devices/techniques. | CO5 |

L) **Suggested Term Work and Self Learning: S2400604E** Some sample suggested assignments, micro project and other activities are mentioned here for reference

a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

b. **Micro Projects:**

1. Prepare a list of solid, liquid and powder form 3D printing raw materials stating their cost, colour opacity, flexibility and weight per unit volume.
2. Download 5 videos of 3D printing of different components using FDM, SLA and SLS each. Watch them and write a report to detail out the steps involved, 3D Printer used, 3D Printing software used, material used, complexity involved, printing time, post processing steps used.

3. Prepare a report on post processing steps and techniques used for 3D printed components using FDM, SLA, SLS.
4. Prepare a report to compare FDM, SLA, SLS based 3D printing process on the basis of cost, surface finish, printer setting time, printing time and post processing time and cost involved.
5. Download 5 videos of 3D printing processes **other than** FDM, SLA and SLS. Watch them and write a report to detail out the steps involved, 3D Printer used, 3D Printing software used, material used, complexity involved, printing time, post processing steps used.
6. Download 1 video related to inspection and testing of 3D printed components using different techniques like Visual inspection, Scanning Electron Microscopy (SEM), CT system, X-ray, Penetration testing, Infrared thermography, Leak or pressure testing for complex structures, Eddy current, Mechanical property inspection to measure tensile, yield, shear, fatigue, hardness, density, impact strength, Metallography (Microstructure testing). Watch them and write a report to detail out the steps involved and equipment used.

c. Other Activities:

1. Seminar Topics:

- Newer 3D printing raw materials
- Direct energy 3D printing process
- Material jetting 3D printing process
- Micro 3D printing process
- Metal and Ceramic 3D printing
- 3D printing of Jewelry
- 3D printing of Bio implants
- Printing of flexible plastic components

2. Visits: Visit nearby tool room/industry with 3D Printing facilities. Prepare report of visit with special comments of 3D printing technique used, material used, single component/batch production/mass production and cost of printed component.

3. Self-Learning Topics:

- 3D printing of transparent, soft and flexible plastic components
- 3D printing of metal components
- 3D printing of ceramic components
- 3D scanning process.
- Chemical post processing techniques

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 15% | 15% | 15% | - | - | 10% | 20% |
| CO-2 | 20% | 20% | 20% | 25% | 25% | 25% | 20% |
| CO-3 | 20% | 20% | 20% | 25% | 25% | 25% | 20% |
| CO-4 | 20% | 20% | 20% | 25% | 25% | 25% | 20% |
| CO-5 | 25% | 25% | 25% | 25% | 25% | 15% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number(s) | Total Marks | ETA (Marks) | | |
|---|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 3D Printing Materials | 6 | CO1 | 10 | 3 | 2 | 5 |
| Unit-2.0 Solid based 3D Printing Processes | 10 | CO1, CO2 | 14 | 4 | 5 | 5 |
| Unit-3.0 Liquid based 3D Printing Processes | 10 | CO1, CO3 | 14 | 4 | 5 | 5 |
| Unit-4.0 Powder based 3D Printing Processes | 10 | CO1, CO4 | 14 | 4 | 5 | 5 |
| Unit-5.0 Post Processing and Quality | 12 | CO1, CO2, CO3, CO4, CO5 | 18 | 5 | 5 | 8 |
| Total | 48 | - | 70 | 20 | 22 | 28 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Develop the assigned digital single complex component using FDM based 3D Printer and available material. | CO1, CO2 | 30 | 60 | 10 |
| 2. | Develop the assigned digital single complex component using SLA based 3D Printer and available material. | CO1, CO3 | 30 | 60 | 10 |
| 3. | Develop the assigned digital single complex component using SLS based 3D Printer and available material. | CO1, CO4 | 30 | 60 | 10 |
| 4. | Develop same digital single complex component using FDM, SLA and SLS based 3D Printers and compare the printed components on the basis of Cost, Time, Surface finish, Strength. | CO1, CO2, CO3, CO4 | 30 | 60 | 10 |
| 5. | Print one assembly on SLA/SLS based 3D Printer. | CO2/CO3/CO4 | 30 | 60 | 10 |
| 6. | Scan the given real complex component and print it using FDM/SLA/SLS based 3D Printer. | CO2, CO3, CO4 | 40 | 50 | 10 |
| 7. | Apply post processing techniques on the 3D printed component of experiment number 1 and/or 2 and/or 3. | CO5 | 40 | 50 | 10 |
| 8. | Check the soundness of the 3D printed component of experiment number 1 and/or 2 and/or 3 using available devices/techniques. | CO5 | 40 | 50 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---|--|--------------------------------------|
| 1. | High end computers | Processor Intel Core i7 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10 | All |
| 2. | Parametric Computer Aided Design software | CATIA/Solid works/NX/Creo OR Available with CoE | 1 to 5 |
| 3. | FDM based 3D printer | Fused Deposition Modelling system with complete accessories; Build Volume-300 x 300 x 300mm or Higher; Layer Thickness-0.1 – 0.4 OR Available with CoE | 1,4,5,6 |
| 4. | SLA based 3D printer | Printing Technology: SLA, 145 x 145 x 175mm build volume, Common layer thickness 25–100 µm, Dimensional Accuracy ± 0.5% (lower limit: ±0.10 mm), cure time of only 1-3s per layer, Material type: UV-sensitive liquid resin, Curing unit. | 2,4,5,6 |
| 5. | SLS based 3D printer | Printing Technology: SLS., Build Volume: 130 x 130 x 180 mm, Recommended min. wall thickness: 0.8 mm, Powder Diameter: 60 Microns, Material Type: Nylon, TPU, Light Source: Laser Diode | 3,4,5,6 |
| 6. | 3D Printing Material | ABS/PLA, Resin based Photosensitive material, Polymer/metal/ceramic powder OR Available with CoE | 1,2,3,4,5,6 |
| 7. | 3D Printing software | Latest version of software like: Cura/PrusaSlicer/ideaMaker/Meshmixer/MeshLab OR Available with CoE | 1 to 6 |
| 8. | 3D Scanner and Processing software | Handheld 3D scanner, Accuracy up to 0.1 mm, Resolution up to 0.2 mm, Real time onscreen 3D model projection and processing, Wireless technology with an inbuilt touch screen and battery, Extended field of view for capturing both large and small objects, Processing Software OR Available with CoE | 6 |
| 9. | Post processing equipments and tools | Deburring tools (tool handle & deburring blades), Electronic Digital Caliper, Cleaning Needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removal spatula, Needle file, Cutting mat, Glue stick, Wire stripper, Chemicals, Etching agents etc. | 7 |
| 10. | Inspection and Testing devices | <ul style="list-style-type: none"> • Visual inspection, Devices related to: • Scanning electron microscopy (SEM), CT system, X-ray, • Penetration testing, • Infrared thermography, • Leak or pressure testing for complex structures, • Eddy current, • Mechanical property inspection to measure tensile, yield, shear, fatigue, hardness, density, impact strength • Metallography (Microstructure testing) | 8 |

R) Suggested Learning Resources:**(a) Books:**

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|---|---|
| 1. | Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing | Lan Gibson, David W. Rosen, Brent Stucker | Springer, 2010 ISBN: 9781493921133 |
| 2. | Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing | Andreas Gebhardt, | Hanser Publisher, 2011 ISBN: 156990507X, 9781569905074 |
| 3. | 3D Printing and Design | Sabrie Soloman | Khanna Publishing House, Delhi ISBN: 9789386173768 |
| 4. | 3D Printing and Rapid Prototyping- Principles and Applications | C.K. Chua, Kah Fai Leong | World Scientific, 2017 ISBN: 9789813146754 |
| 5. | Getting Started with 3D Printing: A Hands-on Guide to the Hardware, Software, and Services Behind the New Manufacturing Revolution | Liza Wallach Kloski, Nick Kloski | Make Community, LLC; 2nd edition, 2021 ISBN: 9781680450200 |
| 6. | Laser-Induced Materials and Processes for Rapid Prototyping | L. Lu, J. Fuh, Y.S. Wong | Kulwer Academic Press, 2001 ISBN: 9781461514695 |

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. <https://archive.nptel.ac.in/courses/112/104/112104265/>
3. <https://bigrep.com/post-processing/>
4. <https://www.mdpi.com/2227-7080/9/3/61>
5. <https://all3dp.com/2/best-3d-printing-books/>
6. <https://www.youtube.com/watch?v=TQY2IF-sFal>
7. <https://www.youtube.com/watch?v=Oz0PoS5LPxg>
8. <https://www.youtube.com/watch?v=6ejjh0GdyDc>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. 3D Printing Projects DK Children; Illustrated edition, 2017
2. The 3D Printing Handbook: Technologies, design and applications Ben Redwood, Filemon Schöffner, Brian Garret, 3D Hubs; 1st edition, 2017
3. <https://www.imprecision.com/inspection-method-for-3d-printed-parts/>
4. 3D Printer Users' Guide
5. 3D Printer Material Handbook
6. Lab Manuals

- A) **Course Code** : 2400604F(T2400604F/P2400604F/S2400604F)
 B) **Course Title** : Industrial Automation (Advanced)
 C) **Pre- requisite Course(s)** : Industrial automation (Basic), Digital
 Electronics and Basic programming skills

D) **Rationale** :

This course on Advanced industrial automation offers students a hands-on approach to implement industrial control using modern controllers like Programmable Logic Controller (PLC), Distributed Control System (DCS) Supervisory Control and Data Acquisition (SCADA). Students will learn to identify and connect field inputs and outputs; communicate with, and program microprocessor-based controllers. Students will also connect, communicate with, and develop displays for computer-based operator interfaces. Process manufacturers typically employ Distributed Control System (DCS) Supervisory Control and Data Acquisition (SCADA) technologies to monitor and control the operations in their facilities. DCS and SCADA systems are now doing much more than simply monitoring and controlling. The course will enable the students to use of basic instructions and addressing, advanced PLC instructions in Ladder Logic and to identify and troubleshoot the faults in PLC system and do PLC maintenance. This course also introduces the students to industrial automation communications, PLC maintenance and troubleshooting also to become a successful automation engineer.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1. Apply the principles of communication for industrial automation.
- CO-2. Test the output of the PLC ladder logic programs for the given application
- CO-3. Maintain PLC systems
- CO-4. Use SCADA for supervisory control and for acquiring data from the field.
- CO-5. Develop simple automation systems

F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | 2 | 2 | 2 | 2 | - | 2 | | |
| CO-2 | 3 | 3 | 3 | 3 | - | - | 2 | | |
| CO-3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | | |
| CO-4 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | | |
| CO-5 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|----------------------------------|------------------------------|---|----------------------|------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2400604F | Industrial Automation (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances/ problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, Online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|----------------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604F | Industrial Automation (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2400604F**

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|--|------------------------|
| TSO.1a Describe how does a PLC communicate? TSO.1b Differentiate between parallel and series communication TSO.1c Describe the data transfer mechanism for the given communication protocols. TSO.1d Describe the given communication protocol used in PLC communication. TSO.1e Summarize PLC to PLC communication procedure TSO.1f Describe the common procedure to interface the PLC with other given hardware. | Unit-1.0 Industrial automation communication and Interfacing 1.1 Analog and Digital Communications on Plant Floors 1.2 Introduction to Industrial Networking 1.3 RS232-422-485 standards for data communication 1.4 Industrial Ethernet 1.5 Concept of Fieldbus 1.6 MODBUS protocol 1.7 Highway Addressable Remote Transducer (HART) Protocol 1.8 Interfacing of Programmable Logic Controller with other hardware | CO-1 |
| TSO.2a Specify the proper I/O addressing format of the given PLC. TSO.2b Explain the use of different relay type instructions for the given operation. TSO.2c Describe how a program is executed with the help of Program Scan cycle TSO.2d Develop ladder logic program using arithmetic functions to perform the given operation. TSO.2e Develop ladder logic programs using logical and comparison instructions to perform the given operation TSO.2f Develop ladder logic programs using on delay, off delay and reset/retentive timer in a given PLC to create a delay in operation. TSO.2g Develop ladder logic programs using Up, Down and UP-down counter in a given PLC to count the number of products | Unit-2.0 PLC Programming 2.1 PLC I/O addressing in ladder logic 2.2 PLC programming instructions using ladder logic and relay type instructions 2.3 Program Scan cycle 2.4 PLC arithmetic functions - Addition, subtraction, multiplication, division instructions, increment decrement, trigonometric 2.5 PLC logical functions - AND, OR, XOR, NOT functions, PLC compare and convert functions. 2.6 Programming Timer –Addressing a timer block, status bits, On delay, Off Delay and reset/retentive timer 2.7 Programming Counter- Addressing a counter block, status bits, Up and Down counter, up-down counter, counter examples, register basics 2.8 Develop ladder logic for various simple applications | CO-2 |
| TSO.3a Describe Requirements for PLC enclosure. TSO.3b Describe Proper grounding techniques. TSO.3c Describe noise reduction Techniques. TSO.3d Explain preventive maintenance procedure | Unit-3.0 Installation and maintenance of PLC systems 3.1 PLC enclosure, grounding requirements, noise generating inductive devices, leaky inputs and outputs, techniques to reduce electrical noise and leakage. 3.2 Introduction to PLC Trouble shooting and maintenance, trouble shooting of hardware and software. 3.3 Diagnostic LED Indicators in PLCs | CO-3 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p>associated with PLC system to reduce environmental impact</p> <p>TSO.3e Identify faults in the given PLC system</p> <p>TSO.3f Explain the procedure for Troubleshooting PLC system</p> <p>TSO.3g Prepare preventive maintenance plan for the PLC system</p> <p>TSO.3h Use safety equipment's.</p> <p>TSO.3i Follow safe practices</p> | <p>3.4 Common problems</p> <ul style="list-style-type: none"> • Internal problems – Check for PLC Power Supply, Emergency Push Button, Power Supply Failure, Battery Failure, Electrical Noise Interference, Verify the PLC Program with the Master Program, Corrupted PLC Memory • External problems - Power failure, faulty grounding and electrical noise interference (RFI or EMI), Status of the Output Modules and their associated Circuitry, Status of the Input Modules and their associated Circuitry, Field Input and Output Devices, Communication Issues. • Environmental Conditions. Check for humidity, temperature, vibration, and noise-level limits specified by its manufacturer <p>3.5 Troubleshooting of Specific Components of the PLC System</p> <ul style="list-style-type: none"> • Power Supply Troubleshooting • I/O Modules Troubleshooting • Troubleshooting PLC Program Errors • Troubleshooting the Working Environment of a PLC • Replacement of CPU <p>3.6 PLC trouble shooting flowchart</p> <p>3.7 PLC maintenance – PLC maintenance checklist, preventive maintenance procedure, maintenance plan for the PLC system.</p> <p>3.8 Safety procedure and safety equipment's.</p> | |
| <p>TSO.4.a Describe the function of given element of a SCADA system.</p> <p>TSO.4.b Interface the given PLC with SCADA system using the given Open Platform Communications (OPC).</p> <p>TSO.4.c Describe the steps to develop a simple SCADA screen for the given industrial application.</p> <p>TSO.4.d Describe the procedure to maintain the SCADA based PLC system for the given application.</p> | <p>Unit-4.0 SCADA and DCS</p> <p>4.1 Introduction, need, benefits and typical applications of SCADA and DCS</p> <p>4.2 SCADA Architecture - Remote Terminal Units (RTUs), Master Terminal Units, Various SCADA editors, Communication protocols for SCADA</p> <p>4.3 Comparison of SCADA with DCS</p> <p>4.4 Interfacing SCADA system with PLC- Typical connection diagram, Object Linking and Embedding for Process Control (OPC) architecture</p> <p>4.5 Creating SCADA Screen HMI for simple object, Steps for linking SCADA object (defining Tags and items, creating trends etc.,) with PLC ladder program using OPC, configuring simple applications using SCADA: Traffic light control, water distribution, pipeline control, Power generation, transmission and distribution etc.</p> <p>4.6 Procedure to maintain the SCADA based PLC system.</p> | CO-3 |
| <p>TSO.5a Identify different components used for automation in the given system</p> <p>TSO.5b Select automation components for a given situation</p> <p>TSO.5c In the given manufacturing or service industry Identify the areas where automation is possible.</p> <p>TSO.5d Prepare plan for sustainable automation as per the requirement.</p> | <p>Unit-5.0 Applications of Industrial Automation</p> <p>5.1 Manufacturing- Industrial Robots- welding robots, pick and place robots, Cabot's, Machine monitoring system, supply chain, Automated assembly system, Flexible Automation and programmable Automation.</p> <p>5.2 Health Care- microscopic robots for medical diagnosis, automated medication dispensing devices, AESOP, ZEUS, RP_7(remote presence 7th generation), DaVinci</p> | CO-5 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--------------------------------------|---|------------------------|
| | <p>5.3 Defense- guided rockets and missiles, counter measures, UAV drones, launcher, radar antenna, engagement control system</p> <p>5.4 Automobile –Break monitoring system, Vehicle tracking system, Rear-view alarm to detect obstacles behind, Four-wheel drive, Traction control system, Dynamic steering response, Anti-lock braking system (ABS) Adaptive cruise control, Adaptive headlamps, Intelligent Parking Assist System, Driverless/Autonomous Cars</p> <p>5.5 Agriculture- harvesters, irrigation systems, plowing machines, self-driving tractors, grain yield sensor</p> <p>5.6 Mining- Mine planning system, mine picture compilation, mine control system, seismic imagining, laser imaging, Rig control system, automated drilling, automated exploration, automated truck</p> | |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604F

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|---|------------------------|
| <i>LSO 1.1</i> Data communication from PLC to PC and vice versa | 1. | Transfer the control data from PLC to PC and vice versa | CO1 |
| <i>LSO 1.2</i> Establish Communication channels between PLC s. | 2. | Transfer the control data from PLC to PLC | CO1 |
| <i>LSO 1.3</i> Transfer data from sensors to PLC and from PLC to PC. | 3. | Transfer the sensor data from sensor to PLC to PLC and PC | CO1 |
| <i>LSO 1.4</i> Interface the given PLC with a PC or a Laptop | 4. | Interface the given PLC with a PC or a Laptop | CO1 |
| <i>LSO 2.1</i> Identify Different parts and front panel indicators of a PLC | 5. | Identify the various parts and front panel status indicators of the given PLC. | CO2 |
| <i>LSO 2.2</i> Develop Ladder logic program for different arithmetic operations | 6. | Develop/Execute ladder logic program for different arithmetic operations such as Addition, subtraction, multiplication, division increment, decrement, trigonometric in a given PLC | CO2 |
| <i>LSO 2.3</i> Develop Ladder logic program for different logical operations | 7. | Develop/Execute ladder logic program for logical operations such as AND, OR, NOT, NAND, NOR, X-OR, X-NOR gate along with truth table | CO2 |
| <i>LSO 2.4</i> Program Latch and Unlatch circuit in a PLC for motor operation | 8. | Program the given PLC to start run and stop the given motor using latch circuit | CO2 |
| <i>LSO 2.5</i> Create delay in operation using on delay, off delay and retentive timer function in a given PLC. | 9. | Test the functionality of on delay, off delay and retentive timer for its correct operation in a given PLC. | CO2 |
| <i>LSO 2.6</i> Count the number of objects/events using Up counter, Down counter and UP/Down counter in a PLC | 10. | Test the functionality of Up, Down and Up-down counter for its correct operation in a given PLC. | CO2 |
| <i>LSO 2.7</i> Program PLC using ladder logic to control a LED/Lamp | 11. | Develop/Execute a ladder logic program to put LED/lamp in the blinking mode | CO2 |
| <i>LSO 2.8</i> Program PLC using ladder logic to control a simple traffic light system | 12. | Develop/Execute a ladder logic program to control a simple traffic light control system using PLC | CO2 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| <p><i>LSO 3.1</i> Use hygrometer to measure the humidity inside the panel</p> <p><i>LSO 3.2</i> Use thermometer to measure ambient temperature inside the panel</p> <p><i>LSO 3.3</i> Use tester to determine the voltage fluctuation at the power supply terminals is within specifications</p> <p><i>LSO 3.4</i> Test the ground connections of the given PLC.</p> <p><i>LSO 3.5</i> A given PLC is not working as per the logic instructions investigate the PLC to identify the cause of failure to show the desired output</p> <p><i>LSO 3.6</i> Investigate the cause of Noise in the given PLC</p> <p><i>LSO 3.7</i> PLC goes on blackout out by losing its operating power. Troubleshoot the cause of failure.</p> <p><i>LSO 3.8</i> Troubleshoot the corrupted PLC memory.</p> <p><i>LSO 3.9</i> Replace CPU and power supply fuses in a given PLC system.</p> | 13. | Troubleshooting of PLC system | CO3 |
| <p><i>LSO 4.1</i> Download any open source SCADA software and install the same.</p> <p><i>LSO 4.2</i> Interpret the available components in symbol factory of SCADA software</p> <p><i>LSO 4.3</i> Create simple SCADA HMI applications and apply dynamic properties. (Select any Three from the given list)</p> <ol style="list-style-type: none"> i. Turn on and off a tube light using a Switch ii. Apply filling and object size properties to a rectangle, square and round object iii. Move the object, fill the object using slider and meter reading. iv. Apply orientation property to a fan and control its direction using a slider. v. Move a square object horizontally first, then vertically and again horizontally by applying visibility property. <p><i>LSO 4.4</i> Create historical and real time trends for the given automation</p> | 14. | Develop simple SCADA HMI applications using any one open source SCADA software and apply dynamic properties | CO4 |
| <p><i>LSO 5.1</i> Develop a smart irrigation device to detect the change in moisture level in the soil and controls the flow of water accordingly with a DC pump.</p> <p><i>LSO 5.2</i> Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application</p> <p><i>LSO 5.3</i> Develop a PLC program to control the robot in such a way that the robot can automatically pick and</p> | 15. | Develop simple automation systems for the given requirement (Select any Three from the given list) | CO5 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| <p>place components and works in sync with the conveyor belt system.</p> <p><i>LSO 5.4</i> Develop a Automation system to Open and close the door in the shop</p> <p><i>LSO 5.5</i> Develop a line following robot with RFID sensor for supplying materials and automating workflow.</p> <p><i>LSO 5.6</i> Develop smart street light controlling mechanism which will Switch on/off the lights automatically depending on the intensity of the sunlight at that particular time of the day.</p> <p><i>LSO 5.7</i> Develop smart automated railway crossing system to detect train arrival and departure and send appropriate signals to the microcontroller.</p> | | | |

L) Suggested Term Work and Self Learning: S2400604F Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- i. State three advantages of using programmed PLC timer over mechanical timing relay.
- ii. It is required to have a pilot light glow, meeting all of the circuit requirements given below:
 - All four circuit pressure Switches must be closed.
 - At least two out of three circuit limit Switches must be closed.
 - The reset Switch must not be closed.
- iii. Using AND, OR, and NOT gates, design a logic circuit that will solve this hypothetical problem
- iv. Prepare a comparison chart of different types of PLC
- v. Prepare a maintenance plan for a given PLC system.

b. Micro Projects:

1. Troubleshoot the faulty equipment/kit available in automation laboratory
2. Select one industry and analyze the process and propose the automation strategies' that can be used for automation.
3. Develop a working model of a given application using given actuators and valves.
4. Develop a smart irrigation device to detect the change in moisture level in the soil and controls the flow of water accordingly with a DC pump.
5. Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application
6. Develop a PLC program to control the robot in such a way that the robot can automatically pick and place components and works in sync with the conveyor belt system.

c. Other Activities:

1. Seminar Topics- PLC instructions, Timers and Counters used in a given PLC
2. Seminar Topics- Industrial Applications of PLC and SCADA, AGV, Application of automation in different area, trouble shooting of different types of PLC
3. Visits – Visit any industry with full or semi automation and prepare a report on industrial automation used by the industry in the given section, components used, power requirement, output achieved and maintenance activities required.
4. Surveys- Carry out a market/internet survey of PLC and prepare the comparative technical specifications of any one type of PLC (Micro or Mini) of different manufacturer.
5. Product Development- Develop a prototype automatic railway crossing system
 - a. Software Development- Download any open source software for PLC and install on your laptop/PC and carry out basic PLC programming
6. Also download any open source software for SCADA and install on your laptop/PC and carry out basic SCADA HMI programming
7. Surveys – Carry out a internet based survey to compare SCADA and DCS

d. Self-Learning Topics:

- Basic concepts of working of robot
- Automated material handling.
- Instrumentation systems for inspection and testing for quality of the product
- Use of robots in different applications
- Intelligent Transportation Systems
- Communication standards and protocols used in PLC
- Use of PLC for different industrial applications
- Use of SCADA for different industrial applications
- Interfacing of PLC

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 10% | 20% | 20% | -- | 33% | 10% | 20% |
| CO-2 | 15% | 25% | 20% | -- | 33% | 15% | 20% |
| CO-3 | 15% | 20% | 20% | -- | 34% | 15% | 20% |
| CO-4 | 30% | 20% | 20% | 50% | -- | 30% | 20% |
| CO-5 | 30% | 15% | 20% | 50% | -- | 30% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self-learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point- (O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number (s) | Total Marks | ETA (Marks) | | |
|--|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-.1.0 Industrial automation Communication and Interfacing | 9 | CO1 | 14 | 5 | 4 | 5 |
| Unit-.2.0 PLC Programming | 12 | CO2 | 17 | 5 | 6 | 6 |
| Unit-.3.0 Installation and maintenance of PLC systems | 10 | CO3 | 14 | 4 | 5 | 5 |
| Unit-.4.0 SCADA and DCS | 9 | CO4 | 14 | 4 | 5 | 5 |
| Unit-.5.0 Applications of Industrial Automation | 8 | CO5 | 11 | 2 | 4 | 5 |
| Total Marks | 48 | | 70 | 20 | 24 | 26 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA * (%) | PDA** (%) | |
| 1. | Transfer the control data from PLC to PC and vice versa | CO1 | 50 | 40 | 10 |
| 2. | Transfer the control data from PLC to PLC | CO1 | 50 | 40 | 10 |
| 3. | Transfer the sensor data from sensor to PLC to PLC and PC | CO1 | 50 | 40 | 10 |
| 4. | Interface the given PLC with a PC or a Laptop | CO1 | 50 | 40 | 10 |
| 5. | Identify Different parts and front panel indicators of a PLC | CO2 | 50 | 40 | 10 |
| 6. | Develop Ladder logic program for different arithmetic operations | CO2 | 50 | 40 | 10 |
| 7. | Develop Ladder logic program for different logical operations | CO2 | 50 | 40 | 10 |
| 8. | Program Latch and Unlatch circuit in a PLC for motor operation | CO2 | 50 | 40 | 10 |
| 9. | Create delay in operation using on delay, off delay and retentive timer function in a given PLC | CO2 | 50 | 40 | 10 |
| 10. | Count the number of objects/events using Up counter, Down counter and UP/Down counter in a PLC | CO2 | 50 | 40 | 10 |
| 11. | Program PLC using ladder logic to control a LED/Lamp | CO2 | 50 | 40 | 10 |
| 12. | Program PLC using ladder logic to control a simple traffic light system | CO2 | 50 | 40 | 10 |

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | Viva-Voce (%) |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | |
| | | | PRA * (%) | PDA** (%) | |
| 13. | Use hygrometer to measure the humidity inside the panel | CO3 | 50 | 40 | 10 |
| 14. | Use thermometer to measure ambient temperature inside the panel | CO3 | 50 | 40 | 10 |
| 15. | Use tester to determine the voltage fluctuation at the power supply terminals is within specifications | CO3 | 50 | 40 | 10 |
| 16. | A given PLC is not working as per the logic instructions investigate the PLC to identify the cause of failure to show the desired output | CO3 | 50 | 40 | 10 |
| 17. | Investigate the cause of Noise in the given PLC | CO3 | 50 | 40 | 10 |
| 18. | PLC goes on blackout out by losing its operating power. Troubleshoot the cause of failure. | CO3 | 50 | 40 | 10 |
| 19. | Troubleshoot the corrupted PLC memory. | CO3 | 50 | 40 | 10 |
| 20. | Replace CPU and power supply fuses in a given PLC system | CO3 | 50 | 40 | 10 |
| 21. | Download any open source SCADA software and install the same. | CO4 | 50 | 40 | 10 |
| 22. | Interpret the available components in symbol factory in SCADA software | CO4 | 50 | 40 | 10 |
| 23. | Create simple SCADA HMI applications and apply dynamic properties (Any Three) . i. Turn on and off a tube light using a Switch ii. Apply filling and object size properties to a rectangle, square and round object iii. Move the object, fill the object using slider and meter reading. iv. Apply orientation property to a fan and control its direction using a slider. v. Move a square object horizontally first, then vertically and again horizontally by applying visibility property. | CO4 | 50 | 40 | 10 |
| 24. | Create historical and real time trends for the given automation | CO4 | 50 | 40 | 10 |
| 24 | Select any three of the following: - i. Develop a smart irrigation device to detect the change in moisture level in the soil and controls the flow of water accordingly with a DC pump. ii. Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application iii. Develop a PLC program to control the robot in such a way that the robot can automatically pick and place components and works in sync with the conveyor belt system. iv. Develop a Automation system to Open and close the door in the shop v. Develop a line following robot with RFID sensor for supplying materials and automating workflow. vi. Develop smart street light controlling mechanism which will Switch on/off the lights automatically depending on | CO5 | 60 | 30 | 10 |

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | Viva-Voce (%) |
|--------|--|------------------------|-------------|-----------|---------------|
| | | | Performance | | |
| | | | PRA * (%) | PDA** (%) | |
| | the intensity of the sunlight at that particular time of the day. vii. Develop smart automated railway crossing system to detect train arrival and departure and send appropriate signals to the microcontroller. | | | | |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---|---|--------------------------------------|
| 1. | SCADA software (reputed make like Allen Bradley, Siemens etc.,) | Ready-to-use symbol library, React and respond in real-time, Real time monitoring, Friendly, manageable, secure, extensible, Easy-to-use, easy to implement, Easy configuration, simplified maintenance, Communication with PLC, easy and flexible alarm definition, data collection and analysis for new and existing systems, easy-to-use for report generation, open access to historical data, different packages available with input/output structure. Open source software SCADA software: like Ellipse/FTVSE/Wonderware/ open SCADA can also be used | 14 |
| 2. | Universal PLC Training System with HMI (Of reputed make such as Allen bradely, Siemens, etc.,) Compatible with SCADA software | Human Machine Interface (HMI) display, PLC with 16 digital inputs, 16 digital outputs with RS232 communication facility. Open platform to explore wide PLC and HMI applications. Industrial look & feel. Toggle Switches, push to ON Switch, proximity sensor, visual indicator, audio indicator, and DC motor. Experiments configurable through patch board. Powerful instruction sets. Several sample ladder and HMI programs. PC based ladder and HMI programming. Extremely easy and student friendly software to develop different programs. Easy downloading of programs. Practice troubleshooting skills. Compact tabletop ergonomic design. Robust construction. PLC gateway for cloud connectivity. Open source software like Ladder logic simulator, Pico soft Simulator, Logixpro simulator, Simple EDA tools can also be used | 1 to 12 |
| 3. | Safety gears | Gloves, Safety goggles, Ear protection, Dust masks and respirators. | 13 |
| 4. | Power tools | Power drills, Orbital sanders, Circular saws, Impact wrenches. | 13 |
| 5. | Hand tools | Screwdrivers, Hammers, Hand saws, Hex Key Allen Wrench Set Inch and Metric, relay puller, Multi-Tool Wire Stripper/Crimper/Cutter | 13 |

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---------------------------------------|---|--------------------------------------|
| 6. | Electrical tools | Wire and cable strippers, Multimeters- Volts, Ohms, and Amps, Crimpers- Side Cutter Crimping, Wire Crimp Connector Kit, Digital Multimeter Clamp Meter with Amp, Volt, and Ohm, Non-Contact Voltage Tester | 13 |
| 7. | Spare parts | PLC Programming Cables, SD Card Reader Compact flash, Wire Nut Set, Fuses- Class J 30, 35, 60, and 100-amp fuses, Class CC 2, 3, 5, 10, 15, 20, and 30-amp fuses, 5mm x 20mm 0.032 (for 4-20mA circuits), 0.5, 1, 2, 5, 10, and 15 amps, Cube Relays, Resistor Kit, batteries, LED Indicators PLC Processor (CPU), Input/ output module | 13 |
| 8. | Thermo-hygrometer | Measuring range Temp.: -30 ... 60°C / -22 ... 140°F Measuring range rel. Humidity: 0 ... 100% rh, Measurement protocol as PDF, Data export possible as CSV, Readable without software, data sets of measured values can be stored. | 13 |
| 9. | Digital Hygrometer | maximum humidity measurement- 100%RH, temperature measurement resolution -0.1degree centigrade, humidity measurement resolution -0.1%RH, minimum operating temperature - -10 to -20-degree centigrade, Maximum operating temperature +45 to +50 degree centigrade | 13 |

R) Suggested Learning Resources:

(a) Books:

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|---|---|---|
| 1. | Introduction to Programmable Logic Controllers | Dunning, G. | Thomson /Delmar learning, New Delhi, 2005, ISBN 13: 9781401884260 |
| 2. | Programmable Logic Controllers | Petruzella, F.D. | McGraw Hill India, New Delhi, 2010, ISBN: 9780071067386 |
| 3. | Programmable Logic Controllers | Hackworth, John; Hackworth, Federic | PHI Learning, New Delhi, 2003, ISBN: 9780130607188 |
| 4. | Industrial automation and Process control | Stenerson Jon | PHI Learning, New Delhi, 2003, ISBN: 9780130618900 |
| 5. | Programmable Logic Controller | Jadhav, V. R. | Khanna publishers, New Delhi, 2017, ISBN: 9788174092281 |
| 6. | Programmable Logic Controllers and Industrial Automation - An introduction, | Mitra, Madhuchandra; Sengupta, Samarjit, | Penram International Publication, 2015, ISBN: 9788187972174 |
| 7. | Control System | Nagrath & Gopal | New Age International Pvt Ltd, ISBN: 9789386070111, 9789386070111 |
| 8. | Linear Control Systems with MATLAB Applications, Publisher: | Manke, B. S. | Khanna Publishers, ISBN: 9788174093103, 9788174093103 |
| 9. | Supervisory Control and Data Acquisition | Boyar, S. A. | ISA Publication, USA, ISBN: 978-1936007097 |
| 10. | Practical SCADA for industry, | Bailey David; Wright Edwin | Newnes (an imprint of Elsevier), UK 2003, ISBN:0750658053 |

(b) Online Educational Resources:

1. Software: - www.fossee.com
2. Software: - www.logixpro.com
3. Software: - www.plctutor.com
4. Software; - www.ellipse.com
5. PLC lecture: - <https://www.youtube.com/watch?v=pPiXefBO2qo>

6. PLC tutorial: http://users.isr.ist.utl.pt/~jag/aulas/apil3/docs/API_I_C3_3_ST.pdf
7. <https://www.youtube.com/watch?v=277wwYWolpw>-PLC system troubleshooting and repair. Industrial control panel. PLC system repair.
8. <https://www.youtube.com/watch?v=5Jmtvrch5Jg>
9. <https://www.youtube.com/watch?v=peyV9bwEaLY>
10. <https://www.youtube.com/watch?v=QdJhRmtKpxk&list=RDCMUCke36Liq-w5fboMHkq1APZw&index=3>
11. <https://www.youtube.com/watch?v=ygrrRwajz3M>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested OER, before use by the students.

(c) Others:

1. Learning Packages
2. Users' Guide
3. Manufacturers' Manual
4. Lab Manuals

- A) **Course Code** : 2400604G(T2400604G/P2400604G/S2400604G)
 B) **Course Title** : Electric Vehicle (Advanced)
 C) **Prerequisite Course(s)** : Electric Vehicle (Basics)
 D) **Rationale** :

The automobile manufacturing sector in India is rapidly switching over to electric vehicles used for the public as well as private transport. The Govt. of India has launched the FAME-II Scheme (Faster Adoption and Manufacturing of Hybrid & Plug-in Electric Vehicles) to encourage the progressive induction of reliable, affordable and efficient electric and hybrid vehicles and to create demand for Electric Vehicles in the country. The technology is being evolved to enhance the vehicle's efficiency and running mileage by controlling the manufacturing, maintenance and recurring costs of such vehicles. Due to the rapid increase in EV demand, industries will also require skilled manpower in this area. This advanced course on electric vehicles is included as an open elective for all the diploma programmes to provide a sound knowledge of EVs to engineering diploma students and develop skills related to testing and maintenance of various electrical, electronic and mechanical systems in EVs.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the learners' accomplishment of the following course outcomes. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the student will be able to-

- CO-1** Compute various parameters affecting Vehicle movement.
CO-2 Test the operation of the different elements of the Automobile System.
CO-3 Test the battery and motor used for Power Transmission in EVs.
CO-4 Test electronic control unit system of EVs.
CO-5 Interpret the impact of Grid to Vehicle (G2V) and Vehicle to Grid (V2G) during the charging cycle.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | 1 | 2 | - | - | 1 | | |
| CO-2 | 3 | 2 | 2 | 3 | 1 | - | - | | |
| CO-3 | 2 | 2 | 2 | 3 | 3 | 1 | 3 | | |
| CO-4 | 2 | 3 | - | 2 | 2 | - | 2 | | |
| CO-5 | 3 | 2 | - | 2 | 3 | 1 | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | | Legend: |
|-------------|-----------------------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|---------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) | |
| | | L | T | | | | | |
| 2400604G | Electric Vehicle (Advanced) | 03 | - | 04 | 02 | 09 | 06 | |

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|-----------------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604G | Electric Vehicle (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at the course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to the attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020-related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2400604G

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|--|------------------------|
| TSO 1a. Explain the vehicle movement process TSO 1b. Derive various equations for the movement of Vehicles TSO 1c. Compute different resistances affecting Vehicle movement. TSO 1d. Explain the dynamics of the given type of EV system. | Unit-1.0 Vehicle Dynamics 1.1 Vehicle Movement 1.2 Rolling Resistance: Equation, Coefficient, factor affecting rolling resistance, typical values of rolling resistance 1.3 Grading resistance 1.4 Road resistance 1.5 Acceleration resistance 1.6 Total driving resistance 1.7 Aerodynamic drag: Equation, typical values of the drag coefficient. 1.8 Vehicle dynamics <ul style="list-style-type: none"> • Hybrid and Electric Vehicles • DC Motor Dynamics and Control • AC Motor Dynamics and Control | CO1 |
| TSO 2 a. Identify the given elements of Automobile Systems. TSO 2 b. Describe the functions of the given elements of Automobile Systems. TSO 2 c. Explain the dynamic characteristics of the Disc Braking System for the given braking steps. TSO 2 d. Describe the Procedure for testing the given AC/DC motors. TSO 2 e. Describe the Procedure of Installation and Testing of the given EV Charging Stations. TSO 2 f. Describe the Procedure for Commissioning EV Charging Stations. TSO 2 g. Explain the functions of the EV Control Unit. | Unit-2.0 Elements of Automobile 2.1 Suspension and Damping systems 2.2 Brake system: Half-step braking, Full step Braking 2.3 Transaxle 2.4 Elements of Noise Vibration and Harshness Control 2.5 Body balancing 2.6 Tyre Technology 2.7 AC/DC motor 2.8 Air-conditioning and Heating System 2.9 Lighting System 2.10 Automotive wiring system 2.11 Earthing and Insulation 2.12 Charging stations – Installation and Commissioning 2.13 Vehicle control unit | CO2 |
| TSO 3a. Compare different power transmission systems in EVs. TSO 3b. List the main Components of the EV Power Train. TSO 3c. Explain the functions of the given EV Power Train component. TSO 3d. Describe the testing procedure of the given EV Power Train component. TSO 3e. Explain the regenerative braking operation in the given EV motor. TSO 3f. Describe the speed control mechanism of the given motor. TSO 3g. Explain various parameters of the given battery. TSO 3h. Select the suitable battery for the given EV application. TSO 3i. Describe the assembling and dismantling procedure of the given battery. | Unit-3.0 EV Power Transmission System_ 3.1 Transmission System: Single and Multi-transmission system 3.2 EV Power Train 3.3 EV Power Train Components: Battery Pack, DC-AC Converter, Electric Motor, On-Board Charger. 3.4 Battery Parameters: Voltage, Current, Charging rate, efficiency, energy density, power density, State of Charge (SoC), Depth of Discharge (DoD), State of Health (SoH), Operating Temperature, specific energy, specific power, life cycle and cost. 3.5 Battery Assembly and Dismantling. 3.6 Gear and Differential Assembly 3.7 Safe disposal of used battery | CO3 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|------------------------|
| TSO 3j. Describe the Mechanism of Gear and Differential Assembly. | | |
| TSO 4a. Describe the Vehicle Control Unit (VCU). TSO 4b. Describe the functions of the given component of the Electronic Control Unit. TSO 4c. Describe the connections of the given control unit with the EV sub-system. TSO 4d. Explain the Interaction of Controller Area Network Communication with VCU. TSO 4e. Describe the Troubleshooting and Assessment procedure of VCU. | Unit- 4.0 Vehicle Control Unit (VCU) 4.1 Electronic Control Unit: Battery Management System, DC-DC Converter, Thermal Management System and Body Control Module. 4.2 Predefined functions 4.3 Connections with EV subsystem 4.4 Controller Area Network (CAN) communication 4.5 Interaction of CAN Communication with VCU. 4.6 Troubleshooting and Assessment 4.7 Dynamometers: Introduction 4.8 Environmental Chambers | CO4 |
| TSO 5a. Explain the Classification of Charging Technologies. TSO 5b. Explain the impact of the Grid on Vehicle Charging and Vehicle Charging on the Grid. TSO 5c. Describe the testing procedure of the given Bi-directional charging systems. TSO 5d. Explain the Energy Management Strategies in the EV. TSO 5e. Explain the Wireless Power Transfer (WPT) technique for EV Charging. | Unit- 5.0 EV Charging Technologies 5.1 Charging Technology: Classification 5.2 Grid-to-Vehicle (G2V) 5.3 Vehicle to Grid (V2G) or Vehicle to Buildings (V2B) or Vehicle to Home(V2H). 5.4 Bi-directional EV Charging Systems. 5.5 Energy Management Strategies. 5.6 Wireless Power Transfer (WPT) technique for EV Charging. | CO5 |

Note: One major TSO may require more than one theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604G

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| LSO 2.1 Test the operation of the Control Disc Braking system and control the regenerative braking system using a test rig. LSO 2.2 Test the performance (Speed v/s Braking Torque) of the Disc Braking System in Half step and Full step braking modes. | 1. | <ul style="list-style-type: none"> Testing of Control Disc Braking system and Control Regenerative Braking system. | CO2 |
| LSO 2.3 Test the performance of different types of propulsion motors. | 2. | <ul style="list-style-type: none"> Testing of Motors | |
| LSO 2.4 Test the continuity of the automotive wiring system in the EV | 3. | <ul style="list-style-type: none"> Testing of the automotive wiring system. | |
| LSO 3.1 Test the performance of a new set of batteries and aged batteries. LSO 3.2 Compare the performance of the battery and find the Fuel Gauge after discharging the battery. a. 0% - 100% b. 30% - 100% c. 50% - 100% LSO 3.3 Evaluate the following parameters of the given EV battery. a. Specific power | 4. | <ul style="list-style-type: none"> Testing of Batteries used in EVs | CO2, CO3 |

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| b. Specific energy c. Life span and d. Cost parameters LSO 3.4 Evaluate the State of Health (SoH) of the given EV Battery after several charge/discharge cycles. | | | |
| LSO 3.5 Test the dynamic performance of the given motor; a) Speed and torque spectrum. b) Speed and torque oscillation c) Friction torque friction spectrum. LSO 3.6 Test the following speed-controlled performance characteristics of the given motor; a. Motor voltage over time b. Motor current over time. c. Speed and torque over time. d. Torque over speed. e. Current over speed. f. Electrical input power and the mechanical input power over speed | 5. | <ul style="list-style-type: none"> Speed control of Electrical Motors | |
| LSO 4.1 Connect the components of the EC Units with EV subsystems. LSO 4.2 Troubleshoot basic faults in the electronic control unit of EV. | 6. | <ul style="list-style-type: none"> Connection of Electronic Control Unit components Troubleshooting of electronic control unit | CO4 |
| LSO 5.1 Evaluate the impact of the Grid on Vehicle Charging and Vehicle Charging on the Grid. | 7. | <ul style="list-style-type: none"> Impacts of G2V and V2G | CO5 |
| LSO 5.2 Prepare a layout of a charging station | 8. | <ul style="list-style-type: none"> Demonstration of Charging stations | |

L) **Suggested Term Work and Self-Learning: S2400604G** Some sample suggested assignments, micro projects and other activities are mentioned here for reference.

a. **Assignments:** Questions/ Problems/ Numerical/ Exercises to be provided by the course teacher in line with the targeted COs.

b. **Micro Projects:**

- Design and build a physical model of an EV motor and powertrain components from scratch.
- Build and simulate communication systems of EVs using some software tools.
- Prepare a report on “the way carbon credit works and companies utilize it to reduce their emission values”.
- Develop an EV prototype power train using locally procured hardware components.

c. **Other Activities:**

1. **Seminar Topics:**

- Safe disposal process of Used Batteries.
- Charging Technologies used for charging the EV.
- EV power transmission systems.

2. **Surveys** – Visit an electric vehicle manufacturing plant and prepare report on HVAC system used in EV.

3. **Self-Learning Topics:**

- Impact of fleet charging of EVs on Power Systems.
- Energy Management in EV.
- Fuel Cell powered bus.
- EV Battery disposal and recycling.
- Mobility and connectors.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use the appropriate assessment strategy and its weightage, in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self-Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 20% | 15% | 20% | -- | -- | -- | -- |
| CO-2 | 20% | 20% | 20% | -- | -- | 35% | 25% |
| CO-3 | 20% | 30% | 20% | 70% | 40% | 40% | 25% |
| CO-4 | 20% | 25% | 20% | 30% | 20% | 10% | 25% |
| CO-5 | 20% | 10% | 20% | -- | 40% | 15% | 25% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point- (O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of the cognitive domain of the full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number (s) | Total Marks | ETA (Marks) | | |
|--|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 Vehicle Dynamics | 8 | CO1 | 12 | 4 | 5 | 3 |
| Unit-2.0 Elements of Automobile. | 10 | CO2 | 15 | 5 | 6 | 4 |
| Unit-3.0 EV Power Transmission System. | 14 | CO3 | 20 | 4 | 10 | 6 |
| Unit-4.0 Vehicle Control Unit (VCU) | 10 | CO4 | 15 | 4 | 6 | 5 |
| Unit-5.0 Charging Technologies | 6 | CO5 | 8 | 3 | 3 | 2 |
| Total Marks | 48 | | 70 | 20 | 30 | 20 |

Note: Similar table can also be used to design class/mid-term/ internal question papers for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1 | Testing of Control Disc Braking system and Control Regenerative Braking system. | CO2 | 60 | 30 | 10 |
| 2 | Testing of Motors. | | | | |
| 3. | Testing of automotive wiring system. | | | | |
| 4. | Testing of Batteries used in EVs | CO2, CO3 | 60 | 30 | 10 |
| 5. | Speed control of Electrical Motors | | | | |
| 6. | Connection of Electronic Control Unit components | CO4 | 60 | 30 | 10 |
| 7. | Troubleshooting of electronic control unit | | | | |
| 8. | Impacts of G2V and V2G | CO 5 | 30 | 60 | 10 |
| 9. | Demonstration of Charging stations | | | | |
| | | | 70 | 20 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both the end semester as well as progressive assessment of practicals. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student's performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|--|---|--------------------------------------|
| 1. | Disc Braking and Regenerative braking system test rig | Test rig equipment for Demonstration of Disc Braking and Regenerative Braking system operation. | 1 |
| 2. | Disc Braking System | Test rig / Software for testing the performance of the disc braking system in Half step and Full step braking mode. | 1 |
| 3. | Induction motor | Induction motor For EV applications with testing kit | 2,5 |
| 4. | Switched reluctance motor | Switched reluctance motor for EV applications with testing kit | 2,5 |
| 5. | Permanent magnet (PM) DC motors | Permanent magnet (PM) DC motors for EV applications with testing kit | 2,5 |
| 6. | Automotive wiring system | Testing facility of automotive wiring system using software /actual EV systems | 3 |
| 7. | Lithium Ion and Lead-acid Batteries | 12V, 7Ah with testing setup. | 4 |
| 8. | Nickel-based batteries (metal hydride and cadmium battery). | 12V, 7Ah with testing setup. | 4 |
| 9. | Battery tester | For testing battery parameters | 4 |
| 10. | Battery charger | Battery charger for EV | 4 |
| 11. | Battery Management System | Training kit or simulation for BMS | 4 |
| 12. | DC-DC Converter | 48V to 12V bidirectional DC-DC Converter | 4 |
| 13. | Power Analyser | To observe the impacts of G2V and V2G | 5 |
| 14. | BMS setup | For Demonstration & training | 4 |
| 15. | DC power supply | 0-32V | 5 |
| 16. | Charging Station Simulator | For Demonstration & training purposes. | 5 |
| 17. | EC Unit with EV subsystems | Electronic Control Unit Hardware parts/ software for demonstrating the Connection of Electronic Control Unit components with EV subsystems. | 6,7 |
| 18. | Facility to demonstrate the impact of the Grid on Vehicle Charging and Vehicle Charging on the Grid. | - | 7 |

R) Suggested Learning Resources:**(a) Books:**

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|---|------------------------------------|---|
| 1. | Electric Vehicles: And the End of the ICE age | Anupam Singh | Kindle Edition ASIN: B07R3WFR28 |
| 2. | Wireless Power Transfer Technologies for Electric Vehicles (Key Technologies on New Energy Vehicles) | Xi Zhang, Chong Zhu, Haitao Song | Springer Verlag, Singapore; 1st ed. 2022 edition (23 January 2022) ISBN-13: 978-9811683473 |
| 3. | Modern Electric, Hybrid Electric, and Fuel Cell Vehicles | EHSANI | CRC Press; Third edition (1 January 2019) ISBN-13: 978-0367137465 |
| 4. | Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles | John G. Hayes, G. Abas Goodarzi | Wiley; 1st edition (26 January 2018) ISBN-13: 978-1119063643 |
| 5. | New Perspectives on Electric Vehicles | Marian Găiceanu (Editor) | IntechOpen (30 March 2022) ISBN-13: 978-1839696145 |
| 6. | Electric and Hybrid Vehicles, | Tom Denton, Taylor & Francis | 2nd Edition (2020) ISBN- 9780429296109 |
| 7. | Hybrid Electric Vehicles: Energy Management Strategies | S. Onori, L. Serrao and G. Rizzoni | Springer (2016) ISBN: 978-1-4471-6781-5 |
| 8. | Electric & Hybrid Vehicles | A.K. Babu | Khanna Publishing House, New Delhi, 1st Edition (2018) ISBN: 9789386173713, 9386173719 |
| 9. | Power Electronics: Circuits, Devices and Applications, | Rashid, M. H. | Pearson, 3rd edition, (2013) ASIN: B07HB3BM1W |

(b) Online Educational Resources:

1. <https://www.energy.gov/eere/fuelcells/fuel-cell-systems>
2. <https://powermin.gov.in/en/content/electric-vehicle>
3. <https://www.iea.org/reports/electric-vehicles>
4. <https://www.oercommons.org/search?f.search=Electric+Vehicles>
5. <https://fame2.heavyindustries.gov.in/Index.aspx>

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others:

1. Learning Packages on EV
2. EV Users' Guide
3. EV Manufacturers' Manual
4. EV Lab Manuals

- A) **Course Code** : 2400604H(T2400604H/P2400604H/S2400604H)
- B) **Course Title** : Robotics (Advanced)
- C) **Pre- requisite Course(s)** : Robotics (Basic)
- D) **Rationale** :
Efficiency and quality are the demands of industry 4.0. Robotics is a constituent of Industry 4.0 which not only provides the former two but also is beneficial for hazardous and similar challenging situations. The use of robotic technology is developing at a very fast rate in all types of industries whether manufacturing, service or tertiary. Engineers should be competent to use the robotic technology for industry and society advantage. This course aims for the diploma engineers to have advanced skills in robotic applications and use in digital manufacturing.
- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1 Plan the use of robots in engineering applications.
- CO-2 Elucidate the conceptual place of the robotic components for engineering processes.
- CO-3 Use robots for small automatic robotic applications.
- CO-4 Compute the economics associated with use of robots in industries.
- CO-5 Select appropriate robot for industrial requirements and other applications.

F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|---|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | - | - | 3 | - | 2 | - | 2 | | |
| CO-2 | - | 2 | 3 | 2 | - | - | - | | |
| CO-3 | 3 | 2 | 3 | - | - | - | 2 | | |
| CO-4 | 3 | - | - | 2 | - | - | - | | |
| CO-5 | 3 | 2 | - | - | 2 | - | - | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|---------------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2400604H | Robotics (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances/ problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|---------------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604H | Robotics (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done internally (40%) as well as externally (60%). Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2400604H**

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| TSO 1a. Define the need and scope of industrial robots. TSO 1b. Describe the concept of robot dynamics with regards to methods for orientation and location of objects. TSO 1c. Analyse robot direct kinematics for the given 2 DOF planar manipulator. TSO 1d. List types of robots TSO 1e. List safety steps while handling the given robot. TSO 1f. Interface robots with the given welding machine. TSO 1g. Interface robots with the given painting machine. TSO 1h. Interface robots with the given assembly machine. | Unit-1.0 Robot Kinematics, Dynamics and Industrial Applications 1.1 Definition need and scope of Industrial robots 1.2 Robot dynamics – Methods for orientation and location of objects 1.3 Planar Robot Kinematics – Direct and inverse kinematics for 2 Degrees of Freedom. 1.4 Safety while operating and handling robot 1.5 Robot Industrial applications: <ul style="list-style-type: none"> Welding Robots-Welding Guns, Welding Electrodes, Welding Power Sources, shielding gases, Robot interfacing Spray painting Robots, assembly operation, cleaning. | CO2, CO3 |
| TSO 2a. Explain the techniques to control robot motion. TSO 2b. Describe the given robot drive system. TSO 2c. Describe the types of grippers. TSO 2d. Design grippers for specific application. TSO 2e. Test the designed gripper for the application. TSO 2f. Use Bar code technology for robotic applications. TSO 2g. Integrate radio frequency identification technology in robotic applications. TSO 2h. Assemble an automated guided vehicle for the given situation using standard components. TSO 2i. Assemble a simple automated storage and retrieval systems (ASRS) for the given situation using standard components. | Unit– 2.0 Robot Drives, Control and Material Handling 2.1 Controlling the Robot motion. 2.2 Position and velocity sensing devices. 2.3 Drive systems – Hydraulic and Pneumatic drives 2.4 Linear and rotary actuators and control valves 2.5 Electro hydraulic servo valves, electric drives, motors 2.6 End effectors – Vacuum, magnetic and air operated grippers 2.7 Material Handling; automated guided vehicle systems, automated storage and retrieval systems (ASRS) 2.8 Bar code technology 2.9 Radio frequency identification technology. | CO2, CO3 |
| TSO 3a. Differentiate between various work cell layouts. TSO 3b. Select work cell for specific robot with justification. TSO 3c. Analyse robot cycle time. TSO 3d. Explain industrial applications of robotic cell. TSO 3e. Follow safety procedures in robotic cell. | Unit– 3.0 Robot Cell Design and Application 3.1 Robot work cell design, control and safety 3.2 Robot cell layouts 3.3 Multiple Robots and machine interference 3.4 Robot cycle time analysis 3.5 Industrial application of robotic cells | CO3 |
| TSO 4a. List different programming languages for the robots TSO 4b. Describe artificial intelligence TSO 4c. Write a programme in the required language to operate a robot for the given task. TSO 4d. Optimise robot programming parameters. | Unit– 4.0 Robot Programming and Economics of Robotization 4.1 Characteristics of task level languages through programming methods 4.2 Motion interpolation | CO1, CO4, CO5 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p>TSO 4e. Select a robot on the basis of cycle time analysis.</p> <p>TSO 4f. Conduct an economic analysis for use of robots.</p> <p>TSO 4g. Follow testing methods and acceptance rules for industrial robots.</p> | <p>4.3 Artificial intelligence: Goals of artificial intelligence, AI techniques, problem representation in AI</p> <p>4.4 Problem reduction and solution techniques.</p> <p>4.5 Application of AI and KBES in Robots</p> <p>4.6 Selection of Robots; Factors influencing the choice of a robot, selection of robot components, robot performance testing, work cycle time analysis</p> <p>4.7 Economics analysis for robotics, cost data required for the analysis</p> <p>4.8 Methods of economic analysis; Pay back method, equivalent uniform annual cost method, return on investment method.</p> <p>4.9 Testing methods and acceptance rules for industrial robots</p> | |
| <p>TSO 5a. Describe applications of robots in healthcare and medicine.</p> <p>TSO 5b. Describe applications of robots in Construction industry.</p> <p>TSO 5c. Describe applications of robots in Underground coal mining.</p> <p>TSO 5d. Describe applications of robots in utilities, military & firefighting operations.</p> <p>TSO 5e. Describe applications of robots in undersea and space</p> <p>TSO 5f. Describe applications of robots in brief in logistics, retail and hospitality, and smart cities.</p> <p>TSO 5g. Describe applications of robots in farming and agriculture in brief explain in brief the use of microrobots, nano robots, soft robots, humanoid robots</p> | <p>Unit-5.0 Applications in Non-manufacturing Environments</p> <p>5.1 Applications of Robots in</p> <ul style="list-style-type: none"> ● Healthcare and medicine ● Construction industry ● Underground coal mines ● Utilities, military & firefighting operations ● Undersea ● Space ● Logistics, ● Retail and Hospitality ● Smart Cities ● Farming and Agriculture <p>5.2 Overview of Microrobots, nano robots, soft robots, humanoid robots</p> | CO5 |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604H

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|---|------------------------|
| LSO 1.1 Identify Wireless Sensor Network. LSO 1.2 Use wireless sensor Network for different robotic applications | 1. | Identify different wireless sensor network in robotics viz. ZigBee, LoRa. | CO1, CO3 |
| LSO 2.1 Identify different Radio Frequency (RF) Controlled Wireless LSO 2.2 Use Radio Frequency (RF) Controlled Wireless for different robotic applications. | 2. | Use different Radio Frequency (RF) Controlled Wireless Robots. | CO1, CO2 |
| LSO 3.1 Identify the different Voice operated robot with speaker identification technology LSO 3.2 Use different Voice operated robot with speaker identification technology for different robotic applications. | 3. | Examine different voice operated robot with speaker identification technology. | CO1, CO3 |
| LSO 4.1 Identify the components required for a computer-controlled pick and place robot (wireless). LSO 4.2 Integrate the components for the required application. | 4. | Design a computer-controlled pick and place robot (wireless) | CO1 |
| LSO 5.1 Identify the components required for a Zigbee controlled Boat with wireless video and voice transmission. LSO 5.2 Integrate the components for the required application. | 5. | Design a Zigbee controlled Boat with wireless video and voice transmission. | CO2, CO3 |
| LSO 6.1 Identify the components required for a PC controlled wireless Multipurpose robot for engineering applications. LSO 6.2 Integrate the components for the required application. | 6. | Design a PC controlled wireless Multipurpose robot for simple engineering applications. | CO2, CO4, CO5 |
| LSO 7.1 Identify the components required for an unmanned arial photography LSO 7.2 Integrate the components for the required application. | 7. | Design an unmanned arial photography system. | CO3, CO5 |
| LSO 8.1 Develop a program LSO 8.2 Simulate palletizing and depalletizing operations through robots. | 8. | Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots. | CO5 |
| LSO 9.1 Develop a program LSO 9.2 Simulate direction control and step control logic for robotization | 9. | Develop TPP / Offline program for vision-based inspection for robots. | CO4, CO5 |
| LSO 10.1 Develop a program LSO 10.2 Simulate robotising an inspection and part assembly. | 10. | Program and simulate coordinated identification, inspection and part assembly for robots. | CO1, CO5 |
| LSO 11.1 Develop a program. LSO 11.2 Simulate obstacle avoidance of robots. | 11. | Develop obstacle avoidance robot Programming | CO1, CO5 |
| LSO 12.1 PLC programming. LSO 12.2 Simulate robotising of welding operation. | 12. | Program and simulate welding operation using robot simulation software. | CO1, CO5 |
| LSO 13.1 Simulate robotising of drilling operation. | 13. | TPP / Offline program for drilling operation. | CO1, CO5 |
| LSO 14.1 Develop a program for an industrial application. LSO 14.2 Execute the robot programme. | 14. | Program to execute an industrial robot application using a given configuration. | CO1, CO5 |
| LSO 15.1 Use robot simulation software for Direct Kinematic analysis upto 4-axis robots LSO 15.2 Correlate the simulated results with respective mathematical calculations. | 15. | Analyse Direct Kinematics of 4-axis robot using available software. | CO2 |

- L) Suggested Term Work and Self Learning: S2400604H** Some sample suggested assignments, micro project and other activities are mentioned here for reference.
- a. Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.
- b. Micro Projects:** A suggestive list of micro-projects is given here. Similar micro-projects that match the COs could be added by the concerned course teacher. The student should strive to identify eco-friendly or recycled material prior to selection for robotic applications.
1. Develop coin separating robot.
 2. Develop robot using radio frequency sensors for material handling.
 3. Develop robot for land mine detection.
 4. Develop a robot for car washing.
- c. Other Activities:**
1. Seminar Topics: Recent developments in the industrial applications of robotics
 2. Visits: Visit a robotic exhibition.
 3. Case Study: Identify a robotic application in automobiles and present a case study
 4. Download videos related to simple robotic applications in domestic and industrial purposes.
 5. Self-Learning Topics:
 - Robotic component manufacturers

- M) Suggested Course Evaluation Matrix:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate CO attainment.

| COs | Course Evaluation Matrix | | | | | | |
|-------------|---|-----------------------------|---------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self- Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 25% | 23% | 20% | 10% | 25% | 10% | 20% |
| CO-2 | 20 % | 23% | 20% | 10% | 25% | 20% | 20% |
| CO-3 | 15% | 17% | 20% | 25% | 25% | 20% | 20% |
| CO-4 | 20% | 20% | 20% | 15% | 25% | 20% | 20% |
| CO-5 | 20% | 17% | 20% | 40% | -- | 30% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self-learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

- N) Suggested Specification Table for End Semester Theory Assessment:** Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Number and Title | Total Classroom Instruction (CI) Hours | Relevant COs Number (s) | Total Marks | ETA (Marks) | | |
|---|--|-------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 Robot Kinematics, Dynamics and Industrial Applications | 12 | CO2, CO3 | 16 | 6 | 5 | 5 |
| Unit- 2.0 Robot Drives, Control and Material Handling | 10 | CO2, CO3 | 16 | 4 | 8 | 4 |
| Unit- 3.0 Robot Cell Design and Application | 8 | CO3 | 12 | 2 | 4 | 6 |
| Unit- 4.0 Robot Programming and Economics of Robotization | 10 | CO1, CO4, CO5 | 14 | 4 | 4 | 6 |
| Unit- 5.0 Applications in Non-manufacturing Environments | 8 | CO5 | 12 | 4 | 4 | 4 |
| Total Marks | 48 | | 70 | 20 | 25 | 25 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| S. No. | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Identify different wireless sensor network in robotics viz. ZigBee, LoRa. | CO1, CO3 | 40 | 50 | 10 |
| 2. | Use different Radio Frequency (RF) Controlled Wireless Robots. | CO1, CO2 | 40 | 50 | 10 |
| 3. | Examine different voice operated robot with speaker identification technology. | CO1, CO3 | 40 | 50 | 10 |
| 4. | Design a computer-controlled pick and place robot (wireless) | CO1, CO4 | 40 | 50 | 10 |
| 5. | Design a Zigbee controlled Boat with wireless video and voice transmission. | CO2, CO3 | 40 | 50 | 10 |
| 6. | Design a PC controlled wireless Multipurpose robot for simple engineering applications. | CO3, CO4 | 40 | 50 | 10 |
| 7. | Design an unmanned arial photography system. | CO3, CO5 | 40 | 50 | 10 |
| 8. | Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots. | CO5 | 40 | 50 | 10 |
| 9. | Develop TPP / Offline program for vision-based inspection for robots. | CO4, CO5 | 40 | 50 | 10 |
| 10. | Program and simulate coordinated identification, inspection and part assembly for robots. | CO1, CO5 | 40 | 50 | 10 |
| 11. | Develop Obstacle avoidance robot Programming | CO1, CO5 | 40 | 50 | 10 |
| 12. | Program and simulate welding operation using robot simulation software. | CO1, CO5 | 40 | 50 | 10 |
| 13. | TPP / Offline program for drilling operation. | CO1, CO5 | 40 | 50 | 10 |
| 14. | Program to execute an industrial robot application using a given configuration. | CO1, CO5 | 40 | 50 | 10 |
| 15. | Analyse Direct Kinematics of 4-axis robot using available software. | CO2, CO3 | 40 | 50 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources(OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/ Practical Number |
|--------|--|---|---------------------------------------|
| 1. | 6 Axis Articulated Robot (Material Handling)- 1 No | <ul style="list-style-type: none"> • Articulated Type • Controlled axis: 6-axes (J1, J2, J3, J4, J5, J6) • Reach: 717 mm • Installation Floor, Upside-down (Angle mount) • Motion range (Maximum Speed) <ul style="list-style-type: none"> • J1 Axis Rotation 7.85 rad/s • J2 Axis Rotation 6.63 rad/s • J3 Axis Rotation 9.08 rad/s • J4 Axis Rotation 9.60 rad/s • J5 Axis Rotation 9.51 rad/s • J6 Axis Rotation 17.45 rad/s • Max. load capacity Wrist: 4Kg • Allowable Load moment 16.6 N-m at wrist J4 Axis, J5 Axis, J6 Axis • Allowable Load inertia).47 kg-m² at wrist J4 Axis J5 Axis, J6 Axis • Repeatability: +/- 0.05mm • Mass: 21 Kg Minimum • Installation environment: Ambient temperature: 0 – 45°C • Ambient humidity: Normally 75%RH or less. No dew, nor frost allowed. • Vibration Acceleration: 4.9 m/s² (0.5G or less) | 1, 2, 3, 12 |
| 2. | 6 Axis Articulated Robot (General Purpose-Welding, Assembly, Drilling) - 1 No | <p>Link 1: 300 mm Link 2: 300 mm Joint actuator: DC Stepper Motor Transmission: Timing Belt Drive Position feedback: Proximity Switch Gripper actuator: Pneumatic Weight of robot: 50 Kg. Accuracy: ±0.3 Repeatability: ±0.2 Tip Velocity range: 500 mm / min Pay load capacity: 2 kg (including gripper) J1 - Waist: ± 140° J2 - Shoulder: - 100 - 60° J3 - Elbow: - 70 + 10° J4 - Wrist rotate: ± 70° J5 - Wrist pitch: ± 35° J6 - Wrist roll: ± 180° External I/O 8 Programmable digital inputs 8 Programmable digital outputs</p> | 8, 9, 14 |
| 3. | A mounted vision system with software (Free open source Robot simulation software) | <p>Integrity Serial Bus System, CAN to Build Intelligent Device Network, Open Hardware Platform, Arduino, to control Robot sub-Systems of motor-sensor, movable Omni Wheel of Omni-Directional, Actuator operation control by DC Encoder Motor, DC-Motor control and operation by Accelerometer, Gyro, Ultrasonic and PSD sensor, Androx Studio; brushless ILM 70×10 Robo Drive DC motor; sensor-actuator units of ARMAR-4; SD-25-160-2A-GR-BB Harmonic Drive reduction gear unit high gear ratio of 160: 1; structural parts (white) are made out of high-strength aluminum, Hollow shaft with strain gauges for torque sensing, motor's magnetic incremental encoder (AMS5306), digital buses (SPI or I2C); Motor interface PCB includes a 13-Bit temperature-to-digital converter with a temperature range from -40°C to 125°C (Analog Devices ADT7302)</p> | 3, 4, 5, 11 |
| 4. | 6-axis Robotics Trainer | <p>Programmable robotic arm with an interactive front panel. Software to demonstrate functioning of the</p> | 3, 4, 5, 13 |

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/ Practical Number |
|--------|---------------------------------------|---|---------------------------------------|
| | | trainer as well as allows a user to develop their own programs. NV330; 8 bit microcontroller to ARM processors; Record and Play capability; Optional interfacing with PLC; Touch operated ON/OFF Switch; Auto set to home position; Applications can be developed; Data acquisition using USB | |
| 5. | E-Yantra Firebird kit | <ul style="list-style-type: none"> • Fire Bird V 2560 Robot • Spark V Robot • Fire Bird V P89V51RD2 adapter card • Fire Bird V LPC2148 adapter card • LSM303 3 axis digital accelerometer and 3 axes magnetometers • L3G4200 3 axis digital gyroscope • Gyroscope, accelerometer and GPS interfacing module for the robot • GPS receiver • Zigbee Modules 100m range • Zigbee Modules Adapter • Metal-gear Servo Motors • Servo Motor Based Gripper kit for the Fire Bird V robot • Sharp infrared range sensor (10cm to 500cm) • Arduino Uno/Nano • Hexapod • 16 Programming Software (AVR studio, Keil, AVR Boot loader, Flash Magic) | 1, 3, 5, 6, 7, 10 |
| 6. | Robot simulator for Robotics | Educational networking licensed Robotic system with simulation software | 2, 8, 10 |
| 7. | Assorted sensors | Optical encoders, Acoustic sensors ,IR, Potentiometer, RTD, Thermistor, strain gauge, piezoelectric, etc. | 4 |
| 8. | Vision equipment | Camera, Imaging Components: Point, Line, Planar and Volume Sensors | 1, 4, 10 |
| 9. | Raspberry Pi kit | 1.2GHz quad-core Broadcom BCM2837 CPU with 1GB DDR2 RAM with in-built Wi-Fi & Bluetooth Video Core IV 3D graphics core 40 pin extended pins - with 27 GPIO pins Micro SD slot Multiple ports: Four USB ports, full sized HDMI, four pole stereo output and composite video port, CSI camera port and DSI display port 10/100 BaseT Ethernet Micro-USB, power source 5V, 2A | 7, 9 |

R) Suggested Learning Resources:**(a) Books:**

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|---|--|---|
| 1. | Introduction to Robotics Mechanics and Control | John Craig | Pearson Education 978-9356062191 |
| 2. | Robotics and controls | Mittal R.K., Nagrath I.J. | Tata McGraw Hill Education Pvt. Ltd.; 2017; 978-0070482937 |
| 3. | Robotics and Image Processing: An Introduction | Janaki Raman. P. A | Tata McGraw Hill Publishing company Ltd., 1998; 978-0074621677 |
| 4. | Industrial Robotics -Technology, Programming and Applications | Nicholas Odrey, Mitchell Weiss, Mikell Groover Roger Nagel, Ashish Dutta | McGraw Hill Education; 2nd Edition; 978-1259006210 |
| 5. | Robotic Engineering: an integrated approach | Richard D. Klafter, Thomas A. Thomas A. Chmielewski, Michael Negin | Prentice Hall of India, N. Delhi, 2009; 978-8120308428 |
| 6. | Industrial Robotics Technology, Programming and Applications | Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey | McGraw-Hill Education, Second Edition, 978-1259006210 |
| 7. | Robotics | Appuu Kuttan K. K. | Dreamtech Press, First Edition, 2020, 978-9389583281 |
| 8. | Introduction to Robotics: Analysis, Control, Applications | Saeed B. Niku | Wiley; Second Edition, 978-8126533121 |
| 9. | Essentials of Robotics Process Automation | S. Mukherjee | Khanna Publication, First Edition, 978-9386173751 |
| 10. | Robotics | R R Ghorpade, M M Bhoomkar | Nirali Prakashan 978-9388897020 |

(b) Online Educational Resources:

- <https://web.iitd.ac.in/~saha/ethiopia/appln.pdf>
- <https://nptel.ac.in/courses/112105249>
- <https://www.robotsscience.com/industrial/industrial-robots-types-applications-benefits-and-future/>
- https://www.marian.ac.in/public/images/uploads/pdf/online-class/MODULE-6%20ROBOTICS%20INDL_APPLNS-converted.pdf
- <https://forcedesign.biz/blog/5-common-industrial-robot-applications>
- <https://www.hitechnectar.com/blogs/top-industrial-robotics-applications-role-of-robots-in-manufacturing/>
- https://en.wikipedia.org/wiki/Industrial_robot
- <https://www.youtube.com/watch?v=fH4VwTgfyRQ>
- https://www.youtube.com/watch?v=aW_BM_S0z4k
- <https://www.automate.org/industry-insights/smarter-robot-grasping-with-sensors-software-the-cloud>
- <https://robots.ieee.org/robots/?t=all>
- https://www.youtube.com/watch?v=fc_Cynqr6jM

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested OER, before use by the students.

(c) Others:**1. Learning Packages:**

- <https://www.edx.org/learn/robotics>
- <https://www.coursera.org/courses?query=robotics>
- <https://www.udemy.com/topic/robotics/>
- <https://library.e.abb.com/public/9a0dacfddec8aa03dc12578ca003bfd2a/Learn%20with%20ABB.%20Robotic%20package%20for%20education.pdf>

2. Users' Guide:

- <https://roboindia.com/store/DIY-do-it-your-self-educational-kits-robotics-embedded-system-electronics>
- <https://www.robomart.com/diy-robotic-kits>
- <https://www.scientechworld.com/robotics>

3. Lab Manuals:

- http://www-cvr.ai.uiuc.edu/Teaching/ece470/docs/ROS_LabManual.pdf
- <https://www.jnec.org/labmanuals/mech/be/sem1/Final%20Year%20B.Tech-ROBOTICS%20LAB%20%20MANUAL.pdf>

- A) **Course Code** : 2400604I(T2400604I/P2400604I/S2400604I)
 B) **Course Title** : Transformer Manufacturing and Repairing (Advanced)
 C) **Pre- requisite Course(s)** : Transformer Manufacturing and Repairing (Basic)
 D) **Rationale** :

Transformers are an essential component in Power systems. They help transmit electrical energy at various voltage and current levels to minimize losses and achieve other technical objectives. They are rated from a few kVA to large MVA. Power systems are growing to meet the increased demand. Hence, the manufacturing of new transformers and repair of existing transformers are vital. This advanced course will help the students understand the concepts of manufacturing and repair of transformers at par with the industries. The knowledge gained through this course will help the students choose their career in transformer manufacturing and repair.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-1** Analyze the materials used in transformer manufacturing.
CO-2 Assemble the transformer based on specific requirements.
CO-3 Design using software based on specific requirements.
CO-4 Analyze the working conditions of transformers.
CO-5 Apply the concepts for practical use.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes(POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | - | - | 2 | - | 3 | | |
| CO-2 | 3 | 3 | 2 | 2 | 2 | - | 3 | | |
| CO-3 | 3 | 2 | 2 | 2 | - | - | 3 | | |
| CO-4 | 3 | 1 | 1 | 1 | 1 | - | 3 | | |
| CO-5 | 3 | 2 | 3 | 3 | 3 | 1 | 3 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

- G) **Teaching & Learning Scheme:**

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | Total Credits (C) |
|-------------|--|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | |
| | | L | T | | | | |
| 2400604 | Transformer Manufacturing and Repairing (Advanced) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: **Term Work** (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, **online educational resources** etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: **TW** and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|--|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604 | Transformer Manufacturing and Repairing (Advanced) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: **Term work & Self Learning Assessment** (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- Separate passing is must for progressive and end semester assessment for both theory and practical.
- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

- I) Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, **Society connect**, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2400604I

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|---|---|------------------------|
| <p><i>TSO 1a.</i> Explain the use of different materials in transformers.</p> <p><i>TSO 1b.</i> List the various types of materials used in transformers.</p> <p><i>TSO 1c.</i> Explain the insulating materials.</p> <p><i>TSO 1d.</i> Explain the winding material.</p> <p><i>TSO 1e.</i> Explain the magnetic materials.</p> | <p>Unit-1.0 Transformer Materials</p> <p>1.1 Review of basic materials and their processing</p> <p>1.2 Insulating oil, insulating paper, pressboard, wood</p> <p>1.3 Insulated copper conductor for windings, crepe paper, sealing materials</p> <p>1.4 cold-rolled grain oriented electrical steel sheet, structural steel, future trends</p> <p>1.5 Magnetic Circuit Materials</p> | CO1 |
| <p><i>TSO 2a.</i> Explain the basic concept of transformer design.</p> <p><i>TSO 2b.</i> List the various parameters to be considered during design.</p> <p><i>TSO 2c.</i> Choose the number of turns, the core diameter.</p> <p><i>TSO 2d.</i> Select the winding wires and strips.</p> <p><i>TSO 2e.</i> Choose the size of HV and LV conductors.</p> | <p>Unit-2.0 Transformer Design</p> <p>2.1 Basic Concept of Design.</p> <p>2.2 Selection of number of turns.</p> <p>2.3 Selection of core diameter.</p> <p>2.4 Selection of winding wires and strips.</p> <p>2.5 Size HV and LV conductors.</p> <p>2.6 Transposition</p> | CO1, CO2 |
| <p><i>TSO 3a.</i> Explain the concept of computer aided design.</p> <p><i>TSO 3b.</i> Learn the programming skills,</p> <p><i>TSO 3c.</i> Modify the programming considering other aspects.</p> <p><i>TSO 3d.</i> Validate and print the design.</p> <p><i>TSO 3e.</i> Use software to design.</p> | <p>Unit-3.0 Transformer Design – Using CAD</p> <p>3.1 Computer aided design: Basic concept, specification needs.</p> <p>3.2 Computer programming, variable inputs, program convergence.</p> <p>3.3 Design output, design modification, other aspects of design.</p> <p>3.4 Design validation, design package, computer design printout.</p> <p>3.5 Software application for design.</p> | CO3, CO4 |
| <p><i>TSO 4a.</i> Explain the testing of Transformer oil.</p> <p><i>TSO 4b.</i> Use of Transformer oil.</p> <p><i>TSO 4c.</i> List the causes of oil ageing.</p> <p><i>TSO 4d.</i> List the various tests to monitor the working conditions of a transformer.</p> | <p>Unit-4.0 Transformer Condition Monitoring</p> <p>4.1 Transformer oil testing and Interpretation</p> <p>4.2 Introduction, mineral insulating oil.</p> <p>4.3 Four functions of transformer oil.</p> <p>4.4 Causes of oil ageing.</p> <p>4.5 Various tests on transformer oil such as power factor, moisture, neutralization number, interfacial tension, relative density, color, visual examination, breakdown voltage, dissolved gas analysis.</p> | CO3, CO4 |
| <p><i>TSO 5a.</i> Apply the concepts for practical use.</p> <p><i>TSO 5b.</i> Design a practical power transformer.</p> | <p>Unit-5.0 Transformer Design - Practical Applications</p> <p>5.1 Design of a 100 KVA transformer.</p> <p>5.2 Design of 630 KVA transformer.</p> <p>5.3 Design of 5 MVA, 33/11 KV transformer</p> | CO4, CO5 |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604I

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|--|--------|---|------------------------|
| <i>LSO 1.1.</i> Knowledge of knowing the various components of a power transformer. <i>LSO 1.2.</i> Explain the use of those components in the power transformer. | 1. | Dismantling a power transformer and understanding various components. | CO1 |
| <i>LSO 2.1.</i> Design a transformer using computer programming considering various aspects. | 2. | Designing a transformer using computer programming. | CO1 |
| <i>LSO 3.1.</i> Use of a commercial software to design a transformer. | 3. | Application of software for transformer design. | CO1 |
| <i>LSO 4.1.</i> Understand the breakdown voltage (BDV) of transformer oil. | 4. | Breakdown voltage test of transformer oil. | CO2 |
| <i>LSO 5.1.</i> Explain the practical applications of power transformers. <i>LSO 5.2.</i> Knowledge of various transformers used in substations. | 5. | Substation visit to see the application of power transformers. | CO3, CO4, CO5 |

L) **Suggested Term Work and Self Learning: S2400604I** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

- Explore recent advancements in core material technology.
- Discuss the lifecycle, recycling, and disposal of transformer materials and their environmental footprint.
- Discuss the key parameters and design equations used in transformer design.
- Explore the steps involved in modeling the transformer core using CAD software.
- Use CAD software to simulate different winding configurations and their impact on performance.
- Discuss the advantages of real-time data collection and analysis for proactive maintenance.
- Investigate the different requirements for distribution transformers in urban versus rural settings.

a.

b. **Micro Projects:**

- Compare the performance of different insulating materials used in transformers (e.g., paper, pressboard, Nomex).
- Study the magnetic properties of different core materials (e.g., silicon steel, amorphous steel).
- Evaluate the environmental impact of transformer materials and their disposal methods.
- Build a small-scale transformer to understand the basics of transformer construction and operation.
- Investigate the impact of different winding techniques on transformer efficiency and performance.
- Compare different core materials to determine their effect on transformer performance.
- Design various core shapes (e.g., E-core, toroidal, C-core) using CAD and analyze their magnetic properties.
- Design and optimize different winding layouts to improve efficiency and reduce losses.
- Design a system to monitor and log the temperature of transformer components.
- Monitor transformer vibrations to detect mechanical issues.
- Design a system to monitor the quality of transformer oil.
- Develop a lightweight, portable transformer for powering equipment at outdoor events.

c. Other Activities:

1. Seminar Topics:

- Silicon Steel in Transformer Manufacturing.
- Impact of Environmental Factors on Transformer Design.
- Introduction to CAD in Transformer Design.
- Cost Estimation and Analysis in Transformer Design Using CAD.
- Impact of Environmental Conditions on Transformer Monitoring.
- Oil Quality Analysis in Transformer Maintenance.
- Designing Transformers for Industrial Applications.

2. Visits:

- Visit to nearby transformer manufacturing station. Prepare report of visit with special comments on transformer winding technique, winding material and insulating material used.
- Visit to nearby transformer manufacturing station. Prepare report of visit with manufacturing process, different stages of production, and the quality control measures and technologies involved in transformer manufacturing.

3. Self-learning topics:

- Types of insulation materials used in transformers (e.g., paper, pressboard, synthetic materials, and mineral oil)
- Nanomaterials in Transformer Construction.
- Thermal management in transformer design.
- Vibration of transformer.
- Smart transformer used in smart grid.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|----------------|-------------------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| | | | Assignments | Micro Projects | Other Activities* | | |
| CO-1 | 15% | 15% | 15% | - | - | 20% | 20% |
| CO-2 | 10% | 10% | 10% | 25% | - | 10% | 20% |
| CO-3 | 15% | 15% | 15% | 25% | 33% | 15% | 20% |
| CO-4 | 30% | 30% | 30% | 25% | 33% | 15% | 20% |
| CO-5 | 30% | 30% | 30% | 25% | 34% | 40% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI) Hours | Relevant COs Number(s) | Total Marks | ETA (Marks) | | |
|--|--|------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 Transformer Materials | 8 | CO1 | 10 | 3 | 3 | 4 |
| Unit-2.0 Transformer Design | 12 | CO1, CO2 | 10 | 3 | 2 | 5 |
| Unit-3.0 Transformer Design-Using CAD | 12 | CO3, CO4 | 10 | 5 | 2 | 3 |
| Unit-4.0 Transformer Condition Monitoring | 8 | CO3, CO4 | 20 | 5 | 6 | 9 |
| Unit-5.0 Transformer Design - Practical Applications | 8 | CO4, CO5 | 20 | 4 | 6 | 10 |
| Total | 48 | - | 70 | 20 | 19 | 31 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

| SN | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|----|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 1. | Dismantling a power transformer and understanding various components. | CO1 | 30 | 60 | 10 |
| 2. | Designing a transformer using computer programming. | CO1 | 40 | 50 | 10 |
| 3. | Application of software for transformer design. | CO1 | 30 | 60 | 10 |
| 4. | Breakdown voltage test of transformer oil. | CO2 | 30 | 60 | 10 |
| 5. | Substation visit to see the application of power transformers. | CO3, CO4, CO5 | 30 | 60 | 10 |

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

| S. No. | Name of Equipment, Tools and Software | Broad Specifications | Relevant Experiment/Practical Number |
|--------|---------------------------------------|--|---|
| 1. | Transformer, Multi-meter, LCR Meter | 3 Phase Transformer, Multi-meter, LCR Meter, Tools to dismantle transformer. | Dismantling a power transformer and understanding various components. |
| 2. | MATLAB, PC | MATLAB Software and Desktop PC (As per requirement). | Designing a transformer using computer programming |
| 3. | | Machine Design Software and Desktop PC (As per requirement). | Application of software for transformer design. |
| 4. | Transformer Oil Testing Kit | Transformer oil testing kit, transformer oil, | Breakdown voltage test of transformer oil. |
| 5. | Equipment for a prototype substation | Power transformer, circuit breaker, relay, Insulator, Isolator, Bus-bar, capacitor bank, Fuse, current transformer, potential transformer. | Substation visit to see the application of power transformers |

R) Suggested Learning Resources:**(a) Books:**

| S. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|--------|--|----------------------------|---|
| 1. | Transformer Engineering Design and Practice | S.V.Kulkarni, S.A.Khaparde | CBS Publishers, 2004 ISBN: 9780824757281, 0824757289 |
| 2. | Design of Transformers | Indrajit Dasgupta | Tata McGraw Hill India, 2002 ISBN: 0071331352, 9780071331357 |
| 3 | Principles of Electrical Machine Design With Computer Programs | S. K. Sen | Oxford & IBH Publishing Company Pvt. Limited, 2006. ISBN: 9788120415218, 8120415213 |

(b) Online Educational Resources:

Note: Teachers are requested to check the creative commons **license** status/ financial implications of the suggested, online educational recourses before use by the students.

(c) Others:

- A) **Course Code** : 2400604J(T2400604J/P2400604J/S2400604J)
 B) **Course Title** : Optical Fiber and 5G Communication (Advance)
 C) **Pre- requisite Course(s)** : Optical Fiber and 5G Communication (Basics)
 D) **Rationale** :

A course on Optical Fiber and 5G Communication (Advance) is essential to understand the modern high-speed data transmission, which is crucial for supporting the growing demand for fast and reliable internet services. It equips students with the knowledge to design and implement 5G networks, which is going to be an integral part of the wireless communication infrastructures fields, students gain comprehensive insights into how advanced communication systems operate and interact, preparing them for careers in telecommunications and networking.

- E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- CO-6** Analyze various 5G radio-access technologies.
CO-7 Identify different components of GSM architecture.
CO-8 Describe the channel and channel behavior of the wireless channel.
CO-9 Analyze different mitigation techniques.
CO-10 Summarize different emerging technologies for next generation communication networks.

- F) **Suggested Course Articulation Matrix (CAM):**

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | - | 2 | 3 | - | - | 2 | | |
| CO-2 | 3 | 2 | 2 | 2 | 2 | 2 | - | | |
| CO-3 | 3 | 2 | 2 | 2 | 3 | 2 | - | | |
| CO-4 | 3 | 3 | - | 2 | - | - | - | | |
| CO-5 | 3 | - | 3 | 3 | 3 | 3 | 2 | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional

- G) **Teaching & Learning Scheme:**

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|--|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2400604J | Optical Fiber and 5G Communication (Advance) | 03 | - | 04 | 02 | 09 | 06 |

Legend:

- CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)
- LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)
- Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.
- TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)
- SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.
- C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)
- Note:** TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|--|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2400604J | Optical Fiber and 5G Communication (Advance) | 30 | 70 | 20 | 30 | 20 | 30 | 200 |

Legend:

- PTA: Progressive Theory Assessment in classroom (includes class test, mid-term test and quiz using online/offline modes)
- PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)
- TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.)

Note:

- Separate passing is must for progressive and end semester assessment for both theory and practical.
- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

- II) Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2400604J

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p><i>TSO 1f.</i> Highlight the need for 5G communication system.</p> <p><i>TSO 1g.</i> Describe the radio spectrum and channel model with the help of suitable sketch and tables.</p> <p><i>TSO 1h.</i> Describe the working of the 5G physical layer with the help of a suitable sketch.</p> <p><i>TSO 1i.</i> Describe 5G network slicing with an example.</p> <p><i>TSO 1j.</i> Explain the mobility and hand-off management in 5G environment.</p> | <p>Unit-1.0 5G Radio Access Technology</p> <p>1.6 5G Radio Spectrum</p> <p>1.7 5G Channel Model</p> <p>1.8 Radio Interface Architecture</p> <p>1.9 5G Physical Layer</p> <p>1.10 5G Radio-Access Technologies</p> <p>1.11 Introduction To 5G Network Slicing</p> <p>1.12 Mobility and Handoff Management In 5G</p> | CO1 |
| <p><i>TSO 2f.</i> Describe the architecture and key components of basic GSM (Global System for Mobile Communications) networks.</p> <p><i>TSO 2g.</i> List the components of the GSM(LTE) system.</p> <p><i>TSO 2h.</i> Describe the working of the various components and their functions of the given type of wireless communication network</p> <p><i>TSO 2i.</i> Analyze the functions of base station subsystems (BS)</p> | <p>Unit-2.0 Study of GSM Architecture</p> <p>2.7 GSM System Architecture (LTE)</p> <p>2.8 Explain the different components of Wireless Communication Network</p> <p>2.9 Operation of base station (BS) subsystems</p> | CO2 |
| <p><i>TSO 3f.</i> Explain different principles and various factors affecting radio wave propagation in different environments.</p> <p><i>TSO 3g.</i> Apply the free space propagation model to estimate signal strength and coverage.</p> <p><i>TSO 3h.</i> Explain how reflection, scattering, and diffraction impact radio wave behaviour and signal quality.</p> <p><i>TSO 3i.</i> Use the given type of path loss models to predict signal degradation over distance.</p> <p><i>TSO 3j.</i> Differentiate between large-scale and small-scale fading and their effects on wireless communication.</p> <p><i>TSO 3k.</i> Analyze the characteristics and behaviour of wireless channels, including their impact on signal transmission.</p> <p><i>TSO 3l.</i> List the noise sources present in the wireless channel.</p> <p><i>TSO 3m.</i> Describe the effects of noise on signal propagation through wireless channels and its impact on signal quality.</p> <p><i>TSO 3n.</i> Calculate the capacity of channels with Additive White Gaussian Noise (AWGN).</p> | <p>Unit-3.0 Channel and channel behavior</p> <p>3.6 Analysis of radio wave propagation</p> <p>3.7 Free Space Propagation Model</p> <p>3.8 Reflection, Scattering, Diffraction of Radio Waves</p> <p>3.9 Path Loss Models</p> <p>3.10 Study of Fading (Large, small-scale fading)</p> <p>3.11 Analysis of Wireless Channel</p> <p>3.12 Analysis of Noise, types of noise</p> <p>3.13 Capacity of AWGN and Fading Channel (only formula and its variable parameters)</p> | CO3 |
| <p><i>TSO 4e.</i> Describe various diversity techniques to improve signal reliability and performance in wireless communication.</p> <p><i>TSO 4f.</i> Describe receiver diversity methods and their impact on enhancing signal quality and reducing errors.</p> <p><i>TSO 4g.</i> Describe transmitter diversity techniques and their role in mitigating fading and improving communication robustness.</p> <p><i>TSO 4h.</i> Describe the principles and applications of Multiple Input Multiple Output (MIMO) technology.</p> <p><i>TSO 4i.</i> Suggest the techniques to correct distortions and mitigate inter-symbol interference in wireless communication systems.</p> | <p>Unit-4.0 Mitigation Techniques</p> <p>4.6 Diversity techniques</p> <p>4.7 Analysis of various receiver diversity techniques</p> <p>4.8 Analysis of various transmitter diversity techniques</p> <p>4.9 MIMO technology advantages in communication systems</p> <p>4.10 Equalization techniques and their importance in communication systems</p> | CO4 |

| Major Theory Session Outcomes (TSOs) | Units | Relevant COs Number(s) |
|--|---|------------------------|
| <p><i>TSO 5c.</i> Discuss the various types of dispersion in optical fibre design</p> <p><i>TSO 5d.</i> Explain the optimization technique of single mode fibre.</p> <p><i>TSO 5e.</i> Describe the working and characteristics of different optical networks.</p> <p><i>TSO 5f.</i> Explain the nonlinear effect on network performance of optical fibre systems.</p> <p><i>TSO 5g.</i> Explain multicarrier modulation techniques to enhance data transmission and system performance.</p> <p><i>TSO 5h.</i> Describe the principles and advantages of Orthogonal Frequency Division Multiplexing (OFDM) in improving bandwidth efficiency and reducing interference.</p> <p><i>TSO 5i.</i> Analyze given emerging technologies.</p> | <p>Unit-5.0 Advanced Optical Fiber Communication and Emerging Technologies</p> <p>5.4 Advanced Optical Fiber: Dispersion issues, Dispersion shifted, Dispersion flattened, Dispersion Compensating fibre</p> <p>5.5 Design and optimization of single-mode fibers</p> <p>5.6 Optical Networks- Basic Networks SONET, SDH-wavelength-routed networks</p> <p>5.7 Nonlinear effect on Network Performance, performance of various systems (WDM, DWDM + SOA)</p> <p>5.8 Multicarrier Modulation Technique</p> <p>5.9 Orthogonal Frequency Division Multiplexing (OFDM)</p> <p>5.10 Emerging Technology: Green Communication network, Vehicle 2 everything (V2X), Aerial Communication, Satellite Communication (LEO), Tactile Internet (TI), Free Space Optics (FSO), Near Field Communication, Quantum Communication, Molecular Communication</p> | CO5 |

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2400604J

| Practical/Lab Session Outcomes (LSOs) | S. No. | Laboratory Experiment/Practical Titles | Relevant COs Number(s) |
|---|--------|--|------------------------|
| <i>LSO 1.3.</i> Noise Modelling and its effect on Wireless Data Transmission | 1. | Characterization and Impact of Noise on Wireless Data Transmission: A Comprehensive | CO1 |
| <i>LSO 2.2.</i> Effect of fading on wireless data transmission in terms of outage probability | 2. | Evaluating Fading Effects on Wireless Data Transmission: Outage Probability Analysis | CO2 |
| <i>LSO 3.2.</i> Capacity of Wireless Channel (AWGN v/s Fading) | 3. | Comparative Study of Channel Capacity: AWGN versus Fading Channels | CO3 |
| <i>LSO 4.2.</i> Implementation of receiver diversity technique. | 4. | Practical Implementation and Evaluation of Receiver Diversity Techniques in Wireless Communication | CO4 |
| <i>LSO 5.3.</i> Implementation of transmitter diversity technique. | 5. | Practical Implementation and Performance Analysis of Transmitter Diversity Techniques | CO4 |
| <i>LSO 6.1</i> Implement the (2X2) of MIMO system. | 6. | Design and Implementation of MIMO Technology | CO4 |
| <i>LSO 7.1</i> Implement of OFDM system and test the performance. | 7. | Performance Evaluation of Orthogonal Frequency Division Multiplexing (OFDM) in Wireless Systems | CO5 |

L) **Suggested Term Work and Self Learning: S2400604J** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

d. **Assignments:** Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

e. **Micro Projects:**

f.

Here are five micro projects that can be included in an optical fiber and 5G communication course to give students hands-on experience with practical applications of the concepts learned:

1. Design of solar cell enabled Base Station for Green Communication Network

Task: Conduct a feasibility study on integrating solar cells with base stations, design a prototype solar-powered base station, simulate its energy efficiency and environmental impact, evaluate its carbon footprint reduction, and document the design and performance outcomes.

2. Path loss models for Aerial Communication Network

Task: Research and adapt existing path loss models for aerial networks, develop tailored models for scenarios like drones, validate with field or simulation data, compare model performance, and document findings with recommendations for network design.

3. Resource allocation for 5G communication Network

Task: Identify challenges in 5G resource allocation, develop an optimization strategy, simulate the strategy's effectiveness, implement it in a test environment, and analyze results to enhance resource allocation and network performance.

4. LEO Satellite based IoT communication

Task: Research LEO satellite technologies for IoT, design a communication system using LEO satellites, simulate system performance, conduct a cost-benefit analysis compared to other methods and prepare a brief report of the same.

5. QoS requirements for Tactile Internet

Task: Define QoS requirements for tactile internet applications, develop a QoS framework, test the framework in various scenarios, evaluate its performance, and prepare a report with recommendations for meeting QoS standards in tactile internet networks.

g. Other Activities:

h. Seminar Topics: Some of the suggested seminar topics are

- i. "Advancements in 5G Technology and beyond"
- ii. "The Future of Wireless Communication: 5G and Beyond"
- iii. "Integrating Haptics with 5G Networks: Opportunities and Challenges"
- iv. "Security Strategies for 5G Networks: Ensuring Robust Protection"
- v. "AR/VR-enabled Systems in 5G: Innovations and Implementation"

i. Visits: Visit nearby telephone exchanges or wireless communication-related companies

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

| COs | Course Evaluation Matrix | | | | | | |
|--------------------|---|-----------------------------|--------------------------------------|-------------------|-----------|----------------------------------|---------------------------------|
| | Theory Assessment (TA)** | | Term Work Assessment (TWA) | | | Lab Assessment (LA)# | |
| | Progressive Theory Assessment (PTA) Class/Mid Sem Test | End Theory Assessment (ETA) | Term Work & Self Learning Assessment | | | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) |
| Assignments | | | Micro Projects | Other Activities* | | | |
| CO-1 | 15% | 15% | 15% | - | - | 20% | 20% |
| CO-2 | 10% | 10% | 10% | 25% | - | 10% | 20% |
| CO-3 | 15% | 15% | 15% | 25% | 33% | 15% | 20% |
| CO-4 | 30% | 30% | 30% | 25% | 33% | 15% | 20% |
| CO-5 | 30% | 30% | 30% | 25% | 34% | 40% | 20% |
| Total Marks | 30 | 70 | 20 | 20 | 10 | 20 | 30 |
| | | | 50 | | | | |

Legend:

- *: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.
 **: Mentioned under point- (N)
 #: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

| Unit Title and Number | Total Classroom Instruction (CI)Hours | Relevant COs Number(s) | Total Marks | ETA (Marks) | | |
|---|---------------------------------------|------------------------|-------------|--------------|-------------------|-------------------------|
| | | | | Remember (R) | Understanding (U) | Application & above (A) |
| Unit-1.0 5G Radio Access Technology | 8 | CO1 | 12 | 4 | 4 | 4 |
| Unit-2.0 Study of GSM Architecture | 8 | CO2 | 12 | 4 | 4 | 4 |
| Unit-3.0 Channel and channel behavior | 8 | CO3 | 12 | 4 | 4 | 4 |
| Unit-4.0 Mitigation Techniques | 12 | CO3 | 14 | 4 | 4 | 6 |
| Unit-5.0 Advanced Optical Fiber Communication and Emerging Technologies | 12 | CO2 | 20 | 6 | 6 | 8 |
| Total | 48 | - | 70 | 22 | 22 | 26 |

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical): Kindly change this table as per the list of experiment in the above list

| Sl. No | Laboratory Practical Titles | Relevant COs Number(s) | PLA/ELA | | |
|--------|---|------------------------|-------------|-----------|---------------|
| | | | Performance | | Viva-Voce (%) |
| | | | PRA* (%) | PDA** (%) | |
| 6. | Characterization and Impact of Noise on Wireless Data Transmission: A Comprehensive | CO1 | 30 | 60 | 10 |
| 7. | Evaluating Fading Effects on Wireless Data Transmission: Outage Probability Analysis | CO2 | 40 | 50 | 10 |
| 8. | Comparative Study of Channel Capacity: AWGN versus Fading Channels | CO3 | 30 | 60 | 10 |
| 9. | Practical Implementation and Evaluation of Receiver Diversity Techniques in Wireless Communication | CO4 | 30 | 60 | 10 |
| 10. | Practical Implementation and Performance Analysis of Transmitter Diversity Techniques | CO4 | 30 | 60 | 10 |
| 11. | Design and Implementation of MIMO Technology | CO4 | 30 | 60 | 10 |
| 12. | Development and Performance Evaluation of Orthogonal Frequency Division Multiplexing (OFDM) in Wireless Systems | CO5 | 30 | 60 | 10 |

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

Please insert laboratory equipment in this format

| Sl. No. | Name of Equipment, Tools, and Software | Relevant Experiment/ Practical Number |
|---------|--|---------------------------------------|
| 1. | Software-Defined Radio (SDR) kit : Allows for the implementation and testing of 5G communication protocols. | All |
| 2. | 5G NR Testbed: Complete test setups for developing and testing 5G NR systems. | All |
| 3. | Vector Signal Analyzer (VSA) and Vector Signal Generator (VSG): For generating and analyzing complex modulated signals used in 5G communication. | All |
| 4. | MIMO (Multiple Input Multiple Output) Test System (2X2, and more): For testing MIMO technology, which is essential for 5G networks. | All |
| 5. | MATLAB/Mathematica | All |

R) Suggested Learning Resources:

(a) Books

Here are some essential books for Optical Fiber and 5G Communication.

| Sl. No. | Titles | Author(s) | Publisher and Edition with ISBN |
|---------|---|---|--|
| 1. | Millimeter Wave Wireless Communications | Theodore S. Rappaport, Robert W. Heath Jr., Robert C. Daniels, and James N. Murdock | Cambridge University Press, 2024. ISBN 9781009489836 |
| 2. | 5G NR: The Next Generation Wireless Access Technology | Erik Dahlman, Stefan Parkvall, and Johan Skold | Academic Press, 2020. ISBN-10. 0128143231; ISBN-13. 978-0128143230 |
| 3. | Wireless Communications | Andreas F. Molisch, | John Wiley & Sons, 2012. ISBN: 8126542322 |
| 4. | Wireless Communications | Andrea Goldsmith | Cambridge University Press, 2005. ISBN: 9780511841224 |

(b) Online Educational Resources:

Here are some valuable online references for a course in Optical Fiber and 5G Communication:

1. Prof. Aditya K. Jagannatham– NPTEL **Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications**
2. **Coursera** - Post Graduate Certificate in 5G Technology and IoT: This program covers the essentials of 4G and 5G systems, including key technical advancements and challenges. It also delves into topics such as massive MIMO, OFDM, and mm Wave communication, providing a solid foundation in modern wireless communication (Coursera).
3. **Coursera** - 5G and Beyond Wireless Technologies: This course provides an in-depth understanding of 5G New Radio standards, beam management, cell-free massive MIMO, and intelligent reflecting surfaces, making it an excellent resource for those looking to explore the cutting-edge aspects of 5G technology (Coursera).
4. **Coursera** - 5G for Everyone: Gain an in-depth understanding of how 5G is revolutionizing the way we do business in the 2020s with technologies that make 5G possible, including mm Wave, Massive MIMO, RAN, and more. Learn how companies can use 5G Private Networks and Industrial IoT to transform the way they operate daily. Gain the base-level knowledge of 5G you need to continue your wireless education and advance in the rapidly growing field of wireless technology.

MIT OCW - Principles of Wireless Communications: This course is an introduction to the design, analysis, and fundamental limits of wireless transmission systems. Topics to be covered include: wireless channel and system models; fading and diversity; resource management and power control; multiple-antenna and MIMO systems; space-time codes and decoding algorithms; multiple-access techniques and multiuser detection; broadcast codes and precoding; cellular and ad-hoc network topologies; OFDM and ultrawideband systems; and architectural issues.

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational resources before use by the students.

(c) Others: In this section provide the software name (if any) data sheet according to this course.

- a. Operating / Manufacturers' Manuals
- b. Lab Manuals

-
- A) **Course Code** : 2421605(P2421605/S2421605)
B) **Course Title** : Major Project
C) **Pre- requisite Course(s)** :
D) **Rationale** :

Project work plays a very important role in engineering education in developing core technical skills, soft skills and higher level of cognitive, psychomotor and affective domain skills. Major Project work is normally done when students have acquired sufficient knowledge, skills and attitude and are able to integrate all these, entirely in new situation or task to solve the problems of the industries/field agencies/etc.

Through major project work, students get direct exposure to the world of work in their relevant field. They are intrinsically motivated to explore new things, new methods, new design, and many more ideas and also develop out of the box thinking abilities, creative and innovative capabilities. It also develops many soft skills like confidence, communication skills, creative ability, inquisitiveness, learning to learn skills, lifelong learning skills, problem solving skills, management skills, positive attitude, ethics etc.

Normally in a curriculum document, there is a mention of project work indifferent context. In situation one, project work is reflected as micro project under each and every course curricular detailing, in the form of Term work mentioned under different semesters. These projects are normally related to the developing skills in respective course of the specific programme.

In the context of diploma programme in Bihar, minor project work will be carried out in Semester 5 with emphasis on project planning.

Major project work is reflected as a course in the total programme structure, normally at 6th semester depending on the requirement of the programme. Through major project, students try to bring the industrial/real world problems in institutional setting, may be in collaboration/ networking with industries/field agencies/enterprises as per the requirement of different diploma programmes.

E) **Course Outcomes:** After completion of the major project work, students will be able to –

- CO-1** Integrate the knowledge (K), skills (S), attitudes (A) developed, in a new task or problem identified in the form of project work.
- CO-2** Develop higher level of cognitive, psychomotor and affective domain skills relevant to the course/programme.
- CO-3** Solve the industrial/real world problems/tasks by Integrating the generic skills/soft skills/employable skills with relevant technical skills.
- CO-4** Develop the capabilities and skills of innovativeness, creativity, resourcefulness, time management, problem solving abilities, interpersonal skills, pro-activeness, cost effectiveness, environment consideration and sustainability.
- CO-5** Prepare the project report.

F) Suggested Course Articulation Matrix (CAM):

| Course Outcomes (COs) | Programme Outcomes (POs) | | | | | | | Programme Specific Outcomes* (PSOs) | |
|-----------------------|---|--------------------------|--|---------------------------|---|----------------------------|----------------------------|-------------------------------------|-------|
| | PO-1 Basic and Discipline Specific Knowledge | PO-2 Problem Analysis | PO-3 Design/ Development of Solutions | PO-4 Engineering Tools | PO-5 Engineering Practices for Society, Sustainability and Environment | PO-6 Project Management | PO-7 Life Long Learning | PSO-1 | PSO-2 |
| CO-1 | 3 | 2 | 3 | - | - | - | 1 | | |
| CO-2 | 3 | - | 3 | - | - | - | 1 | | |
| CO-3 | 3 | - | 3 | 3 | - | - | 1 | | |
| CO-4 | 3 | 2 | 3 | - | 2 | 2 | 1 | | |
| CO-5 | 3 | - | 3 | - | - | 2 | - | | |

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by the respective program coordinator at the institute level. As per the latest NBA guidelines, formulating PSOs is optional

G) Teaching & Learning Scheme:

| Course Code | Course Title | Scheme of Study (Hours/Week) | | | | | |
|-------------|---------------|------------------------------|---|----------------------|-------------------------|---------------------------|-------------------|
| | | Classroom Instruction (CI) | | Lab Instruction (LI) | Notional Hours (TW+ SL) | Total Hours (CI+LI+TW+SL) | Total Credits (C) |
| | | L | T | | | | |
| 2421605 | Major Project | - | - | 08 | 04 | 12 | 06 |

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

| Course Code | Course Title | Assessment Scheme (Marks) | | | | | | Total Marks (TA+TWA+LA) |
|-------------|---------------|-------------------------------------|-----------------------------|--|----------|----------------------------------|---------------------------------|-------------------------|
| | | Theory Assessment (TA) | | Term Work & Self-Learning Assessment (TWA) | | Lab Assessment (LA) | | |
| | | Progressive Theory Assessment (PTA) | End Theory Assessment (ETA) | Internal | External | Progressive Lab Assessment (PLA) | End Laboratory Assessment (ELA) | |
| 2421605 | Major Project | - | - | 20 | 30 | 50 | 100 | 200 |

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Suggested Implementation of Major Project:

Under the minor project in fifth semester, project planning is almost over. The projects are identified and allocated to students. Teacher's role is important as they act as guide, facilitator, catalyser, motivator to promote brain storming, thinking, creativity, initiativeness and many other skills in the students. Teachers should help or guide continually to monitor whether the students are proceeding in the right direction as per outcomes to be attained.

It is also suggested that teachers are not supposed to guide and plan each and every step from the point of view of execution of the project, otherwise it will curb the creativity or thinking process of the students. Teachers have to see that he or she is able to create think tank for this fast-technological world of work for the growth of our country. Following points should be taken into consideration while implementing the major project work.

The following steps are undertaken under the major project-

1. Design, Development and Execution of the Major Project.
2. Quality of Project Report Writing and its Presentation.

1.0 Design, Development and Execution of Major Project:

Projects design, development, execution is done by the students under the guidance and feedback by respective teachers for attainment of courses specific outcomes, POs and PSOs.

Continual Monitoring, feedback and assessment mechanism on weekly progress/updates on action taken on different criteria and sub-criteria of the project work need to be planned for individual and team of students. Path breaking teachers who think out of the box are required to guide, monitor and evaluate the project work.

1.1 Unique Features of Major Project:

Following important characteristic features of project need to be given special emphasis during the implementation and evaluation of the major project work-

- Innovativeness
- Creativity
- Originality
- Pro-activeness
- Initiativeness
- Cost Effectiveness
- Resourcefulness
- Development of Soft Skills/Generic Skills
- Ethical Issues
- Environmental Considerations

- Simulated/Automated Industry's/Improvised Process
- Application or Utility in the World of Work.
- Relevance to the Curriculum
- Mapping of Outcomes of Project with Pos and PSOs (if applicable)
- Feasibility of Implementation of the Project

2.0 Quality of Project Report Writing and its Presentation:

Following points need to be taken care of during report writing, its implementation and evaluation-

- Report writing as per prescribed format
- Clarity of outcomes
- Innovativeness
- Presentation of Data
- Data Analysis, Interpretation and Result
- Quality of Product/Prototype

2.1 Project Report Writing:

The suggested format of the project report is mentioned below for teacher's and students' reference:

- i. Problem Statement/ Project Title
- ii. Abstract
- iii. Literature Review
- iv. Outcomes of the Project
- v. Project Planning, Design and Development
- vi. Methodology
- vii. Implementation and Testing
- viii. Result and its Interpretation
- ix. Summary
- x. References / Bibliography

2.2 Presentation & Discussion:

Quality of presentation of data need to be ensured using the following criteria -

- Clarity in Communication and Presentation
- Voice Audibility
- Use of Media and Methods
- Satisfying the Queries of Audience
- Attainment of Outcomes

2.3 Project's Potential:

Futuristic scope and recommendation for further studies related to project may be assessed from the following criteria -

- Papers Published or Award Received
- Exhibition or Display or Showcase of Project in Competition or Exhibition or Tech Fest
- Evaluation of Working/Testing of Projects or Prototype
- Relevance and Applications in the World of Work
- Recognition in any Form
- Related Areas/Sub Areas for Further Studies

J) Assessment of the Major Project:

For objective, valid and reliable assessment, different tools of assessment such as a checklist, rating scale, assessment rubric, observation schedule, portfolio assessment, incidental records etc. need to be prepared. Even the students may be courage to adopt self-assessment techniques using the assessment rubrics.

The students need to be assessed continuously based on the suggested below mentioned assessment criteria at project planning stage. The project guide must prepare detailed rubric(s) for each criteria to have more valid and reliable assessment. Criteria of assessment of major project work are mentioned below.

Assessment Scheme for Major Project

| S. No. | Suggested Assessment Criteria | Suggested Weightage (%) |
|---------------|--|--------------------------------|
| 1. | Project Planning during Minor Project Work 1.1 Identification of Area/Problem Statement 1.2 Literature Survey 1.3 Formulation of Project Title 1.4 Clarity in Formulation of Outcomes of The Project 1.5 Preparation of Synopsis 1.6 Presentation of Synopsis | 30 |
| 2. | Design, Development and Execution of the Project. 2.1 Unique Features of Major Project | 45 |
| 3. | Quality of Report Writing and Presentation. 3.1 Report Writing 3.2 Presentation & Discussion 3.3 Project's Potential | 25 |
| | TOTAL | 100 |
