Curriculum of Diploma Programme

in

Renewable Energy

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	Course Titles	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				
2470601	**PCC**	**Sustainable Energy Policies and Regulations**	03	-	-	02	05	04
2425602	**PCC**	**Maintenance & Safety of Mechanical & Solar Appliances**	03	-	04	02	09	06
2425603	**PEC**	**Programme Electives*** (Any One)	03	-	04	02	09	06
2400604	**OEC**	**Open Electives**/ COE** (Advanced -Any One)	03	-	04	02	09	06
2425606	**PSI**	**Major Project** (Common for all programmes)	-	-	08	04	12	06
2400107	**NRC**	**Professional Ethics**	01	-	-	-	01	01
2400408	**NRC**	**Employability Skills Development** (Common for All Programmes)	01	-	-	-	01	01
Total			**14**	**-**	**20**	**12**	**46**	**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)

*: Heat and Mass Transfer/ Power Plant Engineering/ Press Tool, Jigs and Fixture/ Hydraulic and Pneumatic Controls/Renewable and Alternate Energy Sources

**: Artificial Intelligence (AI)/ IOT/ Drone Technology/ 3D Printing & Design/ Industrial Automation & Control/ Electric Vehicle/ 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)	
2470601	**PCC**	**Sustainable Energy Policies and Regulations**	30	70	20	30	-	-	150
2425602	**PCC**	**Maintenance & Safety of Mechanical & Solar Appliances**	30	70	20	30	20	30	200
2425603	**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
2425606	**PSI**	**Major Project** (Common for all programmes)	-	-	20	30	50	100	200
2400107	**NRC**	**Professional Ethics**	25	-	-	-	-	-	25
2400408	**NRC**	**Employability Skills Development** (Common for All Programmes)	25	-		-	-	-	25
Total			**170**	**280**	**100**	**150**	**110**	**190**	**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.

*: Heat and Mass Transfer/ Power Plant Engineering/ Press Tool, Jigs and Fixture/ Hydraulic and Pneumatic Controls/Renewable and Alternate Energy Sources

**: Artificial Intelligence (AI)/ IOT/ Drone Technology/ 3D Printing & Design/ Industrial Automation & Control/ Electric Vehicle/ 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 respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activitis.

A) Course Code : 2470601(T2470601/ S2470601)

B) Course Title : Sustainable Energy Policies and Regulations.

C) Pre- requisite Course(s) :

D) Rationale :

Energy policy and regulation are critical to implementing renewable energy and the governance of natural resources. Institutions prioritize the support to reliable and sustainable energy access for any world community. As a result, establishing policies, legislation and institutional structure is crucial to sustain renewable energy. This nation seeking to stimulate investments and boost their energy sectors to accomplish SDG7 must first develop a suitable environment. Policies and regulation help them achieve their goals.

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 Understand energy policy goals, policymaking, security.

CO-2 Different renewable energy policies.

CO-3 Make energy efficiency policies.

CO-4 List carbon pricing, carbon offset program energy certification programs.

CO-5 Understand sustainable development goals.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes(POs)							Programme SpecificOutcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	**PO-2** Problem Analysis	**PO-3** Design/ Development of Solutions	**PO-4** EngineeringTools	**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		
CO-2	3	2	-	2	-	-	-		
CO-3	3	3	-	2	3	-	-		
CO-4	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 Credits (C)
		L	T				
2470601	Sustainable Energy Policies and Regulations	03	-	-	02	05	04

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)
		ory 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)	
2470601	Sustainable Energy Policies and Regulations	30	70	20	30	-	-	150

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: T2470601

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain Energy policy goals and objectives. *TSO 1a.* Policymaking process and difficulties. *TSO 1b.* List regulatory agencies and authorities. *TSO 1c.* Explain energy security and resilience consideration.	**Unit-1.0** Energy Policy Fundamentals 1.1 Energy policy goals and objectives. 1.2 Policymaking process and stakeholders. 1.3 Regulatory agencies and authorities. 1.4 Energy security and resilience consideration.	**CO1**
TSO 2a. Explain feed in tariffs. *TSO 2b.* Learn renewable energy incentives. *TSO 2c.* Understand costs, benefits, and impact of standards or changes to standards. *TSO 2d.* Explain renewable energy auctions and contracts. *TSO 2e.* List different type of community based renewable energy project.	Unit-2.0 Renewable Energy Policies 2.1 Feed in tariffs and renewable energy incentives. 2.2 Renewable portfolio standards(RPS) 2.3 Renewable energy auctions and contracts. 2.4 Community based renewable energy projects. .	**CO1, CO2**
TSO 3a. Explain building codes and energy standards. *TSO 3b.* Select appliance and equipment for best efficiency standards. *TSO 3c.* List energy labeling and certification program. *TSO 3d.* Explain energy efficiency financing mechanisms.	**Unit-3.0** Energy Efficiency Policies. 3.1 Building codes and energy standards. 3.2 Appliance and equipment efficiency standards. 3.3 Energy labeling and certification programs. 3.4 Energy efficiency financing mechanisms.	**CO3, CO4**
TSO 4a. Explain carbon taxes and caps and trade system. *TSO 4b.* Explain carbon offset programs and market. *TSO 4c.* Define emission trading and compliance. *TSO 4d.* List carbon pricing's role in mitigating climate.	**Unit-4.0** Carbon Pricing and Emissions Reduction Strategies. 4.1 Carbon taxes and caps and trade systems. 4.2 Carbon offset programs and markets. 4.3 Emissions trading and compliance. 4.4 Carbon pricing's role in mitigating climate change.	**CO3, CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5a. List international agreement. TSO 5b. Explain sustainable development goals. TSO 5c. Explain energy diplomacy and geopolitics. TSO 5d. List challenges and opportunities in global energy governance.	**Unit-5.0** Global Energy Governance and Sustainability Goals. 5.1 International agreement (e.g., Paris Agreement, Kyoto Protocol) 5.2 Sustainable Development Goals. (SDGs) 5.3 Energy diplomacy and geopolitics . **5.4** Challenges and opportunities in global energy governance	**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:

L) Suggested Term Work and Self Learning: S2470601 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. Collect report on international agreement (e.g.-Paris Agreement, Kyoto Protocol)
2. Visit nearby industry and learn policymaking process.
3. Make renewable energy project.
4. Discuss and prepare process on renewable energy auctions and contracts.

c. Other Activities:

1. Seminar Topics:
   - Commence seminar on progress of Paris Agreement and Kyoto Protocol.
   - Discussion on Sustainable Development Goals.
   - Challenges and opportunities in global energy governance.
   - Regulatory agencies and authorities.

2. Visits: Visit nearby tool room/industry with carbon taxes system. Prepare report of visit with special comments of carbon taxes system and how they slow down carbon emission.

3. Self-learning topics:
   - SDGs
   - Emission trading and compliance.
   - Energy diplomacy and geopolitics.
   - Renewable portfolio standards.

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%	-	-	-	-
CO-2	10%	10%	10%	25%	-	-	-
CO-3	15%	15%	15%	25%	33%	-	-
CO-4	30%	30%	30%	25%	33%	-	-
CO-5	30%	30%	30%	25%	34%	-	-
Total Marks	**30**	**70**	**20**	**20**	**10**	**-**	**-**
			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 (Cl) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Energy Policy Fundamentals	8	CO1	10	3	3	4
Unit-2.0 Renewable Energy Policies	8	CO1, CO2	10	3	2	5
Unit-3.0 Energy Efficiency Policies	8	CO3, CO4	10	5	2	3
Unit-4.0 Carbon Pricing and Emission Reduction Strategies	12	CO3, CO4	20	5	6	9
Unit-5.0 Global Energy Governance and Sustainability Goals	12	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):

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 beprepared 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) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Energy Policies for Sustainable Development Strategies.	Nnaemeka Vincent Emodi	Springer Verlag , Singapore ISBN: 9789811009730

(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:

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A) Course Code : **2425602(T2425602/P2425602/S2425602)**

B) Course Title : Maintenance & Safety of Mechanical & Solar Appliances

C) Pre- requisite Course(s) :

D) Rationale

In day-to-day working we come across different types of Equipment for different purposes and functions. This section covers the different safety aspects of using machinery and maintaining plant and equipment in the workplace. Student should able to know how their worker use machinery and have adequate maintenance arrangements in place to ensure it remains safe to use.

The aim of this course is to dedicated for transforming the students into highly competent Mechanical engineers to meet the needs of the industry, in a changing and challenging technical environment, by strongly focusing in the fundamentals of engineering sciences for achieving excellent results in their professional pursuits.

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/ workshop/ field/ industry.

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

CO-1 Apply various tools and preventive actions for safety.
CO-2 Apply various safety acts and ergonomics in industry.
CO-3 Use relevant maintenance practices for the given situation.
CO-4 Develop maintenance plans & charts to maintain the equipment's and machines
CO-5 Perform various maintenance related to various Mechanical equipment's & Solar Appliance.

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	1	3	3		
CO-2	2	3	2	1	-	2	2		
CO-3	2	3	2	1	2	2	3		
CO-4	3	2	3	1	2	2	2		
CO-5	2	3	-	1	2	2	3		

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

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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				
2425602	Maintenance & Safety of Mechanical & Solar Applieances	03	-	04	02	09	06

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		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)	
2425602	Maintenance & Safety of Mechanical & Solar appliance	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)

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J) Theory Session Outcomes (TSOs) and Units: T2425602

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Describe the role of government in industrial safety. TSO 1b. Explain educational training in safety TSO 1c. Use of various safety equipment's by workers in different industry. TSO 1d. Application of different Firefighting equipment for given industry. TSO 1e. Explain Industrial psychology in accident prevention and Safety trial. TSO 1f. Use of various PPE for given solar appliances in Solar industry. TSO 1g. Explain various solar appliances & its construction, working and function	**Unit-1.0 Industrial Safety Equipment's** 1.1 Introduction to Industrial Safety and Management, safety principal safe working condition and practices, Safety and productivity, 1.2 Role of management and role of Govt. in Industrial safety, motivation for safety. 1.3 Education and training in safety, Survey the plant for locations, Part of body to be protected, cause of accident& prevention, Housekeeping, Accident Preventions, Protective Equipment's and the Acts 1.4 Personal protective equipment (PPE) , PPE for solar industry-hard hats, safety glasses, respiration ,gloves , fall protection equipment , hearing protection 1.5 Medical emergency, introduction to first aid, first aid box, incident management, CPR, bleeding, shock, burns & Scaldes 1.6 Fire, classification of fire, Firefighting equipment-Fire Extinguishers, types of fire extinguishers-Powder foam, CO2, wet chemical, water, uses of different types of fire extinguishers, symbols of fire extinguisher, fire safety sign, fire triangle and tetrahedral, Smoke detectors, Fire Alarm system. 1.7 Accident, Measures in industry, Accident reporting, Investigations, Industrial psychology in accident prevention, accident record keeping. Occupational safety and health assessment (OSHA) 1.8 Introduction to solar appliances, construction, working & function- Solar Water Heater, Photovoltaic Cell, Solar Distillation, solar drying, solar cooker, solar lighting	CO1
TSO 2a. Explain the features of factory Act (Explosive Boiler Act, ESI Act Workman's compensation Act etc). *TSO 2b.* Explain Ergonomics. *TSO 2c. Describe the* methods of controlling chemical hazards for a give situation. *TSO 2d.* Explain Code and regulations for worker safety for solar penal. *TSO 2e.* Use of electricity act 2003 for	**Unit-2.0 Industrial Safety Acts** 2.1 Features of Factory Act (1948), implementation of factory act(1948), Introduction of Explosive Act, Boiler Act(1923), Employee's state insurance Act(1948), Workman's compensation Act(1923),	CO2

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
installation of solar Penal.	2.2 Industrial hygiene, Diseases prevention, Ergonomics& health, Occupational diseases, stress, fatigue, health, safety and the physical environment, 2.3 Methods of controlling chemical hazards, safety and the physical environment, Control of industrial noise and protection against it 2.4 Code and regulation for solar panel installation-Building codes, fire codes and Electrical Codes, Code and regulations for worker safety. 2.5 Major solar policies in India.	
TSO 3a. Explain principle and merits of maintenance. TSO 3b. Define reliability& equipment life cycle. TSO 3c. Explain the need of maintenance TSO 3d. Classified different types of maintenance used in industries TSO 3e. Calculating the costs associated with given asset breakdowns and downtime. TSO 3f. Enlist preventive maintenance of components of given solar appliances TSO 3g. Prepare maintenance contracts for given equipment used in industry.	**Unit-3.0 Principles and Practices of Maintenance** 3.1 Basic Principles of maintenance – Objectives, Benefit of Maintenance systems – Reliability and machine availability, Equipment Life cycle 3.2 Need and type of Maintenance- Breakdown maintenance, Preventive Maintenance, Condition Based monitoring - on line -off line monitoring, visual, temperature, leakage & lubricant monitoring 3.3 Introduction of Condition based Maintenance (CBM), Benefits, Principle and its Application (Temperature Readings, Pressure States and Oil Viscosity). 3.4 Maintenance budget and its components 3.5 Solar panel Maintenance- Preventive maintenance on major components of a solar system (Battery, Solar Panels, Charge Controller, Inverter and Wiring and connections) 3.6 Maintenance contracts and agreements.	**CO3**
TSO 4a. Evaluate role of maintenance planning for a given optimizing operations. TSO 4b. Prepare a maintenance work order for a given equipment. TSO 4c. Prepare Scheduling and maintenance plan for given machine to minimize downtime. TSO 4d. Analyzed CMMS and its function. TSO 4e. Analyzed Implementation and utilization of CMMS for efficient maintenance management in industry TSO 4f. Describe solar system and solar panel TSO 4g. Define maintenance measures and its related terms. TSO 4h. Explain maintenance organization TSO 4i. Prepare the various types of maintenance charts use in industry. TSO 4j. Prepare fault tree analysis for given equipment failures.	**Unit-4.0 Maintenance Planning and Management** 4.1 Role of maintenance planning and scheduling, planning and scheduling techniques, gantt chart and bar chart, types of maintenance strategies, 4.2 Computerized maintenance Management Systems (CMMS)- Introduction to CMMS and its functions, Implementation and utilization of CMMS for efficient maintenance management**,** E-maintenance solution for industrial equipment, Introduction of Software maintenance (SM) (Software-Hippo CMMS, open MAINT), Need for SM, Type of SM, its Process& Advantages. 4.3 Measures for Maintenance Performance: Equipment's breakdowns, Mean Time Between Failures and Repair, Factors of availability, Maintenance organization, 4.4 Repair cycle, Principles and methods of lubrication, Fault Tree Analysis and trouble shooting	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	4.5 Solar System Maintenance schedule, Solar Panel maintenance log sheet.	
TSO 5a. Analyze various solar appliances and its application TSO 5b. Explain Solar Panels TSO 5c. Explain preventive & predictive maintenance of equipment Solar appliances TSO 5d. Prepare a preventive maintenance chart for the given machine/ Engine. TSO 5e. Evaluating the effectiveness of the preventive and predictive maintenance chart for a given equipment. TSO 5f. Prepare service agreements document for given equipment. TSO 5g. Explain warranties and service agreement for given equipment's. TSO 5h. Explain the decision levels for given equipment maintenance. TSO 5i. Explain standards and requirements applicable to the measuring equipment. TSO 5j. Explain the need for calibration of measuring equipment. TSO 5k. Prepare a maintenance record keeping for a given equipment. TSO 5l. Enlist type of maintenance record keeping.	**Unit-5.0 Application of Maintenance of Mechanical Equipment's & Solar Appliances** 5.1 Maintenance checklist of Photovoltaic Cell, Solar Water Heater and Solar lighting. 5.2 Preventive maintenance chart of Lathe machine, drill, refrigerator and four stroke IC Engine. 5.3 Managing equipment warranties, guarantees and service agreements 5.4 Policy and objective for maintenance, Decision levels for equipment maintenance. 5.5 Calibration, need for calibration, standards and requirements, standard operating procedures for calibration. 5.6 Record keeping -need of record keeping, advantages of record keeping, types of record keeping- manual, automatic & computerized record keeping maintenance record format.	**CO5**

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

K) Suggested Laboratory (Practical)Session Outcomes (LSOs)and List of Practical: P2425602

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number (s)
LSO 1.1. Use of personal protective equipment.	1.	Identify given personal protective equipment	CO1
	2.	Select PPE for the given job.	CO1
LSO 1.2. Use first aid for the given injuries	3.	Perform first aid process in bleeding, shock, burns & scalds	CO1
LSO 1.3. Use different types of fire extinguishers	4.	Identify different types of fire Extinguishers.	CO1
	5.	Operate the given fire extinguishers	CO1
LSO 1.4. Apply OSHA	6.	Apply OSHA for the given laboratory	CO1
LSO 1.5. Use Smoke detectors and Fire Alarm Systems	7.	Operate Smoke detectors and Fire Alarm Systems.	CO1
	8.	Test smoke detector and fire alarm system for its performance	CO1
	9.	Inspect test solar panel system and components for its performance	CO1

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number (s)
	10.	Identify the faults in the given solar panel	CO1
	11.	Test solar water heater	CO1
LSO 2.1. Identify hazards	12.	Identify potential hazards in the given laboratory and recommend control measures.	CO2
LSO 2.2. Use sound level meter	13.	Measure noise levels using sound level meters	CO2
LSO 2.3. Install solar systems	14.	Install solar system using codes and regulation	CO2
LSO 2.4. Boiler Act (1923)	15.	Identify the symbols and safety measures given on the boiler	CO2
LSO 3.1 Equipment life cycle	16.	Calculate life of the given equipment	CO3
LSO 3.2 Calculate total breakdown cost.	17.	Calculate direct and indirect breakdown costs of the given equipment	CO3
LSO 3.3 Use maintenance schedule	18.	Perform maintenance of the given solar appliance as per the preventive maintenance schedule.	CO3
LSO 4.1. Calculate MTBF and MTTR for given equipment's	19.	Calculate MTBF and MTTR using provided data sets for the given equipment's	CO4
LSO 4.2. Troubleshoot the given system	20.	Troubleshoot the given solar system	CO4
LSO 4.3. Use CMMS	21.	Apply CMMS for the given equipment	CO4
LSO 4.4. Perform Fault Tree Analysis	22.	Conduct a Fault Tree Analysis for a given maintenance equipment problem	CO4
LSO 4.5. Apply relevant lubrication techniques	23.	Lubricate the given equipment	CO4
LSO 4.6. Use Solar panel maintenance log sheet template	24.	Prepare solar panel maintenance log sheet	CO4
LSO 4.7. Use maintenance software (Software-Hippo CMMS, open-MAINT	25.	Update the laboratory process by adding laboratory equipment to the software system, including details such as maintenance history and specifications.	CO4
	26.	Create work orders, update asset information, and generate maintenance reports of the given equipment.	CO4
LSO 5.1. Solar Panel Installation (mounting, wiring, and configuring the panels)	27.	Install solar panels on a mock roof or structure.	CO5
LSO 5.2.	28.	Inspect clean and repair solar water heaters, including checking pumps and controls.	CO5
LSO 5.3. Maintain solar lighting system	29.	Inspect a solar lighting system using preventive maintenance checklist including battery health, wiring, and light intensity.	CO5
LSO 5.4. Apply step-by-step calibration procedures for the given equipment's	30.	Identify tools and equipment required for calibration.	CO5
	31.	Calibrate the given micrometers and Vernier caliper	CO5
	32.	Calibrate the given pressure gauges	CO5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number (s)
	33.	Calibrate the given screw driver and testers	CO5
	34.	Perform maintenance activities on the lath machine using preventive maintenance schedule	CO5

L) Suggested Term Work and Self Learning: S2425602 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments:

i. Prepare a detailed report on different types of solar appliances used for household with specification and prepare a maintenance plan.
ii. Prepare a detailed report of various type of protective equipment used in industry to prevent the accident.
iii. Compare at least 04 types of maintenance software used in industries based on the given criteria's and select one software which can be applicable in the laboratory with justification.
iv. Explain different codes and regulations used in manufacturing industry for worker safety.
v. Prepare various maintenance chart for given mechanical and solar appliance.
vi. Prepare a detail charts on different types of acts applied in industries and laboratories.
vii. Develop preventive maintenance checklist for major components of a solar system
viii. Prepare maintenance schedule for Solar Water Heater
ix. Develop a preventive Maintenance schedule for a lathe machine, including lubrication, calibration, and tool inspections

b. Micro Projects:

i. Troubleshoot 02 given equipment's can perform the maintenance of the given equipment in industries.
ii. Calculate the life of the given 05 equipment.
iii. Visit the industry and prepare detailed report on maintenance methods and activities adopted to maintain the machines and equipment for 02 industries.
iv. Visit the industry and prepare the report for provision made for safety of man & machine and implementation of OSHA in the industries.
v. Prepare E-maintenance solution for industrial equipment

c. Other Activities:

i. Use demonstration, video/animation films field/industry visit for explaining complex/abstract concepts of Maintenance & Safety of Mechanical &Solar
ii. Students may be asked the method to solve the Problem before accident during lecture periods.

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%	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:

- 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 (Cl) Hours	Relevant COs Number (s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Industrial Safety Equipment's	08	CO1	12	3	4	5
Unit-2.0 Industrial Safety Acts	10	CO2	14	4	5	5
Unit-3.0 Principles and Practices of Maintenance	08	CO3	12	3	4	5
Unit-4.0 Maintenance Planning and Management	11	CO4	16	5	5	6
Unit-5.0 Application of Maintenance in mechanical equipment's & Solar Appliances	11	CO5	16	5	5	6
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.	Identify given personal protective equipment	CO1	40	50	10
2.	Select PPE for the given job.	CO1	40	50	10
3.	Perform first aid process in bleeding, shock, burns & scalds	CO1	40	50	10
4.	Identify different types of fire Extinguishers.	CO1	40	50	10
5.	Operate the given fire extinguishers	CO1	40	50	10
6.	Apply OSHA for the given laboratory	CO1	40	50	10
7.	Operate Smoke detectors and Fire Alarm Systems.	CO1	40	50	10
8.	Test smoke detector and fire alarm system for its performance	CO1	40	50	10
9.	Inspect test solar panel system and components for its performance	CO1	40	50	10
10.	Identify the faults in the given solar panel	CO1	40	50	10
11.	Test solar water heater	CO1	40	50	10
12.	Identify potential hazards in the given laboratory and recommend control measures.	CO2	40	50	10
13.	Measure noise levels using sound level meters	CO2	40	50	10
14.	Install solar system using codes and regulation	CO2	40	50	10
15.	Identify the symbols and safety measures given on the boiler	CO2	40	50	10
16.	Calculate life of the given equipment	CO3	40	50	10
17.	Calculate direct and indirect breakdown costs of the given equipment	CO3	40	50	10
18.	Perform maintenance of the given solar appliance as per the preventive maintenance schedule.	CO3	40	50	10
19.	Calculate MTBF and MTTR using provided data sets for the given equipment's	CO4	40	50	10
20.	Troubleshoot the given solar system	CO4	40	50	10
21.	Apply CMMS for the given equipment	CO4	40	50	10
22.	Conduct a Fault Tree Analysis for a given maintenance equipment problem	CO4	40	50	10

S. No	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
23.	Lubricate the given equipment	CO4	40	50	10
24.	Prepare solar panel maintenance log sheet	CO4	40	50	10
25.	Update the laboratory process by adding laboratory equipment to the software system, including details such as maintenance history and specifications.	CO4	40	50	10
26.	Create work orders, update asset information, and generate maintenance reports of the given equipment.	CO4	40	50	10
27.	Install solar panels on a mock roof or structure.	CO5	40	50	10
28.	Inspect clean and repair solar water heaters, including checking pumps and controls.	CO5	40	50	10
29.	Inspect a solar lighting system using preventive maintenance checklist including battery health, wiring, and light intensity.	CO5	40	50	10
30.	Identify tools and equipment required for calibration.	CO5	40	50	10
31.	Calibrate the given micrometers and Vernier caliper	CO5	40	50	10
32.	Calibrate the given pressure gauges	CO5	40	50	10
33.	Calibrate the given screw driver and testers	CO5	40	50	10
34.	Perform maintenance activities on the lath machine using preventive maintenance schedule	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.	Personal protective equipment's	Different types of personal protective equipment's for workshop, chemical labs, Engg labs etc	1,2
2.	First aid box	First aid box containing all the essential equipment's and medicines	3
3.	Fire extinguishers	Different types of fire extinguishers	4,5
4.	Smoke detectors and fire alarm systems	Different types of Smoke detectors and fire alarm systems and its cut models	7,8

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
5.	Solar panel	Different types of solar panels, Solar panels- 60-cell, 72-cell, and 96-cell, Mechanical Characteristics- Monocrystalline Silicon solar cells, Encapsulated: PC film lamination	9,10, 24, 27
6.	Solar water heater	• Different types of solar water heater • Solar Rating & Certification Corporation Standard 100 Minimum Standards for Solar Thermal Collectors • Solar Rating & Certification Corporation Standard 300 Minimum Standards for Solar Water Heating Systems • Monitoring systems	11, 28
7.	Sound level meter	Class -1 category, Dynamic Range- 100dB to 120dB. Microphone Types- Piezoelectric, Measurement- Frequency Weightings Z type, maximum data hold with built in calibration check	13
8.	Solar systems and solar appliance	Different types of solar systems and appliances	14, 18, 20
9.	CMM software	Different CMM software's for maintenance and upkeep of the lab	25, 26
10.	Solar lighting systems	Different types of solar light systems available in the market. Solar Module 60-500 Wp, Batery (Lithium Ferro Phosphate) 300 Wh (+20% permissible) to 3000Wh (+20%), LED Luminaire 10 W (+20% permissible) to 24W ,4 Nos (+20%)	29
11.	Micrometer	External micrometers and laser micro meters	31
12.	Vernier caliper	Digital Stainless-Steel caliper, approx. 150mm measuring range. Precision reading, laser reticle. Measuring Range: 0-150 millimeter or 0-6 inch. Resolution: 0.01 millimeter or 0.0005 inch. Repeatability: 0.01 millimeter or 0.0005 inch. Maximum measurement speed: 1m/s.	31
13.	Pressure gauges	H types, 1.6% ± EN 837 Class 1.6 (Class 2.5 for 0-600 & 0-1000 bar range, Vacuum: -1 - 0 bar Pressure: 0 - 1000 bar	32
14.	Screw drivers and testers	-	33

R) Suggested Learning Resources:

(a) Books:

S. No.	Title	Author(s)	Publisher and Edition with ISBN
1.	Occupational Health and Hygiene in Industry	SK. Haldar	CBS PUBLISHERS AND DISTIRIBUTORS PVT. LTD., 2022, ISBN-13 : 978-9354664922
2.	Safety In chemical plants /Industry & its Management	B.K.B.Rao R.K.Jain , Vinit Kumar	Khanna Publishers; 2010, ISBN-13 : 978-8174092984
3.	Principles of Fire Safety Engineering,	Das Akhil Kumar	PHI Learning Pvt Ltd; 2nd edition, 2020 ISBN-13 : 978-9389347234
4.	Industrial Safety, Health and Environment Management Systems	Sunil S.Rao R.K.Jain	Khanna Publishers; Latest edition, 2000 ISBN-13 : 978-8174092106
5.	A Textbook of Reliability and Maintenance Engineering	Alakesh Manna	Dreamtech Press, 2020 ISBN-13 : 978-9389698701
6.	Practical Root Cause Failure Analysis: Key Elements, Case Studies, and Common Equipment Failures (Reliability, Maintenance, and Safety Engineering)	Randy Riddell	Taylor & Francis Ltd; 1st edition, 2022 ISBN-13 : 978-1032164656
7.	Industrial Maintenance Management	Srivastava, S.K.	S. Chand and Co, 2002 ISBN: 978-8121916639
8.	Industrial Safety and Maintenance Management	M.P. Poonia, S.C. Sharma	Khanna publishing house, 2019 ISBN:9789386173188, 9386173182
9.	Installation, Servicing and Maintenance	Bhattacharya, S.N.	S. Chand and Co. 2013 ISBN: 9788121908313

(b) Online Educational Resources:

1) http://youtube.com/playlist?list=PLbRMhDVUMngdXebaRB59KdKwstzuAovua
2) https://www.youtube.com/watch?v=f58SW0Hwcf0
3) https://www.youtube.com/watch?v=0dmXvXYMiYU

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

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A) Course Code : 2425603A(T2425603A/P2425603A/S2425603A)

B) Course Title : Heat and Mass Transfer

C) Pre- requisite Course(s) :

D) Rationale :

Heat and mass transfer as the name suggest is based on the findings the rate of heat transferred through the medium such as by conduction, convection and radiation, by virtue of the temperature difference between two mediums. Whenever a temperature difference exists within a system or when two system at different temperatures are brought into contact, energy is transferred. The aim of this course is to impart knowledge of different modes of heat transfer and their equipment

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 Fourier law of heat conduction to different materials.

CO-2 Select fins as per the given situation

CO-3 Apply the principles of forced and natural heat convection in various condition of heat transfer.

CO-4 Design different types of heat exchanger for the given problem.

CO-5 Calculate radiative heat fluxes between surfaces of simple geometries

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/ Developmentof 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	2	1	-	2		
CO-2	2	1	2	2	1	-	2		
CO-3	2	2	3	2	2	1	2		
CO-4	2	2	3	2	1	1	2		
CO-5	2	2	2	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				
2425603A	Heat and Mass Transfer	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)	
2425603A	Heat and Mass Transfer	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: T2425603A

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Differentiate among different mode of heat transfer. *TSO 1b.* Draw graph between temperature and thermal conductivity for different metals. *TSO 1c.* Determine the thermal conductivity of given material. *TSO 1d.* Draw graph of temperature distribution in different materials of given shape. *TSO 1e.* Explain the use of critical radius in cylindrical pipes.	**Unit-1.0 Introduction to Heat Transfer** 1.1 Modes of heat transfer: conduction, convection and radiation 1.2 Combined mode of heat transfer, Overall heat transfer coefficient, thermal conductivity of solid, liquid and gasses, effects of temperature on thermal conductivity of materials. 1.3 Fourier law of heat conduction, Differential equation of heat conduction 1.4 Steady state one dimensional Heat conduction – plane wall, sphere, cylinder, composite slab. 1.5 Thermal contact resistance, Thermal diffusivity, critical radius of insulation.	**CO1**
TSO 2a. Explain the need of fins. *TSO 2b.* Calculate the effectiveness of the given fins. *TSO 2c.* Compare different shape of fins. *TSO 2d.* Find the time constant of the given lumped body. *TSO 2e.* Test the efficiency and effectiveness of different types of fins.	**Unit-2.0 Fins** 2.1 Types of fins, Heat flow through a rectangular fin, infinitely long fin, fin insulated at the tip and fin losing heat at tip. 2.2 Effectiveness and efficiency of fin. 2.3 Transient heat conduction, Lumped system analysis, Time constant, Unsteady state heat conduction in one dimension only, Biot number Heisler's chart	**CO2**
TSO 3a. Draw the temperature profile and velocity profile of given type of convection. *TSO 3b.* Determine convective heat transfer coefficient for a given convection process. *TSO 3c.* Measure the fluid velocity and boundary layer for a given flow. *TSO 3d.* Estimate the different dimensionless *TSO 3e.* Number in given problem. *TSO 3f.* Derive equation of flow	**Unit-3.0 Convection** 3.1 Newton's law of cooling, Natural and forced convection 3.2 Continuity, momentum and energy equation, Thermal and hydrodynamic boundary layer 3.3 Free and Forced Convection during external flow over Plates and Cylinders and Internal flow through tubes. 3.4 Heat transfer co-efficient and its interpretations 3.5 Dimensional analysis applied to forced and natural convection 3.6 Dimensionless number and their physical significance	**CO3**
TSO 4a. Classify different types of heat exchanger. *TSO 4b.* Determine LMTD for parallel and counter flow heat exchanger. *TSO 4c.* Test the fouling factor of a given heat exchanger. *TSO 4d.* Explain the use of NTU in heat exchanger. *TSO 4e.* Describe the design parameter o design heat exchanger. *TSO 4f.* Calculate mean temperature difference and outlet temperature of working fluid	**Unit-4.0 Heat Exchanger** 4.1 Different Types of Heat exchangers, Parallel flow, counter flow, cross flow heat exchanger evaporator and condenser. 4.2 Overall Heat transfer coefficient, Log mean temperature difference (LMTD), effectiveness of heat exchanger Number of transfer unit (NTU). 4.3 fouling factor 4.4 Design of heat-exchange equipment 4.5 Mean temperature difference, calculating the outlet temperature of working fluids	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5a. Determine the radiative heat transfer between two given surfaces. *TSO 5b.* Calculate emissivity of the given plane body. *TSO 5c.* Describe the irradiation and radiosity of a given solid. *TSO 5d.* Explain the concept of shape factor. *TSO 5e.* Interpretation of Fourier's law, *TSO 5f.* Describe Electrical analogy of heat transfer *TSO 5g.* Explain critical radius of insulation.	**Unit-5.0 Thermal Radiation** 5.1 Basic radiation concepts, Black body radiation, Grey body, emissive power, emissivity, reflectivity, transmissivity 5.2 Law of radiation-Plank's, Wein's displacement, Stefan Boltzmann, Kirchoff's. 5.3 Irradiation, Radiosity, Concept of shape factor, Radiation shield. 5.4 Electrical Analogy, 5.5 Radiation through gases.	**CO5**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425603A

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Apply Fourier's law of heat conduction. *LSO 1.2.* Determine Thermal conductivity of given material	1.	Determine Thermal conductivity of a metal rod.	CO1
	2.	Determine Thermal Conductivity of Liquid	CO1
	3.	determine the co-efficient of thermal conductivity of insulating powder	CO1
	4.	Determine of overall heat transfer coefficient of a given composite wall	CO1
LSO 1.3. Select insulating material	5.	Find critical radius of insulating material.	CO1
LSO 2.1. Determine heat transfer coefficient and efficiency of given fin	6.	Determine Effectiveness on a Metallic fin	CO2
	7.	Determine the heat transfer coefficient, fin efficiency and temperature distribution along the length of a pinfin in natural convection.	CO2
	8.	Determine the heat transfer coefficient, efficiency and temperature distribution of a pin fin in forced convection.	CO2
LSO 3.1. Heat transfer coefficient through natural and forced convection	9.	Determine the heat transfer co-efficient in natural convection for vertical tube	CO3
	10.	Determine the heat transfer co-efficient in forced convection for hot air flowing through horizontal tube	CO3
LSO 4.1. Use shell and tube type heat exchanger.	11.	Find coefficient of heat transfer from shell and tube heat exchanger.	CO4
LSO 4.2. Use counter and parallel flow heat exchanger	12.	compare temperature distribution, heat transfer rate, overall heat transfer coefficient in parallel flow and counter flow.	CO4
	13.	Determination of LMDT and Effectiveness in a Parallel Flow and Counter Flow Heat Exchangers.	CO4
LSO 5.1. Determine Stefan-Boltzman constant	14.	Determine the Stefen-Boltzman constant of radiation heat transfer.	CO5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 5.2. Determine emissivity of the given surface	15.	Measure emissivity of a test plate surface	CO5
LSO 5.3. Determine critical heat flux across the given wire	16.	Determine critical heat flux values at different bulk temperatures and to observe the boiling phenomenon	CO5
LSO 5.4. Determine COP of the given system	17.	Determine the COP of vapour compression refrigeration system.	CO5

L) Suggested Term Work and Self Learning: 2425603A 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.

- Derive a general 3 - dimensional conduction equation in Cartesian coordinates.
- Explain initial conditions and boundary conditions of I, II & III kind.
- Derive an expression for critical thickness of insulation for a cylinder.
- Derive an expression for temperature distribution and heat transfer from an extended rectangular surface of finite length with end insulation.
- Explain physical significance of Biot and Fourier numbers.
- Explain Heisler Charts and their significances in solving transient conduction problems

b. Micro Projects:

- Construct a working model of a shell and tube heat exchanger.
- Prepare a list of different types of heat exchanger used in thermal power plants.
- Prepare a list of conducting and insulating materials on the basis of thermal conductivity.
- Develop prototype model of different types of fins used in different machine and equipment's.

c. Other Activities:

1. Seminar Topics:
   - Visual representation of heat exchanger in various parts of thermal power plants.
   - Representation of heat transfer in Refrigerator and AC.
   - Adverse effect of thermal radiation on human body.
   - How to reduce fouling factor to increase heat transfer.
   - Fundamental difference among all three modes of heat transfer.
2. Visits:
   - Visit nearby thermal power plant to gain practical knowledge of different heat exchanger like economizer, Air preheater, Superheater Cooling tower and condenser.
   - Visit the industry which manufacture different types of heat exchanger.
3. Self-Learning Topics:
   - Thermal conductivity in different medium.
   - Necessity of fins in different machines.
   - LMTD and NTU in Heat exchanger.
   - Concepts of Black body in thermal radiation.
   - Natural convection process.

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%	25%	20%	25%	34%	30%	30%
CO-2	15%	15%	15%	30%	33%	15%	15%
CO-3	25%	25%	20%	15%	-	10%	10%
CO-4	20%	20%	25%	30%	33%	20%	20%
CO-5	15%	15%	20%	-	-	25%	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 cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (Cl) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Heat Transfer	12	CO1	20	4	4	12
Unit-2.0 Fins	08	CO2	10	3	3	4
Unit-3.0 Convection	10	CO3	15	5	5	5
Unit-4.0 Heat Exchanger	10	CO4	15	3	5	7
Unit-5.0 Thermal Radiation	08	CO5	10	5	2	3
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):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Determine Thermal conductivity of a metal rod.	CO1	40	50	10
2.	Determine Thermal Conductivity of Liquid	CO1	40	50	10
3.	determine the co-efficient of thermal conductivity of insulating powder	CO1	40	50	10
4.	Determine of overall heat transfer coefficient of a given composite wall	CO1	40	50	10
5.	Find critical radius of insulating material.	CO1	40	50	10
6.	Determine Effectiveness on a Metallic fin	CO2	40	50	10
7.	Determine the heat transfer coefficient, fin efficiency and temperature distribution along the length of a pinfin in natural convection.	CO2	40	50	10
8.	Determine the heat transfer coefficient, efficiency and temperature distribution of a pin fin in forced convection	CO2	40	50	10
9.	Determine the heat transfer co-efficient in natural convection for vertical tube	CO3	40	50	10
10.	Determine the heat transfer co-efficient in forced convection for hot air flowing through horizontal tube	CO3	40	50	10
11.	Find coefficient of heat transfer from shell and tube heat exchanger.	CO4	40	50	10
12.	compare temperature distribution, heat transfer rate, overall heat transfer coefficient in parallel flow and counter flow.	CO4	40	50	10
13.	Determination of LMDT and Effectiveness in a Parallel Flow and Counter Flow Heat Exchangers.	CO4	40	50	10
14.	Determine the Stefen-Boltzman constant of radiation heat transfer.	CO5	40	50	10
15.	Measure emissivity of a test plate surface	CO5	40	50	10
16.	Determine critical heat flux values at different bulk temperatures and to observe the boiling phenomenon	CO5	40	50	10
17.	Determine the COP of vapour compression refrigeration system.	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.	Thermal conductivity apparatus, Metal bar, Electric heater, thermocouple	Length of metal bar 425mm, diameter of metal bar 25mm, No. of thermocouple mounted on bar 2	1
2.	Experimental setup for thermal conductivity of liquid	Aluminum Cylinder: approx. size 100 mm in diameter and 100 mm in length. thermocouples – to measure the oil temperature at intervals of 25 mm, Heaters, cooling arrangements, Thermocouples: K-type to measure temperature, control panel, heat controller or regulator, channel sector, digital voltmeter and ammeter	2
3.	Experimental setup for thermal conductivity of insulating material	Insulating sphere: consists of two concentric spheres. The inner and outer sphere have 250mm and 300 mm diameters respectively. The space between the spheres is filled with insulating powder. Oil heater, Digital voltmeter and ammeter to measure power input, Digital temperature indicator to measure temperature, Thermostat	3
4.	Composite wall apparatus	stop clock, measuring jar,Band heater, Thermocouples: k – type, Channel selector and digital temperature display, Heat control or regulator, Thermostat, Control panel	4
5.	Critical radius of insulating materials Apparatus.	The apparatus consists of one metal cylinder in which heater is fitted. The insulating material as lagging material is covered around the cylinder.	5
6.	Experimental setup to for testing effectiveness of Metallic fin	-	6
7.	Pin fin apparatus	A metallic fin of circular cross section of length 'L' is fitted in the rectangular duct. Thermocouples are provided on the surface of the fin. The duct is provided with a fan to contact the air flow with the help of regulator, multi-channel temperature indicator, ammeter and voltmeter.	7,8
8.	A metallic tube of diameter (d) 45 mm and length (L) 450mm with a electrical heater coil along the axis of the tube	• Seven thermocouples are fixed on the tube surface. • Control panel instrumentation consists of multichannel digital display • Temperature indicator to measure surface temperature T1 to T7 of the tube and ambient temperature T8. • Digital ammeter and voltmeter to measure power input to the heater. • Regulator to control the power input to the heater. • Front transparent acrylic enclosure for safety of the tube when not in use.	9

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
9.	Heat exchanger tube-the tube	Thermally insulated outside to prevent heat transfer losses to the atmosphere. • Heater, wattage :500 watts (approx.) • Regulator to control the power input to the heater • Volt and Ampere Meters to measure power input to the heater • ThermocouplesT1 and T7 to measure air temperature at the inlet and outlet of the duct. T2 - T6 to measure test specimen temperatures. • Channel selector • Digital temperature indicator • Blower: to blow air through the heat exchanger. • Orifice meter with manometer to air flow rate from the blower. • Control panel to house the whole instrumentation	10
10.	Heat transfer coefficient from shell and tube heat exchanger	Shell and tube heat exchanger.	11
11.	Parallel and counter flow heat exchanger	Concentric tubes- inner tube made of copper and outer tube is made of Stainless steel. Thermocouple	12,13
12.	Stefan Boltzman's Apparatus	Main switch, thermo couple, selector switch, Digital temperature indicator, test chamber with placement of thermocouples, water heating chamber with kettle element fitted and a test chamber, thermo meter and a stop watch.	14
13.	Emissivity apparatus	Two circular plate of identical dimension, Thermocouple, Diameter of plate is 150 mm	15
14.	critical heat flux setup	Glass container – diameter: 200 mm(approx.), height 100 mm(approx), Heater for initial heating (Nichrome wire) (R1) – 1 KW, Test heater (Nichrome wire, size: ϕ 12 mm) (R2), Length of the test heater (R2) – 100 mm	16
15.	Vapour compression test rig	Vapour compression test rig	17

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Heat and Mass Transfer: Fundamentals and Applications	Yunus A. Cengel Afshin J. Ghajar	McGraw Hill, 6th Ed., 2020 ISBN-13: 978-9390185283
2.	Heat and mass transfer	R.K. Rajput	S.Chand & Co. New Delhi , 7th ed.,2019 ISBN-13: 978-9352837212
3.	Essentials of Radiation Heat Transfer	C. Balaji	Springer Nature Switzerland AG,2022 ISBN-13: 978-3030626198
4.	Engineering Heat and Mass Transfer	Mahesh M. Rathore	Laxmi Publications; 4th ed. 2023 ISBN-13: 978-8131806135
5.	Advances in Heat and Mass Transfer in Micro/Nano Systems	Junfeng Zhang, Ruijin Wang	Mdpi AG, 2022 ISBN-13: 978-3036549682
6.	Heat and mass transfer	P. K.Nag	S Chand & Co. New Delhi 2011 ISBN:9788187433514

7.	Heat and mass transfer	Dr. D.S. Kumar	S.K. Kararia & sons, New Delhi,2011 ISBN: 978-81-265-4396
8.	Incropera's Principles of Heat and Mass Transfer	Frank P. Incropera David P. Dewitt Theodore L. Bergman Adrienne S. Lavine	Wiley India Edition, 2018 ISBN-13: 978-8126578245

(b) Online Educational Resources:

1) www.nptel.swayam
2) www.discoveryforengineers.com
3) https://youtu.be/rxTK_SvSmvs
4) https://youtu.be/Er1GLURinDg
5) https://youtu.be/2LaqQhxaXkk
6) https://youtu.be/Och17wpOYtc
7) https://youtu.be/wx16m7UP0D0
8) https://youtu.be/FwE_muP2pMY
9) https://youtu.be/nI1TvJjaYSk
10) https://youtu.be/aEd9Rj86UoU

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:

1. Heat and mass transfer data book
2. Lab Manuals
3. Conference

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A) Course Code **: 2425603B(T2425603B/P2425603B/S2425603B)**

B) Course Title **:** Power Plant Engineering

C) Pre- requisite Course(s) **:** Applied thermodynamics and Heat transfer

D) Rationale :

This course aims at providing an overview of different power plants and detailing the role of mechanical engineer in their construction, operation and maintenance for addressing the underlying concepts and their applications. This course on one side deals with conventional fossil fuel based power plants like Thermal and Gas power plants while on the other side it also try to develop understanding of Nuclear, Hydro and Solar Power plants, for which India has set high targets of employing renewable sources of energy for all possible applications to reduce the dependency on the fossil fuels.

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** Explain the operation and maintenance procedure of Coal thermal power plant components.
- **CO-2** Explain the operation and maintenance procedure of Gas power plant components.
- **CO-3** Identify the components and process involved in Nuclear power plant.
- **CO-4** Explain the operation and maintenance procedure of Micro/Pico Hydro power plant and Solar power plant components.
- **CO-5** Outline the safety, economic and environmental aspects related to different power plants.

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/ Developmentof 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	-	-	-		
CO-2	3	1	-	2	-	-	-		
CO-3	3	-	-	2	-	-	-		
CO-4	3	1	-	2	-	-	-		
CO-5	3	-	-	2	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				
2425603B	Power plant Engineering	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)	
2425603B	Power plant Engineering	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: T2425603B

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Identify the elements of coal thermal power plant. *TSO 1b.* Explain the working of the given components of Coal thermal power plant like boiler, condenser, cooling tower and economizer etc. *TSO 1c.* Compare the salient features of given type of high pressure boiler. *TSO 1d.* List the salient features of Fluidized bed combustion boilers *TSO 1e.* Explain the given control system of the steam power plant. *TSO 1f.* Outline the maintenance procedure of a modern Coal thermal power plant.	**Unit-1.0 Coal Thermal Power Plant** 1.1 General layout of modern coal thermal power plant and present scope of power generation in India. 1.2 Working of Rankine cycle. 1.3 Operation and Maintenance of Water treatment unit, Coal and ash handling unit and Natural Draught system. 1.4 High Pressure Boilers – Classification; Construction and principle of working of Lamont boiler, Benson boiler, Loeffler boiler, Velox boiler, Schmidt Hartman boiler, Ramsin boiler; 1.5 Fluidized bed combustion boilers (FBC): principle, need, types, various arrangement, control system and advantages over other boiler systems. 1.6 Indian Boiler Regulation Act 1.7 Maintenance procedure of major components of high pressure and FBC boilers. 1.8 Operation and Maintenance of Steam turbine, Steam nozzle, Steam condenser, Cooling tower, Economizer, Heat exchanger.	**CO1**
TSO 2a. Identify the given component(s) of gas turbine power plant. *TSO 2b.* Explain the working of the given component (s) of Gas power plant. *TSO 2c.* Explain the preventive maintenance of given major component of Gas power plant. *TSO 2d.* Explain the predictive maintenance of given major component of gas power plant.	**Unit-2.0 Gas Turbine Power Plant** 2.1 Classification, open and closed cycle gas turbine 2.2 Gas turbine fuel 2.3 Brayton cycle: Optimum pressure ratio for maximum efficiency, work ratio, airrate, specific fuel consumption rate 2.4 Effect of operating variable on thermal efficiency and work. 2.5 Operation and Maintenance of main components of Gas turbine power plant.	**CO2**
TSO 3a. Sketch labeled arrangement of given nuclear power plant *TSO 3b.* Explain the working of given reactor and other components of Nuclear power plant. *TSO 3c.* Compare the calorific value of the given type of nuclear fuel. *TSO 3d.* Interpret the regulation of nuclear power plant smoothly. *TSO 3e.* Explain the methods of disposal of different Nuclear wastes.	**Unit-3.0 Nuclear Power Plant** 3.1 Introduction to nuclear fission and fusion, 3.2 Types of nuclear fuels, nuclear power plant fuels in India 3.3 Components of nuclear reactor, pressurized water reactor and boiling water reactor 3.4 Nuclear waste and its disposal	**CO3**
TSO 4a. Identify the given component(s) of Hydro/Solar power plants.	**Unit-4.0 Hydroelectric power plant and Solar power plant**	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4b. Explain the working of the given component (s) of Hydro/Solar power plants. *TSO 4c.* Explain the maintenance procedure of given major component of Hydro/Solar power plants.	4.1 Introduction of Hydro power plant and Solar power plant, and its location in India. 4.2 Operation and Maintenance of Micro and Pico Hydro power plant components. 4.3 Operation and Maintenance of Solar power plant components.	
TSO 5a. Estimate the cost of electricity in given situation using simple numerical problem situation. *TSO 5b.* Calculate the performance parameter of the given power plant using simple numerical problem situation. *TSO 5c.* Outline the common safety practices in a typical power plant. *TSO 5d.* Estimate capital and operating costs in the given power plant. *TSO 5e.* Explain pollution control techniques and waste disposal options in the given power plant	**Unit-5.0 Safety, Maintenance cost, Economic and Environmental Aspects** 5.1 Safety (protective) Equipment, safety training 5.2 Types, schedule, and cost of maintenance for different power plant 5.3 Load distribution parameter, load curve, comparison of site selection criteria 5.4 Capital and operating cost of different power plant 5.5 Pollution control technique and waste disposal option of different power plant	**CO5**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425603B

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Identify the given component(s) used in Coal thermal power plant. *LSO 1.2.* Explain the operation of the given component(s) of Coal thermal power plant.	1.	Identify and demonstrate working of various components used in Coal thermal power plant using models, charts, visits, simulated and real videos.	CO1
LSO 2.1. Maintain the condenser, economizer etc. components of Coal thermal power plant.	2.	Demonstrate maintenance procedures of main components of Coal thermal power plant using models, charts, visits, simulated and real videos	CO1
LSO 3.1. Explain the construction details of the given nozzle. *LSO 3.2.* Maintain the given nozzle of the steam power plant.	3.	Study the different type of steam nozzles.	CO1
LSO 4.1. Identify the given component(s) of High Pressure Boiler. *LSO 4.2.* Explain the operation of the given High Pressure Boiler.	4.	Demonstrate working of any two types of High Pressure Boilers using models, charts, visits, simulated and real videos.	CO1
LSO 5.1. Identify component(s) of the given Fluidized Bed Combustion Boiler. *LSO 5.2.* Explain the operation of the given Fluidized Bed Combustion Boiler.	5.	Demonstrate Fluidized Bed Combustion Boilers using models, charts, visits, simulated and real videos.	CO1
LSO 6.1. Identify component(s) of the given Electro Static Precipitator. *LSO 6.2.* Explain the operation of the given Electro Static Precipitator.	6.	Demonstrate the working of Electro Static Precipitators using model, charts, visits, simulated and real videos.	CO1
LSO 7.1. Identify the component(s) of the given Temperature and Feed Water Control systems.	7.	Demonstrate the working of Temperature and Feed Water Control systems using model, charts, visits, simulated and real videos.	CO1

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 7.2. Explain the operation of the given Temperature and Feed Water Control systems.			
LSO 8.1. Identify the given Temperature and Coal and Ash handling system. *LSO 8.2.* Explain the operation of the given Coal and Ash handling system.	8.	Identify and demonstrate working of Coal and Ash handling system.	CO1
LSO 9.1. Prepare the model diagram of natural draught system of the steam power plant. *LSO 9.2.* Explain the operation of the given Natural Draught system.	9.	Study of Natural Draught system.	CO1, CO2
LSO 10.1. Prepare the model, chart of the given water treatment plant. *LSO 10.2.* Explain the operation of the given Water treatment plant.	10.	Develop the working model of Water treatment plant.	CO1, CO2
LSO 11.1. Identify the given component(s) of cooling tower. *LSO 11.2.* Explain the operation of the given Cooling tower.	11.	Develop the working model of Cooling tower.	CO1, CO2
LSO 12.1. Identify the given component(s) used in Gas thermal power plant. *LSO 12.2.* Explain the operation of the given component(s) of Gas thermal power plant.	12.	Identify and demonstrate working of various components used in Gas thermal power plant using models, charts, visits, simulated and real videos	CO2
LSO 13.1. Maintain the given component(s) of Gas thermal power plant.	13.	Demonstrate maintenance procedures of main components of Gas thermal power plant using models, charts, visits, simulated and real videos	CO2
LSO 14.1. Maintain Fuel nozzles, Liners, Spark plugs, Flex hoses, Check valves etc. component of Gas turbine power plant	14.	Maintain Fuel nozzles, Liners, Spark plugs, Flex hoses, Check valves etc. component of Gas turbine power plant	CO2
LSO 15.1. Identify the given component(s) used in Nuclear power plant. *LSO 15.2.* Explain the operation of the given component(s) of Nuclear power plant.	15.	Identify and demonstrate working various components used in Nuclear power plant using models, charts, visits, simulated and real videos.	CO3
LSO 16.1. Identify the given component(s) used in Micro/Pico Hydro power plant. *LSO 16.2.* Explain the operation of the given components of Micro/Pico Hydro power plant.	16.	Identify and demonstrate working of various components used in Micro/Pico Hydro power plant using models, charts, visits, simulated and real videos.	CO4
LSO 17.1. Maintain the given component of Micro/Pico Hydro power plant.	17.	Demonstrate maintenance procedures of main components of Micro/Pico Hydro power plant using models, charts, visits, simulated and real videos	CO4
LSO 18.1. Identify the given component(s) used in Solar power plant. *LSO 18.2.* Explain the operation of the given component(s) of Solar power plant.	18.	Identify and demonstrate working of various components used in Solar power plant using models, charts, visits, simulated and real videos.	CO4
LSO 19.1. Maintain the given component(s) of Solar power plant.	19.	Demonstrate maintenance procedures of main components of Solar power plant using	CO4

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
		models, charts, visits, simulated and real videos	
LSO 20.1. Identify the various energy consuming elements in the given setup. *LSO 20.2.* Estimate the cost of electricity consumption.	20.	Calculate cost of electricity consumption of any one Laboratory.	CO5

L) Suggested Term Work and Self Learning: S2425603B 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:

- Prepare/Download the specifications of followings:

  i. Coal Thermal Power plant equipment.
  ii. Gas turbine power plant equipment and elements.
  iii. Nuclear power plant equipment and elements.
  iv. Hydro power plant equipment and elements.
  v. Solar power plant equipment and elements.

- Prepare/Download control system components in the followings:

  i. Coal Thermal Power plant
  ii. Gas turbine power plant equipment
  iii. Nuclear power plant equipment
  iv. Hydro power plant equipment
  v. Solar power plant equipment

- Prepare/Download the safety practices and pollution control approaches in the followings:

  i. Coal Thermal Power plant
  ii. Gas turbine power plant equipment
  iii. Nuclear power plant equipment
  iv. Hydro power plant equipment
  v. Solar power plant equipment

- Download the maintenance procedure of the main equipment of the followings:

  i. Coal Thermal Power plant
  ii. Gas turbine power plant equipment
  iii. Nuclear power plant equipment
  iv. Hydro power plant equipment
  v. Solar power plant equipment

- Collect information/videos of control systems of power plant.
- Collect information/videos about cogeneration plant.
- Perform comparative study of various parameters of performance evaluation of a power plant.
- Measure operating parameters of Boiler using appropriate instruments.
- Collect information regarding preventive, predictive and breakdown maintenance of various power plants.
- Develop maintenance procedure for preventive and predictive maintenance of a typical Hydro Power Plant and its components.

- Develop maintenance procedure for preventive and predictive maintenance of typical FBC boilers and its components.
- Develop maintenance procedure for preventive and predictive maintenance of a typical High-pressure boiler and its components
- Develop maintenance procedure for preventive and predictive maintenance of a typical Steam Power Plant and its components.
- Develop maintenance procedure for preventive and predictive maintenance of a typical Gas Power Plant and its components.
- Develop maintenance procedure for preventive and predictive maintenance of a typical Micro/Pico Hydro Power Plant and its components.
- Develop maintenance procedure for preventive and predictive maintenance of a typical Solar Power Plant and its components.

c. Other Activities:

1. Seminar Topics:
    - Steam generator.
    - Scope of solar energy.
    - Present scenario of nuclear power plant.
    - Safety (protective) Equipment in various power plants.
    - Capital and operating cost of different power plants.
    - Pollution control technique and waste disposal option of different power plants.

2. Visits:
    - Visit to any Power plant and prepare a report consisting of
        i Various components
        ii Operation of power plant
        iii Control system
        iv Safety equipment and practices
        v Maintenance of components of power plant observed.
        vi Various advanced systems
        vii Various standards

3. Self-Learning Topics:
    - Solar Panels
    - Hydel energy
    - Pico Hydro Power Plants
    - Safety practices in various power plants
    - Fluidized Bed Combustion Boilers
    - Pollution control technique
    - Waste from different power plants
    - Waste disposal approached used in different powr plants

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%	25%	25%	20%	20%	40%	20%
CO-2	20%	20%	20%	20%	20%	15%	20%
CO-3	15%	15%	15%	20%	20%	15%	20%
CO-4	25%	25%	25%	20%	20%	15%	20%
CO-5	15%	15%	15%	20%	20%	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 (Cl) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Coal Thermal Power Plant	12	CO1	16	5	6	5
Unit-2.0 Gas Turbine Power Plant	08	CO2	16	4	6	6
Unit-3.0 Nuclear Power Plant	08	CO3	12	3	4	5
Unit-4.0 Hydroelectric Power Plant and Solar Power Plant	10	CO4	16	4	6	6
Unit-5.0 Safety, Maintenance, Economic and Environmental Aspects	10	CO1, CO2, CO3, CO4, CO5	10	4	3	3
Total	**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 and demonstrate working of various components used in Coal thermal power plant using models, charts, visits, simulated and real videos.	CO1	30	60	10
2.	Demonstrate maintenance procedures of main components of Coal thermal power plant using models, charts, visits, simulated and real videos	CO1	30	60	10
3.	Study the different type of steam nozzles.	CO1	30	60	10
4.	Demonstrate working of any two types of High Pressure Boilers using models, charts, visits, simulated and real videos.	CO1	30	60	10
5.	Demonstrate Fluidized Bed Combustion Boilers using models, charts, visits, simulated and real videos.	CO1	30	60	10
6.	Demonstrate the working of Electro Static Precipitators using model, charts, visits, simulated and real videos.	CO1	30	60	10
7.	Demonstrate the working of Temperature and Feed Water Control systems using model, charts, visits, simulated and real videos.	CO1	30	60	10
8.	Identify and demonstrate working of Coal and Ash handling system.	CO1	30	60	10
9.	Study of Natural Draught system.	CO1, CO2	30	60	10
10.	Develop the working model of Water treatment plant.	CO1, CO2	30	60	10
11.	Develop the working model of Cooling tower.	CO1, CO2	30	60	10
12.	Identify and demonstrate working of various components used in Gas thermal power plant using models, charts, visits, simulated and real videos	CO2	30	60	10
13.	Demonstrate maintenance procedures of main components of Gas thermal power plant using models, charts, visits, simulated and real videos	CO2	30	60	10
14.	Maintain Fuel nozzles, Liners, Spark plugs, Flex hoses, Check valves etc. component of Gas turbine power plant	CO2	30	60	10
15.	Identify and demonstrate working various components used in Nuclear power plant using models, charts, visits, simulated and real videos.	CO3	30	60	10
16.	Identify and demonstrate working of various components used in Micro/Pico Hydro power plant using models, charts, visits, simulated and real videos.	CO4	30	60	10
17.	Demonstrate maintenance procedures of main components of Micro/Pico Hydro power plant using models, charts, visits, simulated and real videos	CO4	30	60	10
18.	Identify and demonstrate working of various components used in Solar power plant using models, charts, visits, simulated and real videos.	CO4	30	60	10
19.	Demonstrate maintenance procedures of main components of Solar power plant using models, charts, visits, simulated and real videos	CO4	30	60	10
20.	Calculate cost of electricity consumption of any one Laboratory.	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.	Model of Coal thermal power plant.	Working model, Charts, downloaded Videos including all major components	01 to 11
2.	Steam Power plant	Working model of Steam Power plant- oil fired Boiler (min Capacity- 0.5KW), Reaction steam Turbine, Surface Condenser, generator, power distribution system to power bank.	
3.	Condenser and Economizer	Condenser, economizer etc. components of Steam power plant.	
4.	Loffler Boiler	Working model of Loffler Boiler	
5.	Benson Boiler	Working model of Benson Boiler	
6.	Electro static Precipitator	Working model of Electro static Precipitator	
7.	FBC Boiler	Model of FBC Boiler	
8.	Feed water control system	Working model of Feed water control system	
9.	Temperature sensor and temperature sensing system	Temperature sensor and temperature sensing system	
10.	Model of gas power plant including major components	Working model including all major components	12, 13, 14
11.	Model of Nuclear power plant	Working model including all major components	15
12.	Model of Hydel power plant	Working model including all major components	16, 17
13.	Model of Solar power plant	Working model including all major components	18, 19
14.	Thermodynamic Simulation Software	AxCYCLE Software: Thermodynamic Simulation Software for heat balance calculations of heat production and energy conversion cycles.	All

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
15.	Safety equipment used in power plant	Various safety equipment used in power plant	All

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Power plant engineering	P.K. Nag	McGraw-Hill Education (4th edition) ISBN13, 978-9339204044
2.	Power plant technology	M.M. EI -Wakil	McGraw-Hill Education (1st edition) ISBN-13 ,978-0070702448
3.	Power plant engineering	P C SHARMA	S k. kataria sons ISBN-13 ,978-9350143841
4.	Thermal engineering	R K RAJPUT	Laxmi Publication (11th edition) ISBN-13,978-8131808047

(b) Online Educational Resources:

1. https://nptel.ac.in/
2. https://npti.in/default.aspx
3. https://www.youtube.com/watch7v-hooifWJljY
4. https://www.youtube.com/watch7vMfCmYbupS4u-k
5. https://www.youtube.com/watch?v=rEJKiUYjWlE
6. https://www.youtube.com/watch?v=-hooifWJ1jY
7. https://www.youtube.com/watch?v=Uhjhufhg3Xk
8. https://www.youtube.com/watch?v=_UwexvaCMWA
9. https://www.youtube.com/watch?v=_AdA5d_8Hm
10. https://www.youtube.com/watch?v=ChvI2v85fsU
11. https://www.youtube.com/watch?v=IdPTuwKEfmA
12. https://www.youtube.com/watch?v=XjbczcFNrNU
13. https://www.youtube.com/watch?v=0rsPFdkwR0
14. https://www.youtube.com/watch?v=gDVukHOxURc
15. https://www.youtube.com/watch?v=02p5AKP6W0Q
16. https://www.youtube.com/watch?v=FXBqvLWxbr0
17. https://www.youtube.com/watch?v=dCPfHifMbOk
18. https://www.youtube.com/watch?v=b6-n0pFu5d4
19. https://www.youtube.com/watch?v=iUXHzYLgrB0
20. https://www.youtube.com/watch?v=ZssGiY6rfYE
21. https://www.youtube.com/watch?v=F01AFJe2j2A
22. https://www.youtube.com/watch?v=c6wDRQMD-YE
23. https://www.youtube.com/watch?v=ks-G4FYVtg
24. https://www.youtube.com/watch?v=H6EClYcfXKw
25. https://www.youtube.com/watch?v=KmYbupS4u-k
26. https://www.youtube.com/watch?v=rEJKiUYjW1E
27. https://arupatan.in/info/959/coal_mill_operation_power_plant/
28. https://www.youtube.com/watch?v=KmYbupS4u-k

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:

1. conference
2. Lab Manuals

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A) Course Code : **2425603C(T2425603C/P2425603C/S2425603C)**

B) Course Title : Press Tool, Jigs and Fixtures.

C) Pre- requisite Course(s) : Manufacturing Engineering.

D) Rationale :

Press Tool, Jigs and Fixtures is the industrial production tools. Press tools are commonly used in hydraulic, pneumatic and mechanical presses to produce components at high volumes. Mass production methods demand a fast and easy method of positioning work for accurate operations on it. Jigs and fixtures are production tools used to accurately manufacture duplicate and interchangeable parts. This course on Press Tool, Jigs and Fixtures tries to develop understanding of the process parameters and handling of above tools among the students. It also covers the detailed constructional and design of press tools, jigs and fixtures. The knowledge gained through this course will help the students to develop a habit of industry oriented.

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 relevant press tools and press tools operations,

CO-2 Use relevant die and punch for forging simple components.

CO-3 Use relevant jig and fixtures and clamping device for components and machining operations.

CO-4 Use relevant jig boring machine for the given situations.

CO-5 Design press tools, jigs and fixtures suitable to different machining operations.

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/ Developmentof 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	1	2	1	-	-		
CO-3	3	2	1	2	1	-	1		
CO-4	3	2	1	2	1	-	1		
CO-5	3	2	3	3	1	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				
2425603C	Press Tool, Jigs and Fixtures.	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)	
2425603C	Press Tool, Jigs and Fixtures.	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: T2425603C

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain the use of press tools and accessories. *TSO 1b.* Select different types of press tool for the given situation with justification. *TSO 1c.* Select suitable press tool in different operations for the given situation. *TSO 1d.* Select relevant method for mounting punches and dies.	**Unit-1.0 Press Tools** 1.1 Introduction to press tools. 1.2 Recent development in press tools. 1.3 press tools and accessories 1.4 Types of presses and Specifications 1.5 Cutting tools, bending tools, drawing tools, punching tools, blanking tools, notching tools, lancing tools, Embossing and Coining tools. 1.6 Effect of clearances and Stages of cutting operation. 1.7 Methods of mounting punches and dies.	**CO1**
TSO 2a. Select suitable press working operation for given situation with justification. *TSO 2b.* Explain clearances and its effect in punch and die operations. *TSO 2c.* Calculate press tonnage for the given press tool component. *TSO 2d.* Calculate blank size for the given simple part. *TSO 2e.* Select the type of die for the given part with justification. *TSO 2f.* Estimate the cost for developing a simple component by each operation *TSO 2g.* Compare post processing operations on developed component	**Unit-2.0 Press Working** 2.1 Press working operations - Cutting, bending drawing, punching, blanking, notching, lancing, Embossing and Coining. 2.2 Punch and die clearances for blanking and piercing, effect of clearance. 2.3 blanking and piercing tools, load variation during blanking-Calculation of press tonnage for blanking and piercing. 2.4 Bending allowances, bending methods. Bending pressure-calculation of blank size and press tonnage for drawing metal flow during drawing operations. 2.5 Die set components- punch and die shoe, guide pin, bolster plate, stripper, stock guide, feed stock, pilot. 2.6 Types of dies, simple, compound, combination and progressive dies.	**CO2**
TSO 3a. Differentiate between given jig and fixture. *TSO 3b.* Select the suitable jigs for the given component with justification. *TSO 3c.* Select the suitable fixtures for the given component with justification. *TSO 3d.* Explain the principles of location and clamping with reference to the given work piece. *TSO 3e.* Select different types of locators for the given situation. *TSO 3f.* Select different types of clamping devices for the given situation.	**Unit-3.0 Jigs and fixtures**: 3.1 Necessity for jigs and fixtures. 3.2 Definitions and concept of Jig and fixture. 3.3 Advantages of jigs and fixtures. 3.4 Elements of jigs and fixtures 3.5 Types of jigs: leaf jig, box & handle jig template jig, plate jig, indexing jig universal jig, vice jig- constructional details, working and application of above jigs. 3.6 Types of fixtures: vice fixtures, milling fixtures, boring fixtures, grinding fixtures- constructional details, working and application of above fixtures. 3.7 Basic principles of location: locating methods and devices,	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	3.8 Types of locators – pins and studs, V block, cup and cone location points, adjustable locating points, special adjustable stops, location from finished holes in the work, Diamond pin locator, Cam operated 'V' locator, Quick action 'V ' locator, Six point location of a three legged object ,Location of a cylinder on a v-block 3.9 Basic principles of the clamping: types of clamps-lever clamp, hinged clamp, two-way clamp, swinging clamp, wedge clamp, eccentric clamping arrangement, quick action clamp, Cam operated clamp, strap clamps quarter turn screw, Toggle clamp, Pneumatic and hydraulic clamps, Washers - 'C' washer, spherical and flat washer	
TSO 4a. Explain jig boring. *TSO 4b.* Select the type of jig boring for the given situation. *TSO 4c.* Explain construction and working of jig boring. *TSO 4d.* Explain system of location of holes.	**Unit-4.0 Jig Boring:** 4.1 Introduction to jig boring. 4.2 Jig boring on vertical milling machine 4.3 Types jig boring machines: Open front machine, Cross rail type machine - constructional details & their working. 4.4 System of location of holes.	**CO3, CO4**
TSO 5a. Explain the design procedure for the given Die and punch. *TSO 5b.* Explain the design procedure for given jig. *TSO 5c.* Explain the design procedure for given fixture	**Unit-5.0 Design of Press tool, jigs and fixtures.** 5.1 Design considerations and procedure for Die and punch. 5.2 Design of simple, compound and progressive dies. 5.3 Design considerations and procedure for following jigs- Template jig, plate jig, universal jig, leaf jig. 5.4 Design considerations and procedure for following fixtures-turning fixture, milling fixture, grinding fixture, boring fixture, welding fixture.	**CO5**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425603C

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Use press tools. *LSO 1.2.* Prepare a list of parameters for comparison among qualities.	1.	Analyze the effect of different press tools process parameters on the different materials such as material required, power required, time, surface finish, etc.	CO1
LSO 1.3. Use the methods of mounting of die and punch. *LSO 1.4.* Select components for mounting die and punch.	2.	Remount different types of die and punch set already available in your workshop.	CO1

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.5. Dismantle and assemble different press tools- Blanking die, piercing die and progressive die, compound die, V bending die, and drawing die	3.	Dismantle the components of the given press tools as per assembly drawing.	CO1
	4.	Assemble the components of the given press tools as per assembly drawing.	CO1
LSO 2.1. Perform suitable press tool operation relevant to job development.	5.	Develop following job using suitable press tool operation. • washer • ring.	CO2
LSO 2.2. Surf web for downloading readymade list of products develop by die punch operation. *LSO 2.3.* Perform suitable die punch operation.	6.	Download three models of job available on web and then develop them by using suitable die and punch operation.	CO2
LSO 2.4. Choose the requirements of tools related to bending operation. *LSO 2.5.* Perform bending operation on the selected material w.r.t different parameters.	7.	Perform bending operation on two different material sheets and compare power requirement, time, surface finish etc.	CO2
LSO 3.1. Test the given fixtures	8.	Carry out load test on the given jigs & Fixtures.	CO3
	9.	Conduct the trial tests of fixture to ensure conformance to the standards	CO3
LSO 3.2. Measure the dimensions as per assembly drawing	10.	Measure the dimension of jigs and Fixture using measuring instrument like CMM or laser tracker	CO3
LSO 3.3. Analyze each and every jig and fixture in the workshop in context of function location and clamping facility	11.	Identify different jigs and fixtures available in workshop.	CO3
LSO 3.4. Use of available 3D scanner. *LSO 3.5.* Develop 3D digital model using scanning approach. *LSO 3.6.* Develop job using embossing process.	12.	Perform embossing operation on a suitable size of material available in your workshop.	CO3
LSO 3.7. Prepare list of press tool operation available workshop. *LSO 3.8.* Compare post processing operations on developed component	13.	Prepare a list of different press tools operations available in your workshop and estimate the cost for developing a simple component by each operation.	CO3
LSO 3.9. Identify the components of hydraulic press, surface and cylindrical grinder etc. available in work shop	14.	Identify and list different components of the given types of press and machines.	CO3
LSO 4.1. Identify and list different components of jig boring machines available in the work shop	15.	Identify and list different components of jig boring machines.	CO4
LSO 4.2. Identify tools & equipment's for the given job.	16.	Identify tools & equipment's as per desired specifications for drilling and tapping.	CO4
LSO 4.3. Set the job and cutting tool and analyze its effect on metal cutting.	17.	Set the job in four jaws chuck, truing.	CO4
	18.	Set the cutting tool on tool post, at centre height.	CO4
LSO 4.4. Select suitable jigs and fixtures for welding parameters.	19.	Compare the surface finishing of a job during following operations one using jigs and fixtures and other any clamping device Welding , Milling, Grinding, boring.	CO4

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 4.5. Measure the cutting force of the given machine tool	20.	Measure cutting force of lathe	CO4
	21.	Measure cutting force of milling	CO4
LSO 5.1. Design and develop (model) different types of Jigs and fixtures in the workshop	22.	Design and develop simple plate type drill jig as per the given design	CO5
	23.	Design and develop milling fixtures as per the given design	CO5
	24.	Design and develop model of Blanking (simple) die set components as per the given design	CO5
	25.	Design and develop of Piercing (simple) die set components as per the given design	CO5
	26.	Design and develop model of Progressive (simple) die set components as per the given design	CO5
	27.	Design and develop model of compound dies components as per the given design	CO5
	28.	Design and develop model of simple 'V' bending die components as per the given design	CO5
	29.	Develop model of Drawing die set components as per the given design	
LSO 5.2. Choose suitable material for punch die operation *LSO 5.3.* Choose suitable size to create a product. *LSO 5.4.* Produce washers in flexible sizes.	30.	Design a set of punch and die for the development of different sizes of washers.	CO5
LSO 5.5. Design and develop different types of Jigs as per the given specifications	31.	Design and develop a channel jig for the given mild steel components to drill the hole of 18mm.running fit	CO5
	32.	Design and develop leaf jig for drilling two holes of 10 mm diameter on the given work piece.	CO5
	33.	Design and develop indexing jig for the flange coupling to drill 4 holes of diameter 10mm on its pitch circle diameter	CO5

L) Suggested Term Work and Self Learning: S2425603C 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.

- Prepare a chart on safety precautions to be followed during working on press machine
- Describe fly and power press on the basis of -its parts, function of each part, operating procedure of presses, mounting procedure of die set on press machine, alignment technique between punch and die assembly.

b. Micro Projects:

- Measure press capacity of any press available in workshop/nearby industry.
- Download 5 videos on Press tools operations of different components, watch them and write a report to detail out the steps & material used.
- Make two job components using different material by Die & Punch and compare their strength, surface roughness, weight, cost.
- Collect specifications of different jigs and fixtures available in nearby market.
- Sketch different jigs /fixtures/clamps/locating devices available in your institute workshop.
- Design simple jigs /fixtures/clamps/locating devices for simple jobs.

c. Other Activities:

1. Seminar Topics:
   - Commercially available press tools, jigs and fixtures.
   - Recent development in press tool working industry.
   - Quality of product by using different jigs and fixtures in different machining operations.
2. Visits: Visit nearby tool room/industry with press tools operation facilities. Prepare report of visit with special comments of press tools operations used, material used, single component/batch production/mass production and cost of component.
3. Self-Learning Topics:
   - Undertake a market survey of local dealers for different jigs and fixtures available and prepare a report.
   - Visit to any industry and prepare a report consisting of types of press tools, dies operations, jigs and fixtures.
   - Prepare a list of books available in your library on press tools, jigs and fixtures.

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%	**20%**	20%
CO-2	20%	20%	20%	20%	20%	**20%**	20%
CO-3	20%	20%	20%	20%	20%	**20%**	20%
CO-4	20%	20%	20%	20%	20%	**20%**	20%
CO-5	25%	25%	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: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (Cl) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Press tools	8	CO1	10	4	3	3
Unit-2.0 Press Working	10	CO2	15	4	5	6
Unit-3.0 Jigs and fixtures	10	CO3	15	4	5	6
Unit-4.0 Jig Boring	9	CO4	10	4	3	3
Unit-5.0 Design of Press tool, jigs and fixtures	11	CO5	20	4	6	10
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.	Analyze the effect of different press tools process parameters on the different materials such as material required, power required, time, surface finish, etc.	CO1	50	40	10
2.	Remount different types of die and punch set already available in your workshop.	CO1	50	40	10
3.	Dismantle the components of the given press tools as per assembly drawing.	CO1	50	40	10
4.	Assemble the components of the given press tools as per assembly drawing.	CO1	50	40	10
5.	Develop following job using suitable press tool operation. • Washer • ring.	CO2	50	40	10
6.	Download three models of job available on web and then develop them by using suitable die and punch operation.	CO2	50	40	10
7.	Perform bending operation on two different material sheets and compare power requirement, time, surface finish etc.	CO2	50	40	10
8.	Carry out load test on the given jigs & Fixtures.	CO3	50	40	10

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
9.	Conduct the trial tests of fixture to ensure conformance to the standards	CO3	50	40	10
10.	Measure the dimension of jigs and Fixture using measuring instrument like CMM or laser tracker	CO3	50	40	10
11.	Identify different jigs and fixtures available in workshop.	CO3	50	40	10
12.	Perform embossing operation on a suitable size of material available in your workshop.	CO3	50	40	10
13.	Prepare a list of different press tools operations available in your workshop and estimate the cost for developing a simple component by each operation.	CO3	50	40	10
14.	Identify and list different components of the given types of press and machines.	CO4	50	40	10
15.	Identify and list different components of jig boring machines.	CO4	50	40	10
16.	Identify tools & equipment's as per desired specifications for drilling and tapping.	CO4	50	40	10
17.	Set the job in four jaws chuck, truing.	CO4	50	40	10
18.	Set the cutting tool on tool post, at centre height.	CO4	50	40	10
19.	Compare the surface finishing of a job during following operations one using jigs and fixtures and other any clamping device. Welding , Milling, Grinding, boring.	CO4	50	40	10
20.	Measure cutting force of lathe	CO4	50	40	10
21.	Measure cutting force of milling	CO4	50	40	10
22.	Design and develop simple plate type drill jig as per the given design	CO5	50	40	10
23.	Design and develop milling fixtures as per the given design	CO5	50	40	10
24.	Design and develop model of Blanking (simple) die set components as per the given design	CO5	50	40	10
25.	Design and develop of Piercing (simple) die set components as per the given design	CO5	50	40	10
26.	Design and develop model of Progressive (simple) die set components as per the given design	CO5	50	40	10
27.	Design and develop model of compound dies components as per the given design	CO5	50	40	10
28.	Design and develop model of simple 'V' bending die components as per the given design	CO5	50	40	10
29.	Develop model of Drawing die set components as per the given design	CO5	50	40	10
30.	Design a set of punch and die for the development of different sizes of washers.	CO5	50	40	10

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
31.	Design and develop a channel jig for the given mild steel components to drill the hole of 18mm.running fit	CO5	50	40	10
32.	Design and develop leaf jig for drilling two holes of 10 mm diameter on the given work piece.	CO5	50	40	10
33.	Design and develop indexing jig for the flange coupling to drill 4 holes of diameter 10mm on its pitch circle diameter	CO5	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 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.	Different press tools	Press tools for cutting, bending, lancing drawing notching etc.,	1 to 7
2.	Die and punches	Embossing, coining etc.	2, to 7
3.	Different types of jigs.	Template jig, plate jig, channel jig, leaf jig, ring jig etc.	8-13
4.	Different types of fixtures	Turning fixture, milling fixtures boring fixture, welding fixture, etc.	7,9
5.	Different clamping & holding devices	Vices of different specifications and different clamping devices	All
6.	Measuring tools and machines	Scale, calipers, micrometers, welding machine, milling machine, lathe machine, boring machine etc.	All
7.	Post processing equipment and tools	Deburring tools (tool handle & deburring blades), Electronic Digital Caliper, Cleaning Needles, files of different specifications, long nose pliers, Flash cutters, Wire brush, Needle file, Wire stripper etc.	All

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Press tool design and construction	P.H. Joshi	S. Chand Publisher, Delhi, 4 July 2017 ISBN: 978-8121929387
2.	Elements of workshop technology vol-ii	S.K. Hajra Choudhary Nirjhar Roy	Media Promotors & Publishers Pvt.Ltd. 1 Jan. 2010 ISBN: 978-8185099156
3.	Jigs And Fixtures	P.H. Joshi	Mc Graw Hill Education.Noida,3rd edition, 1 July 2017 ISBN: 978-0070680739
4.	Design Of Jigs, Fixtures and Press Tools	V.Balachandran	Notion Press; 1st Edition, 22 April 2015, ISBN: 978-9352060306
5.	Jigs And Fixtures: Non-Standard Clamping Devices.	Hiram E . Grant	Mc Graw Hill Education, Noida 16 July 1971, ISBN: 978-0070993297.

(b) Online Educational Resources:

1. https://youtu.be/uOYIoX3srbw
2. https://youtu.be/gTm9VCmbeDs
3. https://youtu.be/rKSqZiMjggk
4. https://youtu.be/ZFHxxp19eyQ
5. https://youtu.be/dX_vyQb3w1M
6. https://youtu.be/_Np461igdGk
7. https://youtu.be/LKEG3p3yx1g
8. https://youtu.be/74DggoOx34c
9. https://youtu.be/HVbbSl5WreA
10. https://youtu.be/NVTEKYFMHLU
11. https://youtu.be/C_vqMerH-oQ
12. https://youtu.be/jEkVDmg7Eww
13. https://youtu.be/B4ssW2bsp3w
14. https://youtu.be/Utp-pghGCkg
15. https://youtu.be/L1WpszXOFaM
16. https://youtu.be/6sz8f3zUilQ
17. https://amzn.eu/d/01DIJUo
18. https://innovatorproject.in/analysis-composite/press-tool-based-analysis-projects/

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:

1. Punches, Dies And Tools For Manufacturing In Presses By Joseph V.Woodworth; Illustrated In Forgotten Books 10 Nov 2022 , Isbn:9780282082154.
2. Die design fundamentals ,3rd edition: Vukota boljanovic and J.R. Paquin
3. Press tools Users' Guide
4. Jigs and fixtures Handbook
5. Lab Manuals

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A) Course Code **: 2425603D(T2425603D/P2425603D/S2425603D)**

B) Course Title **:** Hydraulic & Pneumatic Controls

C) Pre- requisite Course(s) **:**

D) Rationale **:**

Hydraulic and pneumatic operated machines and equipment are widely used in various mechanical and process industries due to its versatility and adaptability to automation. Engineering workforce in such industries are required to maintain hydraulic and pneumatic systems in different segments of industries. This competency needs the knowledge and basic skills related with construction and working of different components of such systems. This course will give the students, the basic skills and knowledge to use and maintain different types of hydraulic systems and pneumatic 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** Analyze the various parameters of pneumatic and hydraulic systems
- **CO-2** Select pump and actuators for the given system.
- **CO-3** Select relevant control valves and sensors for the given system
- **CO-4** Select relevant compressor, components and accessories for the given system
- **CO-5** Design hydraulic and pneumatic circuits for the given application.
- **CO-6** Design electro - pneumatic and electro- hydraulic circuits for the given application.

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	-	1		
CO-2	3	2	1	2	2	-	1		
CO-3	3	2	1	2	2	-	1		
CO-4	3	2	1	2	2	-	1		
CO-5	3	2	2	2	2	-	1		
CO-6	3	2	2	2	2	-	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				
2425603D	Hydraulic and Pneumatic Controls	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)	
2425603D	Hydraulic and Pneumatic Controls	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: T2425603D

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Describe various laws governing fluid flow. *TSO 1b.* Differentiate between aerostatic, hydrostatic, and hydrodynamic support *TSO 1c.* Describe the cause of pressure drop and its effect *TSO 1d.* Explain the properties of the given hydraulic oil. *TSO 1e.* Select the hydraulic fluid for the given application based on the given criteria *TSO 1f.* Describe the factors affecting hydraulic oil contamination *TSO 1g.* Draw ISO symbols for the given hydraulic and pneumatic components *TSO 1h.* Explain the safety procedure for the given industrial hydraulics and pneumatics systems. *TSO 1i.* Identify the Hazards in using given hydraulic and pneumatic systems *TSO 1j.* Describe the guiding rules for designing the given hydraulic and pneumatic system. *TSO 1k.* Calculate the parameters of pneumatic and hydraulic systems	**Unit-1.0 Introduction to Hydraulic and Pneumatic Systems** 1.1 Fluid power- history, concept and Definition, Fluid transport systems, Fluid power systems, merits and limitations 1.2 Classification of Fluid Power Systems- Based on the control system and its type 1.3 Concept of Hydrostatic and hydrodynamic 1.4 Laws governing fluid flow- Pascal's law, Continuity equation, Bernoulli's theorem 1.5 Flow through pipes-types, pressure drop in pipes. 1.6 Hydraulic fluid - types ISO and SAE grades of oil and designations, properties, oil contamination and their advantages and limitations. 1.7 General layout and ISO Symbols of hydraulic and pneumatic systems 1.8 Hazard and safety in industrial hydraulics and pneumatics.	**CO1**
TSO 2a. Compare given two types of pumps on the basis of the given criteria. *TSO 2b.* Select relevant pump for the given application with justification. *TSO 2c.* Compare the given actuators with respect to identified criteria. *TSO 2d.* Assess the different factors that impact on actuator choice for a given application *TSO 2e.* Describe with sketches the construction and working of the given actuators. *TSO 2f.* Select the relevant actuators for the given application with justification. *TSO 2g.* Identify the faults in the given pump and suggest the remedies *TSO 2h.* Explain routine maintenance procedure of the pump and actuator *TSO 2i.* Troubleshoot the given hydraulic system *TSO 2j.* Calculate pump efficiency and Brake Horse Power (BHP) of the pump	**Unit-2.0 Pumps and Actuators** 2.1 Classification of pumps. 2.2 Construction and working of gear, vane, screw, lobe and piston pumps (axial and radial) 2.3 Performance characteristics, specifications and selection criteria of pumps. 2.4 Classification of hydraulic and pneumatic actuators. 2.5 Construction and working of linear actuators – single acting and double acting cylinders, Cylinder –cushioning, stop tube 2.6 Construction and working of rotary actuators (rotary Motors)-. Gear motors, Vane motors, Axial - in-line - swash plate piston motors 2.7 Specifications and selection criteria of actuators 2.8 Maintenance procedure for pumps and actuators	**CO2**
TSO.3a Classify the given types of control valves with respect to identified criteria.	**Unit-3.0 Control Valves and Sensors**	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.3b Describe with sketches the construction and working of the given valves. *TSO.3c* Describe the actuation method of the given valves for the given application. *TSO.3d* Select relevant control valve for the given application with the justification.	3.1 Classification of control valves 3.2 Construction and working of i. pressure control valves-relief, unloading, sequence, counter balance, pressure reducing valves. ii. Direction control valves- check valves, 2/2, 3/2, 4/2, 4/3, 5/2, 5/3 D.C. Valves used in hydraulics and pneumatics. iii. Servo valves and Flow control valves – Non-compensated, Pressure and temperature compensated. 3.3 Standard centre positions, methods of actuation, Types of valve element 3.4 Hydraulic and pneumatic sensors - Introduction, Unique features 3.5 Types-Pressure and temperature monitoring sensors, hydraulic flow rate sensor, level sensor, Pneumatic Proximity Sensors, Back Pressure Sensor (Pilot tube), Reflex Sensor (Screen Nozzle) Air Barrier Sensor,	
TSO 4a. Describe the function and working of the given compressor *TSO 4b.* Select the relevant compressor for the given application with justification. *TSO 4c.* Select the relevant accessories for the given type of hydraulic /pneumatic system with justification. *TSO 4d.* Select appropriate hydraulic and pneumatic pipe for given application *TSO 4e.* Use and maintain FRL unit in pneumatics *TSO 4f.* Select hydraulic and pneumatic accessories with its location on hydraulic and pneumatic system. *TSO 4g.* Calculate mechanical efficiency, volumetric efficiency and isothermal efficiency of the compressor.	**Unit-4.0 Compressor, Components and Accessories** 4.1 Pneumatic Control System-Introduction, Air Preparation-Primary and Secondary Air Treatment 4.2 Pneumatic Power Source- Compressor, Classification, Air Receiver and Control Methods 4.3 Compressors-Types, construction, working principle of Reciprocating Type Air Compressor-Single and Multi-stage Piston Pump, Rotary compressors, PV Diagram and Work Done 4.4 Construction, working principle of FRL unit, Dual (twin) pressure valve, shuttle valve, Quick exhaust valve, Time delay valve. 4.5 Accessories: Oil reservoir, pipes, hoses, fittings, oil filters, air filters, seals and gaskets, intensifiers, accumulators, heat exchanger, muffler, Air Dryer 4.6 Hydraulic pipes and pneumatics pipes -Types, standards, designation methods and specifications, pressure ratings, applications and selection criteria	**CO4**
TSO 5a. Interpret given hydraulic and pneumatic circuit drawings. *TSO 5b.* Explain with sketches the working of the given hydraulic and pneumatic circuit. *TSO 5c.* Select the relevant components required to develop the given hydraulic and pneumatic circuit with justification. *TSO 5d.* Analyze the given hydraulic and pneumatic circuits *TSO 5e.* Select relevant components for the given hydraulic and pneumatic application *TSO 5f.* Design hydraulic and pneumatic circuits *TSO 5g.* for the given application	**Unit-5.0 Hydraulic and Pneumatic Circuits** 5.1 Working and applications of basic Hydraulic Circuits, types - intensifier, regenerative, synchronizing, sequencing, speed components 5.2 Design hydraulic circuits -single and double acting hydraulic cylinders, motors, circuit for speed control Meter-in, Meter-out, Bleed Off circuit 5.3 Design hydraulic circuit for Regenerative, synchronizing counterbalance, Sequencing circuits, two pumps unloading	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5h. Describe the procedure for maintaining basic hydraulic circuit pneumatic circuits based on given system requirements. *TSO 5i.* Identify the faults in the given hydraulic system and pneumatic system and remedial measures *TSO 5j.* Troubleshoot the given hydraulic and pneumatic system *TSO 5k.* Use hydraulic software and pneumatic software to develop circuits *TSO 5l.* Simulate different components hydraulic and pneumatic systems	5.4 Design hydraulic circuits for Milling, Grinding and Shaper machine **Pneumatic circuits** 5.5 Circuit diagram, components, working and applications. Analysis of Multiple Actuators 5.6 Design pneumatic circuit by classic, cascade, step counter, karnaugh and combinational circuit design 5.7 Design pneumatic circuits for- direct /indirect control of single and double acting air cylinders, motors, two step feed control, automatic cylinder reciprocation, time delay, sequencing circuits, Logic AND/OR circuits 5.8 Design pneumatic circuits for Speed control of cylinders and motors. 5.9 Analysis of Hydraulic and Pneumatic Circuits 5.10 Use of simulation software for hydraulic and pneumatic circuits 5.11 Selection of relevant components, fault detection, Remedies and Maintenance of hydraulic and pneumatic systems.	
TSO 6a. Differentiate between Pneumatic servo system, Hydro-Pneumatics, Electro-Pneumatics, Electro-hydraulic systems *TSO 6b.* Interpret given, Electro-hydraulic and Electro pneumatic circuit drawings. *TSO 6c.* Describe the given Electro- pneumatic controls *TSO 6d.* Select the relevant components required to develop the given Electro -hydraulic and electro-pneumatic circuit with justification. *TSO 6e.* Analyze the given Electro-hydraulic and Electro pneumatic circuit *TSO 6f.* Select relevant components for the given Electro-hydraulic and Electro pneumatic application *TSO 6g.* Design Electro-hydraulic and Electro pneumatic circuit for the given application *TSO 6h.* Use electro-hydraulic and electro-pneumatic software to simulate different Electro-hydraulic and Electro pneumatic systems	**Unit-6.0 Electro Pneumatic System and Electro Hydraulic Systems** 6.1 Introduction to Pneumatic servo system, Hydro-Pneumatics, Electro-Pneumatics, Electro-hydraulic 6.2 Applications, Advantages and Disadvantages of above systems. 6.3 Electro -pneumatic controls, operation of electric actuated valves, Pneumatic electrical transducers, Electric converters, signal processors. Relays and protection relays. Connections of direct and indirect management. 6.4 Logic circuits- Time Tracking Control, Checking workflows, Proportional pneumatics, Proportional switching 6.5 Electrohydraulic control, electro Hydraulic cylinders, Control of pneumatic and hydraulic processes using a PLC controller 6.6 Design of basic electro-pneumatic and electrohydraulic circuits. 6.7 Application of hydraulic and Electro Hydraulic System - working principle, major elements of - Automotive hydraulic brake and power steering, Industrial Fork lift, Hydraulic jack, Hydraulic press, Rotary machining station 6.8 Application of pneumatic and Electro pneumatic System- working principle, major elements of -Allocating device, sorting device, edge folding device, Foil welding, Feed rail separator, Input station for laser cuter, Drilling machine	**CO6**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425603D

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Identify components and draw ISO symbols of the components used in hydraulic and Pneumatics system	1.	Identify the components in the given hydraulic and pneumatic systems.	CO1
	2.	Identify and draw ISO symbols used in given hydraulic and Pneumatics components	CO1
LSO 1.2. Use Hydrostatics and properties of fluids apparatus	3.	Determine the effect of temperature and pressure on hydraulic oil performance	CO1
	4.	Determine the properties of the given hydraulic fluid	CO1
LSO 1.3. Use Bernoulli test rig	5.	Investigate the validity of the Bernoulli equation when it is applied to a steady flow of water through a tapered duct.	CO1
LSO 1.4. Use Flow losses in pipe apparatus	6.	Determine the Co-efficient of friction of flow through pipes of various sizes	CO1
	7.	Determine minor losses in flow through pipes	CO1
LSO 2.1. Use hydraulic bench / Centrifugal pump test rig	8.	Determine the various efficiencies of the given pump	CO2
	9.	Determine the efficiency of a given centrifugal pump and plot the following graphs. (i) I/P vs Discharge (ii) Total head vs Discharge (iii) Efficiency vs Discharge.	
	10.	Determine the operational characteristics of two centrifugal pumps when they are configured as a single pump, two pumps in series, and two pumps in parallel.	CO2
	11.	Determine the various performance of the single stage centrifugal pump for constant & variable speed.	CO2
	12.	Determine the various performance of the multi stage centrifugal pump for constant & variable speed.	CO2
	13.	Determine the various performance of the reciprocating pump for (1) Variable speed and constant head (2) Constant speed and variable head	CO2
	14.	Determine the efficiency of a given gear pump and plot the following graphs i) Percentage efficiency vs head ii) Percentage slip vs head iii) Discharge vs head iv) Output vs head	CO2
LSO 2.2. Use DC servo motor	15.	Determine speed-torque characteristic of D.C servomotor.	CO2
LSO 2.3. Use AC servo motor	16.	Determine speed torque characteristics of AC servo motor.	CO2
LSO 2.4. Use stepper motor	17.	Program the motor to operate in CCW and CW direction with user control speed	CO2
	18.	Identify of stepper motor terminals and control in wave step mode	CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 2.5. Use hydraulic and pneumatic trainer	19.	Design circuit to actuate double acting cylinder using pneumatic direction control valve	CO2
	20.	Control the direction and speed of cylinders.	CO2
LSO 3.1. Use Control Valve Characteristics Trainer	21.	Determine the flow coefficient Cv of the linear control valve	CO3
	22.	Determine the flow coefficient Cv of the quick open control valve	CO3
	23.	Calculate rangeability of linear control valve	CO3
	24.	Calculate rangeability of quick open control valve.	CO3
LSO 3.2. Use hydraulic and pneumatic trainer	25.	Design a circuit using direction control valve and pressure control valve for clamping device for jigs and fixture	CO3
LSO 3.3. Use Pressure Process Control Training System	26.	Determine the performance of ON-OFF/P/PI/PD/PID controllers on pressure process.	CO3
LSO 3.4. Use Level Control Trainer.	27.	Determine the performance of ON – OFF/P/PI/PD/PID controllers on level process	CO3
LSO 3.5. Use Flow Control Trainer	28.	Determine the performance of ON – OFF/P/PI/PD/PID controllers on flow process	CO3
LSO 3.6. Use temperature Control Trainer.	29.	Determine the performance of ON-OFF/P/PI/PD/PID controllers on temperature process.	CO3
LSO 4.1. Use compressor test rig	30.	Determine Performance of a two stage Reciprocating Air Compressor	CO4
	31.	Determine performance of a two-stage single acting reciprocating air compressor.	CO4
	32.	Determine volumetric efficiency and isothermal efficiency of two stage single acting reciprocating air compressor	CO4
	33.	Determine various performance of the given compressor	CO4
LSO 4.2. Use hydraulic ram test rig	34.	Determine the working characteristics of hydraulic ram at constant valve lift and constant supply head and plot the following curves. • Pumped water v/s Delivery head • waste water v/s Delivery head • D' aubussion efficiency v/s Delivery head • Rankines's efficiency v/s Delivery head • Number of heats/sec v/s Delivery head	CO4
LSO 5.1. Use hydraulic trainer with simulation software	35.	Design, assemble and operate hydraulic circuit to actuate and control SAC and DAC	CO5
	36.	Design, assemble and operate Meter-in, Meter out hydraulic circuit.	CO5
	37.	Design, assemble and operate any suitable sequencing hydraulic circuit	CO5
	38.	Design the hydraulic system circuit based on given input and parameters using hydraulic simulation software.	CO5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
	39.	Design, assemble and operate Regenerative Circuit	CO5
	40.	Design, assemble and operate hydraulic circuit using accumulator	CO5
	41.	Develop Automatic cylinder reciprocation circuit using hydraulic trainer.	CO5
LSO 5.2. Use pneumatic trainer with simulation software	42.	Design, assemble and operate Pneumatic circuits to actuate and control SAC, DAC, Air motor	CO5
	43.	Design, assemble and operate Pneumatic circuits for controlling speed	CO5
	44.	Design, assemble and operate indirect/pilot control Pneumatic circuit	CO5
	45.	Develop any suitable sequencing Pneumatic circuit.	CO5
	46.	Design, assemble and operate Pneumatic circuits for Logic functions (AND/OR/Time delay)	CO5
	47.	Develop Automatic cylinder reciprocation circuit using pneumatic trainer	CO5
LSO 6.1. Use electro pneumatic trainer	48.	Design, assemble and operate Electro Pneumatic circuits to actuate and control SAC, DAC, Air motor	CO6
	49.	Design, assemble and operate Electro Pneumatic circuits for the given application	CO6
LSO 6.2. Use electro hydraulic trainer	50.	Design, assemble and operate Electro Hydraulic circuits to actuate and control SAC, DAC, Air motor	CO6
	51.	Design, assemble and operate Electro Hydraulic circuits for the given application	CO6

L) Suggested Term Work and Self Learning: S2425603D 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.

- Produce a presentation analyzing fluid viscosity using Stokes' Law and validate how this relates to Navier–Stokes equations
- Stating any assumptions, compare the applications of practical hydraulic and pneumatic systems
- Prepare report of agriculture equipment's working on hydraulics and pneumatics.
- Prepare report on working of hydraulic jack and its system.
- Analyze the methods in fluid power principles and working of hydraulic pumps

b. Micro Projects:

- Prepare working model of hydraulic crane using waste injections used by doctors.
- Develop working model of automation of bench vice used in carpentry/fitting shop.
- Market survey of oil used in hydraulic system (Manufacturers, specification, trade names, cost, packing size)
- Design of hydraulic / pneumatic system and related components for any industrial application

c. Other Activities:

1. Seminar Topics:
    - Hazard and safety in industrial hydraulic and pneumatic.
    - Remedies and faults detection in pneumatic and hydraulic circuits.
    - Prototype working model of hydraulically operated hospital bed.
    - Types of oil filters.

2. Visits: Visit nearby tool room/industry with hydraulic and pneumatic operated machines. Prepare report of visit with special comments of hydraulic and pneumatic operated machine used, material used, single component/batch production/mass production and cost of machine used.

3. Self-Learning Topics:
    - Prepare journal based on practical performed in Industrial fluid power laboratory. Journal consist of drawing, observations, required measuring tools, equipment's etc.
    - Prepare visit report of any automobile service station to observe use of pneumatic hand tools.
    - Hydraulic operated crane operation.
    - Visit nearby industry and learn to operate pneumatic machine.

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%	15%
CO-2	15%	15%	15%	20%	-	10%	15%
CO-3	15%	15%	15%	20%	33%	15%	20%
CO-4	20%	20%	20%	20%	33%	20%	20%
CO-5	20%	20%	20%	20%	34%	20%	15%
CO-6	15%	15%	15%	20%		15%	15%
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 Hydraulic and Pneumatic Systems	8	CO1	10	3	3	4
Unit-2.0 Pumps and Actuators	8	CO2	10	3	2	5
Unit-3.0 Control Valves and Sensors	8	CO3	10	3	2	5
Unit-4.0 Compressor, Components and Accessories	8	CO4	15	5	5	5
Unit-5.0 Hydraulic and Pneumatic Circuits	8	CO5	15	5	4	6
Unit-6.0 Electro Pneumatic System and Electro Hydraulic Systems	8	CO6	10	3	3	4
	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 Experiment/Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Identify the components in the given hydraulic and pneumatic systems	CO1	40	50	10
2.	Identify and draw ISO symbols used in given hydraulic and Pneumatics components	CO1	40	50	10
3.	Determine the effect of temperature and pressure on hydraulic oil performance	CO1	40	50	10
4.	Determine the properties of the given hydraulic fluid	CO1	40	50	10
5.	Investigate the validity of the Bernoulli equation when it is applied to a steady flow of water through a tapered duct.	CO1	40	50	10
6.	Determine the Co-efficient of friction of flow through pipes of various sizes	CO1	40	50	10
7.	Determine minor losses in flow through pipes	CO1	40	50	10
8.	Determine the various efficiencies of the given pump	CO2	40	50	10
9.	Determine the efficiency of a given centrifugal pump and plot the following graphs. (i) I/P vs Discharge (ii) Total head vs Discharge (iii) Efficiency vs Discharge.	CO2	40	50	10
10.	Determine the operational characteristics of two centrifugal pumps when they are configured as a single pump, two pumps in series, and two pumps in parallel.	CO2	40	50	10
11.	Determine the various performance of the single stage centrifugal pump for constant & variable speed.	CO2	40	50	10

S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
12.	Determine the various performance of the multi stage centrifugal pump for constant & variable speed.	CO2	40	50	10
13.	Determine the various performance of the reciprocating pump for (1) Variable speed and constant head (2) Constant speed and variable head	CO2	40	50	10
14.	Determine the efficiency of a given gear pump and plot the following graphs i) Percentage efficiency vs head ii) Percentage slip vs head iii) Discharge vs head iv) Output vs head		40	50	10
15.	Determine speed-torque characteristic of D.C servomotor.	CO2	40	50	10
16.	Determine speed torque characteristics of AC servo motor.	CO2	40	50	10
17.	Program the motor to operate in CCW and CW direction with user control speed	CO2	40	50	10
18.	Identify of stepper motor terminals and control in wave step mode	CO2	40	50	10
19.	Design circuit to actuate double acting cylinder using pneumatic direction control valve	CO2	40	50	10
20.	Control the direction and speed of cylinders.	CO2	40	50	10
21.	Determine the flow coefficient Cv of the linear control valve	CO3	40	50	10
22.	Determine the flow coefficient Cv of the quick open control valve	CO3	40	50	10
23.	Calculate rangeability of linear control valve	CO3	40	50	10
24.	Calculate rangeability of quick open control valve.	CO3	40	50	10
25.	Design a circuit using direction control valve and pressure control valve for clamping device for jigs and fixture	CO3	40	50	10
26.	Determine the performance of ON-OFF/P/PI/PD/PID controllers on pressure process.	CO3	40	50	10
27.	Determine the performance of ON –OFF/P/PI/PD/PID controllers on level process	CO3	40	50	10
28.	Determine the performance of ON –OFF/P/PI/PD/PID controllers on flow process	CO3	40	50	10
29.	Determine the performance of ON-OFF/P/PI/PD/PID controllers on temperature process.	CO3	40	50	10
30.	Determine Performance of a two stage Reciprocating Air Compressor	CO4	40	50	10
31.	Determine performance of a two-stage single acting reciprocating air compressor.	CO4	40	50	10
32.	Determine volumetric efficiency and isothermal efficiency of two stage single acting reciprocating air compressor	CO4	40	50	10

S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
33.	Determine various performance of the given compressor	CO4	40	50	10
34.	Determine the working characteristics of hydraulic ram at constant valve lift and constant supply head and plot the following curves. • Pumped water v/s Delivery head • waste water v/s Delivery head • D' aubussion efficiency v/s Delivery head • Rankines's efficiency v/s Delivery head • Number of heats/sec v/s Delivery head	CO4	40	50	10
35.	Design, assemble and operate hydraulic circuit to actuate and control SAC and DAC	CO5	40	50	10
36.	Design, assemble and operate Meter-in, Meter out hydraulic circuit.	CO5	40	50	10
37.	Design, assemble and operate any suitable sequencing hydraulic circuit	CO5	40	50	10
38.	Design the hydraulic system circuit based on given input and parameters using hydraulic simulation software.	CO5	40	50	10
39.	Design, assemble and operate Regenerative Circuit	CO5	40	50	10
40.	Design, assemble and operate hydraulic circuit using accumulator	CO5	40	50	10
41.	Develop Automatic cylinder reciprocation circuit using hydraulic trainer	CO5	40	50	10
42.	Design, assemble and operate Pneumatic circuits to actuate and control SAC, DAC, Air motor	CO5	40	50	10
43.	Design, assemble and operate Pneumatic circuits for controlling speed	CO5	40	50	10
44.	Design, assemble and operate indirect/pilot control Pneumatic circuit	CO5	40	50	10
45.	Develop any suitable sequencing Pneumatic circuit.	CO5	40	50	10
46.	Design, assemble and operate Pneumatic circuits for Logic functions (AND/OR/Time delay)	CO5	40	50	10
47.	Develop Automatic cylinder reciprocation circuit using pneumatic trainer	CO5	40	50	10
48.	Design, assemble and operate Electro Pneumatic circuits to actuate and control SAC, DAC, Air motor	CO6	40	50	10
49.	Design, assemble and operate Electro Pneumatic circuits for the given application	CO6	40	50	10
50.	Design, assemble and operate Electro Hydraulic circuits to actuate and control SAC, DAC, Air motor	CO6	40	50	10
51.	Design, assemble and operate Electro Hydraulic circuits for the given application	CO6	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.	Hydrostatics and properties of fluids apparatus	Self-contained apparatus for many experiments in fluid mechanics and properties of fluids, hydrostatic principles and buoyancy / floatation and Archimedes' principle.	3,4
2.	Bernoulli test rig	Take tank 2/3 full of water, floating vessel or pontoon fitted with a pointed pointer moving on a graduated scale, with weights adjusted on a horizontal beam	5
3.	Flow losses in pipe apparatus	Flow losses in pipe apparatus with flow control device and manometer, valve fitted with each pipe to Regulate the flow, a measuring tank fitted with a piezometer tube and a graduated scale, Stop watch, arrangement for uniform supply of water, pipe fittings consisting of sudden enlargement, sudden contraction, elbow and bend, measuring tank with a piezometer and a scale, manometer	6,7
4.	Cut section of different types of pump and working models of pump	Working/actual models of pumps, valves, cylinders, motors, accumulators, filters etc. Cut section of pumps, valves, cylinders, motors, accumulators, filters etc.	8-14
5.	Hydraulic bench / Centrifugal pump test rig	fitted with a single centrifugal pump that is driven by a single-phase A.C. motor, speed control unit, auxiliary pump, Pressure gauges installed at the inlet and outlet of the pumps, watt-meter unit, vacuum gauges, Flow measuring unit	8-14
6.	DC servo motor	DC servo motor	15
7.	AC servo motor	AC servo motor	16
8.	Stepper motor	Stepper motor	17-18
9.	SAC and DAC cylinders actuators	SAC and DAC cylinders actuators	19-20
10.	Working models of different types of control valves.	Working models of different types of control valves.	21-24
11.	Control Valve Characteristics Trainer	Mounting of different types of control valves of different design	21-24
12.	Pressure Process Control Training System	Pressure Process Control Training System for laboratory purpose	25-26
13.	Computerized Level Control Trainer	Computerized Level Control Trainer for laboratory purpose	27
14.	Computer Controlled Flow Control Trainer	Computer Controlled Flow Control Trainer	28
15.	Temperature Process Control trainer	Temperature Process Control trainer	29

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
16.	Compressor test rig	Single/multistage reciprocating compressor (pressure 0-10 bar)	30-33
17.	Hydraulic ram test rig	hydraulic ram connects to the supply tank using supply pipes, pressure gauge to measure delivery pressure, arrangement for, measuring the waste water, arrangement for measuring the perfect water, stop watch, Graph	34
18.	Hydraulic trainer with simulation software	Hydraulic trainer with transparent/actual working components.	19,20, 25 35-41
19.	Pneumatic trainer with simulation software	Pneumatic trainer with transparent/actual working components.	19,20, 25, 42-47
20.	Electro pneumatic trainer with simulation software	Electro pneumatic trainer with transparent/actual working components	48-49
21.	Electro hydraulic trainer with simulation software	Electro hydraulic trainer with transparent/actual working components	50-51

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Design Concepts in Pneumatic Systems	Joji Parambath	Kindle Edition, 2023 ASIN : B0C7PMFKRL
2.	Work on hydraulic systems: components and applications of hydraulic	James Johnson	Kindle Edition, 2023 ASIN : B09V3M6TBL
3.	Fundamentals of Pneumatics and Hydraulics	Md. Abdus Salam	Springer Nature; 1st ed. 2022 ISBN-10 : 9811908540 ISBN-13 : 978-9811908545
4.	Elements of Hydrostatics Hydraulics and pneumatics (Hindi Paperback)	Navina Chandra Rai	Legare Street Press, Hindi Edition, 2022, ISBN-10: 1017960445 ISBN-13: 978-1017960440
5.	Design of Pneumatic Systems	Joji Parambath	Independently Published, 2020 ISBN-13: 979-8653408809 ASIN: B08BF7NYP1
6.	Hydraulic and Pneumatic Controls 3e	Srinivasan R.	Vijay Nicole Imprints, 2019 ISBN-10: 8182095786 ISBN-13: 978-8182095786
7.	A Textbook of Fluid Mechanics and Hydraulic Machines	Dr. R. K. Bansal	LAXMI PUBLICATION, 11th ed. 2023 ISBN-10: 8131808157 ISBN-13: 978-8131808153
8.	Modular Approach to Designing Pneumatic-Hydraulic Wellhead Control System	Subrata Chatterjee	Book Rivers, 2023 ISBN-10: 9355158416 ISBN-13: 978-9355158413
9.	Pneumatic Systems-Principles and Maintenance	S. R. Majumdar	McGraw-Hill Education, 2017 ISBN:9780074602317
10.	Hydraulics and Pneumatics	Vinayak V. Gaikwad Dr. Vikas v. Shinde	Technical Publications, 2020 ISBN:9789333219112

(b) Online Educational Resources:

1) https://www.google.com/search?q=hydraulic+and+pneumatic+control&oq=hydraulic+and+pn eumatic+control&aqs=chrome.69i57j69i61l2j69i60.23552j0j4&sourceid=chrome
2) https://archive.nptel.ac.in/courses/112/106/112106300/
3) https://pc-coep.vlabs.ac.in/exp/direct-single-acting-cylinder/theory.html

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

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A) Course Code **: 2425603E(T2425603E/P2425603E/S2425603E)**

B) Course Title **:** Renewable and Alternate Energy Sources

C) Pre- requisite Course(s) **:** Environmental Education and Sustainable Development

D) Rationale **:**

In the context of rapidly depleting fossil fuel resources and increasing power demand along with environmental concern it is imperative to look for the alternative sources of energy. Non-conventional energy sources have become the most urgent sources for replacement of conventional energy sources because of rising costs, decreasing availability, and causing pollution to the environment. The future of Wind, Solar, Tidal and other alternate energy sources is bright and these will play an important role in the world energy scenario and future employments. This course aims at developing the ability in the students to cope up with the working and construction aspects of machinery, devices and components associated with these energy systems. Knowledge of new technologies will enrich the technical know-how of students and increase their employment opportunities in the upcoming sector of renewable energy.

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 Explore the role and prospects of non-conventional energy sources.

CO-2 Explain construction and working of Solar energy devices and components.

CO-3 Describe construction and working of Wind energy related systems and subsystems.

CO-4 Explain construction, working, maintenance of Biomass plants and energy from Waste.

CO-5 Describe construction and working of Geothermal, OTEC, Tidal systems and subsystems.

CO-6 Describe construction and working of Fuel cells and Hydrogen energy

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	-	1		
CO-2	3	-	1	2	3	-	1		
CO-3	3	-	1	2	3	-	1		
CO-4	3	-	1	2	3	-	1		
CO-5	3	-	-	2	3	-	1		
CO-6	3	-	1	-	3	-	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				
2425603E	Renewable and Alternate Energy Sources	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)	
2425603E	Renewable and Alternate Energy Sources	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: T2425603E

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain renewable and non-renewable energy sources. *TSO 1b.* Compare renewable and non- renewable energy sources *TSO 1c.* Explain primary and secondary energy sources. *TSO 1d.* Explain Hybrid energy systems, Distributed energy systems and dispersed generation (DG) *TSO 1e.* Identify different issues, prospects and need of renewable and alternate energy sources.	**Unit-1.0 Introduction to Energy Sources** 1.1 Major sources of energy: Renewable and Non-renewable and comparison. 1.2 Primary and secondary energy sources. 1.3 Energy Scenario: - Prospects an Need of renewable and alternate energy sources. 1.4 Hybrid energy systems, Distributed energy systems and dispersed generation (DG). 1.5 Prospects and Achievements of renewable energy sources in India in general and Bihar state in particular. 1.6 Issues related to power generation through renewable energy sources.	**CO1**
TSO 2a. Explain Beam and diffuse radiation. *TSO 2b.* Explain the given earth sun angle(s). *TSO 2c.* Enumerate the uses of the given Solar energy collector. *TSO 2d.* Describe the construction and working of the given Solar energy device(s). *TSO 2e.* Explain the utility of low cost solar cooker as alternative cooking appliances in villages. *TSO 2f.* Select photo-voltaic cells for domestic lightning in houses.	**Unit-2.0 Solar Energy** 2.1 Solar radiation: Beam and diffuse radiation, Solar constant, Solar Radiations at earth's surface Solar Radiation Geometry: Declination, hour angle, altitude angle, incident angle, zenith angle, solar azimuth angle attenuation and measurement of Solar radiation, local Solar time, derived Solar angles. 2.2 Flat plate collectors, concentrating collectors, elements and working 2.3 Solar air heaters-types, Solar driers, elements and working. 2.4 Storage of Solar energy-thermal storage, Electrical storage, Chemical storage. 2.5 Solar water heaters, Solar distillation, Solar still, Solar cooker, elements and working. 2.6 Photovoltaic - Solar cells & its applications, Solar panels, Solar PV pump, Solar Home lighting systems, Solar street lights, elements and working. (no derivations and numerical)	**CO2**
TSO 3a. Describe the principle of conversion of wind energy. *TSO 3b.* State advantages and limitations of wind energy. *TSO 3c.* Determine wind power, power coefficient and maximum power. *TSO 3d.* Select sites for the given wind mill. *TSO 3e.* Explain construction and working of the given horizontal and vertical axis wind mills *TSO 3f.* Compare horizontal and vertical wind mills.	**Unit-3.0 Wind Energy** 3.1 Basic Principle of wind energy conversion. 3.2 Power in wind, Available wind power formulation, Power coefficient, Maximum power 3.3 Main considerations in selecting a site for wind mills. 3.4 Advantages and limitations of wind energy conversion. 3.5 Classification of wind mills 3.6 Construction and working of horizontal and vertical axis wind mills, their comparison	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 3g. Use wind energy for power generation and pumping in the given situation.	3.7 Main applications of wind energy for power generation and pumping.	
TSO 4a. Identify common species recommended for biomass. *TSO 4b.* Describe the methods for obtaining energy from the given biomass. *TSO 4c.* Classify biomass- gasified, fixed bed and fluidized. *TSO 4d.* Explain the constructional details of Bio gas conversion plant. *TSO 4e.* Explain the application of Gasifier. *TSO 4f.* Explain the production and application of biodiesel. *TSO 4g.* Use agricultural waste as a biomass. *TSO 4h.* Explain biomass digester. *TSO 4i.* Compare biomass with conventional fuels. *TSO 4j.* Describe the maintenance procedure of Biogas plants and components. *TSO 4k.* Explain procedure to extract energy/fuel/gases from various waste like Tire, Rubber, Plastic, Mixed Solid Municipal waste. *TSO 4l.* Explore other alternate energy sources like flowing drain water, mass mobility of human and vehicles at Railway stations, Malls, Highways by modifying speed breakers, steps, stairs etc.	**Unit-4.0 Energy from Biomass** **Energy from Biomass** 4.1 Common species recommended for biomass. 4.2 Methods for obtaining energy from biomass 4.3 Thermal classification of biomass a) Gasified, b) Fixed bed and fluidized 4.4 Comparison of Biomass with conventional fuels 4.5 Constructional details, site selection, filling a digester for starting, maintaining Biogas production, Fuel properties of Bio gas, and applications of Biogas. 4.6 Maintenance of Biogas plants. 4.7 Application of gasifier 4.8 Biodiesel production and application 4.9 Agriculture waste as a biomass 4.10 Biomass digester **Energy from wastes:** 4.11 Recycling of plastic and Tire/Rubber waste to produce fuel. 4.12 Recycling of Mixed Solid Municipal waste to produce energy/Synthetic gases. 4.13 Recycling of used Vegetable oil. 4.14 Energy from flowing drain water, Energy from mass mobility of human and vehicles at Railway stations, Malls, Highways by modifying speed breakers, steps, stairs etc.	**CO4**
TSO 5a. Identify environmental implications of geothermal energy *TSO 5b.* Describe working of Geothermal plant. *TSO 5c.* Describe the given Ocean Thermal Electric Conversion (OTEC) systems *TSO 5d.* Explain construction and working of a tidal energy plant.	**Unit-5.0 Geothermal Energy, Energy from Oceans** 5.1 Introduction, geothermal sources, classification, compressed resources, exploration, environmental implications, applications, advantages and disadvantages. 5.2 Geothermal plant. 5.3 Ocean Thermal Electric Conversion (OTEC) systems like open cycle, closed cycle. 5.4 Energy from tides, basic principle of tidal power, single basin and double basin tidal power plants, advantages, limitation.	**CO5**
TSO 6a. Classify the types of fuel cells. *TSO 6b.* List applications of fuel cells. *TSO 6c.* State advantages and limitations of fuel cells. *TSO 6d.* Explain the working principleof the given Fuel cell. *TSO 6e.* Explain production, storage and transportation of hydrogen energy. *TSO 6f.* Explain the safety measures in hydrogen energy utilization. *TSO 6g.* Compare hydrogen energy with other automobile fuels. *TSO 6h.* Describe the utility of hydrogen powered vehicle.	**Unit-6.0 Fuel Cells and Hydrogen Energy** 6.1 Fuel Cells- Introduction, Classification :-proton exchange membrane fuel cells (PEMFCs), solid oxide fuel cells (SOFCs), and alkaline fuel cells, Principles, performance, application, advantages and limitations. 6.2 Hydrogen Energy - Introduction, production, storage, transportation, safety, utilization of hydrogen gas, comparison with other automobile fuels.	**CO6**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425603E

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Identify the given component(s) used in Flat Plate Solar Collector. *LSO 1.2.* Explain the operation of the given component(s) of Flat Plate Solar Collector.	1.	Identify and demonstrate working of various components used in Flat Plate Solar Collector using test rig, models, charts, visits, simulated and real videos.	CO2
LSO 2.1. Identify the given component(s) used in Solar air heaters and Solar driers. *LSO 2.2.* Explain the operation of the given component(s) of Solar air heaters and Solar driers.	2.	Identify and demonstrate working of various components used in Solar air heaters and Solar driers using test rig, models, charts, visits, simulated and real videos.	CO2
LSO 3.1. Identify chemicals that have capability to store heat energy. *LSO 3.2.* Explain the chemical storage method user for solar energy.	3.	Prepare a desk top model for storing heat energy using chemical storage. Measure the quantity of heat stored and duration.	CO2
LSO 4.1. Correlate the effect of input parameters on the performance parameters of the given Flat Plate solar collector. *LSO 4.2.* Estimate the conversion efficiency of the given Flat Plate solar collector.	4.	Measure the heat radiations received and heat collected in the given Flat Plate solar collector.	CO2
LSO 4.3. Correlate the effect of input parameters on the performance parameters of the given Concentrating Parabolic trough solar collector. *LSO 5.1.* Estimate the conversion efficiency of the given Concentrating Parabolic trough solar collector *LSO 5.2.* Compare the performance of the given Concentrating Parabolic trough solar collector with the flat plate collector.	5.	Measure the heat radiations received and heat collected using a Concentrating Parabolic trough solar collector with varying tracking angles. Compare its performance with the flat plate collector.	CO2
LSO 6.1. Identify the component(s) of the given Solar energy device. *LSO 6.2.* Explain the operation of the given Solar energy device. *LSO 6.3.* Correlate the effect of input parameters on the performance parameters of the given Solar energy device.	6.	Estimate the performance parameters in any one: Solar water heaters/Solar distillation/Solar still/Solar cooker.	CO2
LSO 6.4. Identify the component(s) of the given Solar energy device. *LSO 6.5.* Explain the operation of the given Solar-Electro energy device. *LSO 6.6.* Correlate the effect of input parameters on the performance parameters of the given Solar-Electro energy device.	7.	Estimate the performance parameters in any one: Photovoltaic Solar panels, Solar PV pump, Solar Home lighting systems, Solar street lights.	CO2
LSO 8.1. Identify the given component(s) of Solar appliances like drier, cooker, lantern etc.	8.	Estimate the performance parameters in any one: Solar appliances like drier, cooker, lantern etc.	CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 8.2. Explain the operation of the given Solar appliances like drier, cooker, lantern etc. *LSO 8.3.* Correlate the effect of input parameters on the performance parameters of the given Solar appliances like drier, cooker, lantern etc.			
LSO 9.1. Identify the components of a wind power generation system. *LSO 9.2.* Explain the operation of the given wind power generation system. *LSO 9.3.* Draw the characteristic curves of the given generator: Three-phase voltage depending on the speed of rotation.; Continuous voltage depending on the speed of rotation; Torque based on the generated current; Three-phase active power depending on the speed of rotation; Power in direct current as a function of the speed of rotation. *LSO 9.4.* Calculate constant of torque / current and voltage / speed of rotation of the given generator.	9.	Study the operation of portable wind power generation system. Draw the characteristic curves of the generator and calculate constant of torque / current and voltage / speed of rotation of the generator.	CO3
LSO 10.1. Identify the given component(s) of the rectifier. *LSO 10.2.* Explain the operation of the given rectifier. *LSO 10.3.* Correlate the effect of input parameters on the performance parameters of the rectifier.	10.	Evaluate performance of the rectifier and determine optimum operating points against variable atmospheric conditions	CO3
LSO 11.1. Identify the given component(s) used in portable Biogas plant. *LSO 11.2.* Explain the operation of the given component(s) of portable Biogas plant. *LSO 11.3.* Correlate the effect of input parameters on the performance parameters.	11.	Evaluate performance parameters of a portable Biogas plant with different mix of solid municipal waste.	CO4
LSO 12.1. Identify the given component(s) used in Geothermal plant. *LSO 12.2.* Explain the operation of the given component(s) of Geothermal plant.	12.	Identify and demonstrate working of various components used in Geothermal plant using models, charts, visits, simulated and real videos.	CO5
LSO 13.1. Identify the given component(s) used in Ocean Thermal Electric Conversion (OTEC) systems. *LSO 13.2.* Explain the operation of the given component(s) of Ocean Thermal Electric Conversion (OTEC) systems.	13.	Identify and demonstrate working of various components used in Ocean Thermal Electric Conversion (OTEC) systems using models, charts, visits, simulated and real videos.	CO5
LSO 14.1. Identify the given component(s) used in Single basin and Double basin tidal power plants.	14.	Identify and demonstrate working of various components used in Single basin and Double basin tidal power plants using models, charts, visits, simulated and real videos.	CO5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 14.2. Explain the operation of the given component(s) of Single basin and Double basin tidal power plants.			
LSO 15.1. Identify the given component(s) used in Proton exchange membrane fuel cells (PEMFCs), Solid oxide fuel cells (SOFCs), and alkaline fuel cells. *LSO 15.2.* Explain the operation of the given component(s) of Proton exchange membrane fuel cells (PEMFCs), Solid oxide fuel cells (SOFCs), and alkaline fuel cells.	15.	Identify and demonstrate working of various components used in Proton exchange membrane fuel cells (PEMFCs), Solid oxide fuel cells (SOFCs), and alkaline fuel cells using models, charts, visits, simulated and real videos.	CO6

A judicial mix of minimum 14 or more practical need to be performed, out of which, the practical marked as '' are compulsory.

L) Suggested Term Work and Self Learning: S2425603E 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. Quantify the harmful effects of pollutants from conventional energy sources.
ii. Briefly introduce the importance of energy sources in our daily lives and their impact on the environment.
iii. Create a table or chart comparing the energy sources you've discussed in terms of their environmental impact, efficiency, and availability.
iv. Prepare a chart of cumulative achievements of renewable energy sources in India.
v. Determine the collector efficiency of Solar flat plate collector.
vi. Identify the basic components of Solar water heater.
vii. Determine the collector efficiency of concentrating type flat plate collector.
viii. Identify of basic components of photo voltaic cell.
ix. Identify of basic components of Solar cooker.
x. Prepare a demonstration model of Wind energy conversion system
xi. Compare horizontal and vertical Wind mill.
xii. Explore the potential sites for Wind mill installation in India.
xiii. Identify the various components of Bio gas plant model.
xiv. Identify the different Bio gas digesters.
xv. List the Performance characteristics of Bio gas plant.
xvi. Slurry treatment parameters for efficient utilization of Bio gas fuels.
xvii. Identify the different parts of geothermal plant.
xviii. Justify the use of geothermal plant as a renewable source of energy.
xix. List the site selection criterion of geothermal plant.
xx. Identify the different parts of fuel cell.
xxi. Analyze the working of hydrogen powered vehicle.
xxii. Describe the chemical reactions in $H_2 – O_2$ fuel cell.
xxiii. Enlist the practical fields where hydrogen is used as a fuel.
xxiv. Select one specific region or country and investigate its energy mix. Discuss the primary energy sources used, the reasons for their selection.
xxv. Identify and describe at least three different types of fuel cells. Discuss how each type works and their specific applications.
xxvi. Describe real-world applications of fuel cells in various sectors, such as transportation, stationary power generation, and portable devices.
xxvii. Describe the practical applications of geothermal energy.
xxviii. Create a table or chart comparing the geothermal energy sources in terms of their production country wise.

b. Micro Projects:

i. Write a report summarizing the project, explaining the process of hydrogen production through electrolysis and its use in the fuel cell to generate electricity.
ii. Write a report explaining how wave energy is converted into electrical energy in the wave energy model.
iii. Create a visual display showcasing different renewable energy sources and their benefits.
iv. Demonstrate the working principle of non conventional energy devices (at least three) with the help of classroom models.
v. Construct a model of low cost Solar cooker.
vi. Explore different methods for tilting the axis of Solar collector to adjust for variation in Solar energy during different hours of day.
vii. Collect videos and user manuals related to maintenance of Wind mills and turbines components.
viii. Prepare a report on various types of gear boxes used in Wind mills and turbines.
ix. Prepare a list of mechanical components used in Wind mills and turbines.
x. Collect videos related to maintenance of Bio gas plants.
xi. Make a small model of low cost Bio gas plant.
xii. Build lab and desk top model to harness energy from flowing drain water, Energy from mass mobility of human and vehicles at Railway stations, Malls, Highways by modifying speed breakers, steps, stairs etc.
xiii. Build lab scale/desktop model to produce energy from wood Gasifier.
xiv. Build lab scale/desktop model to produce diesel from plastic waste.
xv. Build lab scale/desktop model to produce diesel from used vegetable oil.
xvi. Prepare a report on performance of various Geothermal, OTEC and Tidal energy systems and subsystems available in our country.
xvii. Collect state wise information of usage of Fuel cells and Hydrogen Energy through www.

c. Other Activities:

1. Seminar Topics:
   - Energy from kitchen waste
   - Diesel from plastic waste
   - Domestic Solar appliances
   - Micro wind turbines
   - Energy from wind ventilators
   - Portable biogas plants
   - Diesel from Rubber tire waste
   - Pico hydro turbines for flowing water in pipes and trenches
   - Bio diesel from Jatropha, Neem seed and other biomass.

2. Visits:
   - Visit a nearby power plant/industry related to renewable or alternate energy and prepare a report on the type of input raw materials used, equipment/method used type of energy produced, capacity, quantity of input material required, waste produced during energy generation, energy storage and transportation.
   - Visit nearby municipal/ private garbage/waste management plant and prepare a report on how CNG/ Diesel/Electricity is produced from the waste.

3. Self-Learning Topics:
   - Position of India in Solar, Wind and Hydro power generation.
   - Tidal energy
   - Hydrogen as an IC Engine fuel
   - Micro wind mills
   - Solar water heaters
   - Solar Driers
   - Gasifiers

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%	-	-	-	-
CO-2	20%	20%	20%	20%	20%	40%	20%
CO-3	20%	20%	20%	20%	20%	15%	20%
CO-4	20%	20%	20%	20%	20%	15%	20%
CO-5	15%	15%	15%	20%	20%	15%	20%
CO-6	10%	10%	10%	20%	20%	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 (Cl) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Energy Sources	10	CO1	14	4	4	6
Unit-2.0 Solar Energy	07	CO2	12	4	3	5
Unit-3.0 Wind Energy	07	CO3	10	3	3	4
Unit-4.0 Energy from Biomass	07	CO4	10	3	3	4
Unit-5.0 Geothermal Energy, Energy from Oceans	10	CO5	14	3	5	6
Unit-6.0 Fuel Cells and Hydrogen Energy	07	CO6	10	3	3	4
Total	**48**		**70**	**20**	**21**	**29**

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

O) Suggested AssessmentTable for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Identify and demonstrate working of various components used in Flat Plate Solar Collector using test rig, models, charts, visits, simulated and real videos.	CO2	40	50	10
2.	Identify and demonstrate working of various components used in Solar air heaters and Solar driers using test rig, models, charts, visits, simulated and real videos.	CO2	40	50	10
3.	Prepare a desk top model for storing heat energy using chemical storage. Measure the quantity of heat stored and duration.	CO2	40	50	10
4.	Measure the heat radiations received and heat collected in the given Flat Plate solar collector.	CO2	40	50	10
5.	Measure the heat radiations received and heat collected using a Concentrating Parabolic trough solar collector with varying tracking angles. Compare its performance with the flat plate collector.	CO2	40	50	10
6.	Estimate the performance parameters in any one: Solar water heaters/Solar distillation/Solar still/Solar cooker.	CO2	40	50	10
7.	Estimate the performance parameters in any one: Photovoltaic Solar panels, Solar PV pump, Solar Home lighting systems, Solar street lights.	CO2	40	50	10
8.	Estimate the performance parameters in any one: Solar appliances like drier, cooker, lantern etc.	CO2	40	50	10
9.	Study the operation of portable wind power generation system. Draw the characteristic curves of the generator and calculate constant of torque / current and voltage / speed of rotation of the generator.	CO3	40	50	10
10.	Evaluate performance of the rectifier and determine optimum operating points against variable atmospheric conditions	CO3	40	50	10
11.	Evaluate performance parameters of a portable Biogas plant with different mix of solid municipal waste.	CO4	40	50	10
12.	Identify and demonstrate working of various components used in Geothermal plant using models, charts, visits, simulated and real videos.	CO5	40	50	10
13.	Identify and demonstrate working of various components used in Ocean Thermal Electric Conversion (OTEC) systems using models, charts, visits, simulated and real videos.	CO5	40	50	10
14.	Identify and demonstrate working of various components used in Single basin and Double basin tidal power plants using models, charts, visits, simulated and real videos.	CO5	40	50	10
15.	Identify and demonstrate working of various components used in Proton exchange membrane fuel cells (PEMFCs), Solid oxide fuel cells (SOFCs), and alkaline fuel cells using models, charts, visits, simulated and real videos.	CO6	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.	Flat plate Solar collector	Orientation Vertical (Portrait) Height / Width / Depth (mm) 2035 / 1233 / 80 Overall collector area (mm) 2.51 Aperture area (m2) 2.35 Absorber area (m2) 2.32 Weight (empty) (kg) 38 Capacity (solar fluid) (l) 1.85 Solar glass transmission (%) 91 Solar radiation absorption (%) 95 Solar radiation emission (%) 5 Efficiency (%) 79.0 Efficiency coefficient a1 (W/M2K) 2.41 Efficiency coefficient a2 (W/M2K2) 0.049 Max operating pressure (bar) 10 Stagnation temperature (‹C) 210 Certification CE 0036 & Solar Keymark Absorber Sheet Aluminium Absorber plate coating Sunselect (selective) Absorber tube Copper Absorber tube joints Laser welded Frame Aluminium Extruded sides / sheet rear Glazing Safety glass (low iron), 3.2mm Rear insulation 40mm Solar fluid Water / propylene glycol Flow / return connections DN 16 (G3/4”)	1,4
2.	Parabolic trough Solar collector with tracking system	Parabolic trough reflecting surface Reflectors with aluminium sheet or mirror Total Collector Area 288m2 Number of collector modules 48 Number of collectors per row 8 Number of rows 6 Area of each module 6m2 Module power 2 kW Coated receiver tubes enclosed in glass Fluid Inlet Temperature (nominal) 110 C Fluid Outlet Temperature (nominal) 220 C Tracking- Moves East-West Fixed North-South; Control system-Programmable Logic Controller (PLC) or Manual; Drive mechanism-Servo or Stepper motor, single axis.	5
3.	Storage water heater test rig for laboratory	Material - SS Frequency-50/60 Phase- Single/Three Body Material Usage/Application-Laboratory Equipment Collector area-3 m2 Intercept efficiency-0.76	6

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
		Efficiency slope-15.48 kJ/hrm2K Tested flow rate-72kg/hrm2 Collector slope-45 Degrees Tank volume-0.2m3 Overall loss coefficient-5.4kJ/hrK Maximum heating rate-6500kJ/hr	
4.	Standalone Solar P V System Test Rig for Laboratory	Specifications Panel Size: 250 W, Li Fe Battery, Inverter and Load Bank. Voltmeter and Ammeter for the measurement output of the panel. Powder Coated MS Structure . Number Of Phases Single Phase Sliding Speed 1400 rpm Pipe Diameter 100 mm Cooling Tower Air Cooled Accuracy +- 2%	7
5.	Solar Dryer	Thickness of insulation to drying box13 mm cork-sheet Number of drying trays-1 Size of the drying tray-560 x 560 mm Solar air heating collector area 0.376 m2 Overall size of the storage box- 660 x 610 x610 mm3 Type of the fan-12V, DC. Size: 13x13mm2 Top cover of the box=Glass covers of 4 mm Thickness of the PVC-Sheet thick 5 mm Inclination of the solar glass with respect horizontal-25°	8
6.	Solar appliances like drier, cooker, lantern etc.	• Solar Lantern: Housing material ABS, Chimney Material Acrylic, Polycarbonate or Shane, LED SMD LED, SPV Module High efficiency silicon cell based SPV module, Battery 12V-7.2Ah @ C-20 SMF lead acid battery of Absorbed Electrolyte type. • Solar Fan: High speed ceiling fan, Operated by 12V DC 1.5A, RPM = 320, SIZE = 1200MM, MULTI SPEED • Solar Air drier: can generate hot air with temperature ranges from 40°C to 100°C. used for removing moisture from variety of agricultural products and food items without causing any harmful affect • Solar water pumps • Solar torches • Solar street lighting systems • Solar traffic blinker • Solar mobile charger	6, 7, 8
7.	Windmill Power Plant Trainer	Structure of anodized aluminum. Single-phase network analyzer with indication of active, reactive and apparent power, current, voltage, frequency, power factor, etc. Three-phase synchronous generator of permanent magnets. Battery Charge Controller: Regulator with operation 12 or 24V DC, and maximum current = 10A. Maximum input voltage = 45V. Battery of 12V 12Ah. 1.5 kW asynchronous motor. STECA 200VA 230V / 50Hz inverter. Frequency inverter 1,5 kW. Data acquisition module. Computer with software (SCADA system). DIMENSIONS: Generator-engine structure: 790x450x80 mm. Panel modules structure: 1080x510x1150 mm. Input: 230V/50Hz.	9, 10
8.	Demonstration model of Biogas plant.	Portable Domestic Biogas Plant Plant Capacity: 1 Cubic Meter, 1 Kg	11

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
		Usage/Application: Making Cooking Gas Area to Be Covered: 4 feet X 4 feet Waste Input: 1 Kg Body: Plastic With pipe, pressure gauge, regulator and burner	
9.	Models, Charts and videos related to non-conventional sources of energy	Standard	All

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Non-conventional Energy Sources	G D RAI	Khanna, ISBN-10. 9788174090737 ISBN-13. 978-8174090737
2.	Non-conventional Energy Sources and Utilization	O. P. Khanna	S. Chand
3.	Non-conventional Sources of Energy (Hindi)	S.S.L. PATEL	Standard Publishers and Distributors

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc22_me75/preview
2. Introduction: http://indiacore.com/bulletin/kssidhu-non-conventional-energy-resources.pdf
3. Introduction : http://www.newagepublishers.com/samplechapter/000329.pdf
4. Wind turbines : http://wind.machine-reliability.com/?adtype=Maschinenausf%C3%A4lle&addate=20161117&gclid=CJ350N6Wk9QCFdKHaAodYLICXw
5. Wind turbines : http://www.awea.org/operations-and-maintenance
6. Wind turbines : http://www.windmeasurementinternational.com/wind-turbines/om-turbines.php
7. Wind turbines : https://www.gerenewableenergy.com/wind-energy/turbine-services/wind-turbine-maintenance.html
8. Wind turbines : https://www.wind-energy-the-facts.org/operation-and-maintenance-costs-of-wind-generated-power.html
9. Wind turbines : http://archive.northsearegion.eu/files/repository/20120320111424_PC_Skills-Compendiuminmaintenance.pdf
10. Solar panels : https://www.thesolarco.com/how-to-maintain-your-solar-panels/
11. Solar panels : http://www.wikihow.com/Maintain-a-Solar-Panel
12. Solar panels : http://www.poweringhealth.org/Pubs/Guyana_Solar_PV_Systems_Maintenance_Guide.pdf
13. Parabolic trough collector maintenance: http://mnre.gov.in/file-manager/UserFiles/CST-Manuals/PTC_E.pdf
14. Flat plate solar collector maintenance: http://www.htproducts.com/literature/lp-364.pdf
15. Specifications of solar devices: http://mnre.gov.in/information/systems-specifications/

16. Biogas plants : http://www.snv.org/public/cms/sites/default/files/explore/download/handbook_on_operation_and_maintenance_of_biogas_plants_bio-slurry_use_and_management.pdf
17. Biogas plants : http://collections.infocollections.org/ukedu/en/d/Jg33ime/15.html
18. Biogas plants : https://www.youtube.com/watch?v=iOsixN3nTsc
19. Solar cooker : https://www.youtube.com/watch?v=7rYFXCciEx4
20. Solar cooker : http://www.sempersolaris.com/guide-solar-cookers/
21. Wind turbine : https://www.youtube.com/watch?v=oPhNQ35_Dwo
22. Wind turbine : https://www.youtube.com/watch?v=OzfM9NVgcjI
23. Wind turbine : https://www.youtube.com/watch?v=haPheNEitHQ
24. Fuel cells: https://www.youtube.com/watch?v=_TqSU21aWoA

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:

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

*****

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 ensurethe 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, Sustainabilityand 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 TSO 4f: Implement Bidirectional Associative Memory (BAM) model in Artificial Neural Network	**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**
TSO 5a. Illustrate the features of Tens or flow TSO 5b. Manipulate tensors TSO 5c. Explain features of Tens or Board	**Unit-5.0 Tensor flow** features of TensorFlow, Tensor Data structure- Rank, shape, type, one dimension	**CO-5**

Major Theory Session Outcomes (TSOs)	Units	Relevant Cos Number (s)
visualization TSO 5d Explain the concept and features of Tens or flow playground	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	

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 SessionOutcomes (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 algorithms and comment on the quality of clustering. You can add Python ML library classes/API in the program.	CO-2

Practical/Lab SessionOutcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
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 linewith 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 (Cl) 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
5.	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
6.	Artificial Intelligence: Concepts, Techniques and Applications	Alexis Keller	States Academic Press, 2022 ISBN-9781649649245
7.	Artificial Intelligence: An Introduction	Jacob Pearson	Willford Press 2022 ISBN 9781682860911
8.	Fundamentals of Machine Learning	Mia Williams	Willford Press 2022 ISBN 9781682860920
9.	Artificial Intelligence: A Modern Approach	Emilia Stones	Larsen and Keller Education 2022 ISBN 9781641728525

(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/P2400604C/S2400604C)**

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-

Use basic Python features in Programming.
Use advance Python features in Programming.
Explain features of Cloud and IoT data storage on it.
Explain IoT Networking and its application.
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**
	3	3	2	2	-	2	-		
	3	3	2	2	-	2	-		
	1	-	3	2	2	2	2		
	1	-	2	3	-	2	2		
	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.

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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.

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: -** Installation of Python Variables, Print () function, Escape character sequence and run python Program Python Tuple, Dictionary, operators Python arrays, create, reverse and append data into it. Python 2 Dimensional arrays. 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 2.0 Python Advance: -** 2.1 Python Do & while loops 2.2 Python break, continue, pass statements 2.3 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 C05**
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: -** Cloud computing and IoT cloud Benefits of cloud in IoT Types of Cloud public, private and hybrid Cloud services like SaaS, PaaS and IaaS Cloud connectivity and Data storage on Cloud. Arduino: Architecture, Programming, and Applications 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.4.0 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. 5.0 IoT App Development**: - Framework selection for IoT app development Identify stages of app to be developed. Develop, Implement, and Deploy the App Testing and Integration 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.	Install given version of Python on the computer system. Prepare a python program using print() function and run it. Access given value from the tuple Print the given value of key from the dict. Write a Python program to create an array of 5 integers and display the array items. Access individual element through indexes Write a Python program which takes two digits m (row) and n (column) as input and generates a two-dimensional array. Write a python program to check whether person is eligible for voting or not. (accept age from the user) Write a python program to check whether the entered number is even or odd. Write a python program to check whether entered number is divisible by another entered number. 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.	Prepare a python program which can print first 10 even and odd numbers using while statement Write a python program which can print first 10 integers and its square using while/for loop. Write a python program which can print sum of first 10 natural numbers using while/for loop. Write a python program which can identify the prime number between the range given using while/for loop. 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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
		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. Create a Class with instance attributes Create a Vehicle class without any variables and methods Write a Python function to find the Max of three numbers. Write a Python program to reverse a string.	
Signup for free cloud storage Store data into cloud and retrieve it.	3.	Create a free cloud account 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.

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

Micro Projects:

Prepare a report on Python programming language.
Develop a small software in python to solve a IoT data analysis.
Create a id on free cloud storage and share data on it for others.
Create a heterogenous network and connect different dives.
Create a an IoT app for the identified problem

Other Activities:

Seminar Topics: - "Future of wireless network."
"Smart electricity billing ", "Cloud computing and IoT"
Visit to industry for IoT implementation in industrial process.
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.
Building IoT Applications like pressure, air quality, temperature and motion detector using Arduino and raspberry-pi Universal boards.
Surveys of market for availability of various types of network devices and its pricing.
Product Development: Development of projects for real life problem solution app.
Software Development: Using Python

d. Self-Learning Topics:

Deeper knowledge in Python features
Network devices and its capabilities
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, C03	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** (%)	
	Install given version of Python the computer system.	CO-1	70	20	10
	Prepare a python program using print() function and run it.	CO-1	60	30	10
	Access given value from the tuple	CO-1	60	30	10
	Print the given value of key from the dict.	CO-1	60	30	10
	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
	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
	Write a python program to check whether person is eligible for voting or not. (accept age from the user)	CO-1	60	30	10
	Write a python program to check whether the entered number is even or odd.	CO-1	60	30	10
	Write a python program to check whether entered number is divisible by another entered number.	CO-1	60	30	10
	Write a python program to display “Yes” is entered number is divisible by 5 otherwise display “No”	CO-1	60	30	10
	Prepare a python program which can print first 10 even and odd numbers using while statement	CO-2	60	30	10
	Write a python program which can print first 10 integers and its square using while/for loop.	CO-2	60	30	10
	Write a python program which can print sum of first 10 natural numbers using while/for loop.	CO-2	60	30	10
	Write a python program which can identify the prime number between the range given using while/for loop.	CO-2	60	30	10
	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
	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

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA /ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
	Create a Class with instance attributes	CO-2	60	30	10
	Create a Vehicle class without any variables and methods	CO-2	60	30	10
	Write a Python function to find the Max of three numbers.	CO-2	60	30	10
1.	Write a Python program to reverse a string.	CO-2	60	30	10
2.	Create a free cloud account	CO-3	70	20	10
3.	Store data on cloud and retrieve it.	CO-3	60	30	10
4.	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
5.	Connect the computers in Local Area Network	CO-4	70	20	10
6.	Connect 2 or more devices using Bluetooth	CO-4	70	20	10
7.	Connect 2 or more devices using infrared	CO-4	70	20	10
8.	Connect 2 more machine using m2m	CO-4	70	20	10
9.	Connect 2 or more different devices using access point	CO-4	70	20	10
10.	Connect 2 devices suing LPWAN (Smart Meter)	CO-4	70	20	10
11.	Connect 2 or more devices using RFID	CO-4	70	20	10
12.	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.

K) 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 connecters 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	-
7	Arduino development board	Arduino Uno and Arduino Nano.	-
8	Raspberry Pi	Raspberry Pi 4/ Raspberry Pi 3/ Raspberry Pi 2	-

R) Suggested Learning Resources:

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
6	Fundamentals of Internet of Things	Eden Scott	States Academic Press 2023 ISBN 9781649649235
7	Internet of Things	Alaina Wilson	Murphy & Moore Publishing 2023 ISBN 9781649872731
8	Principles of Internet of Things	Hallie Parker	Larsen and Keller Education 2023 ISBN 9781641728312 (b)

(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:

Legend:

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

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 • Free body diagram of drone • Method of finding resultant of force system • Equilibrium of coplanar force system 1.2 Center of Gravity • Centroid of plane figure • Center of gravity of solid bodies 1.3 Force analysis in drone • Force analysis in drone • Forces of flight • Principle axes and rotation of aerial systems 1.4 Dynamics of machine • 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 • Calculation principle for drome frame sizes • Quadcopter frame design • Smart materials for UAV frame • Green material uses in drone 2.2 Advance Drones component • GPS, Interfacing of GPS hardware • Thermal and chemical sensor • Tilt and LiDAR sensor 2.3 RF transmitter and receiver • RF blocks • RF antennas 2.4 Micro-electromechanical systems (MEMS) based sensor 2.5 HD and thermal Image camera	**CO-2**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number (s)
TSO 3a. Identify features and specifications of FCB use in different application TSO 3b. Explain ports of any given advance flight controller board. 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.	**Unit-3.0 Advance Flight Controller Board (FCB)** 3.1 Specification and ports of FCB 3.2 Software for FCB • Software installation 3.3 Radio Communication with FCB • 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	**CO-3**
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 • 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 • 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 • 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 done 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 5.2Measure 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 Identity 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 done 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

7.	Drone Technology	Miranda Hall	NY Research Press 2023 ISBN 9781632389574
8.	Introduction to UAV Systems	Rupert Baker	Willford Press 2023 ISBN 9781682860890
9.	Theory, Design, and Applications of Unmanned Aerial Vehicles	Tyler Wood	Larsen and Keller Education 2023 ISBN 9781641728338

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	4.8 Cost estimation of SLS based 3D printed component.	
TSO 5a. Justify the need of post processing in the given 3D printed component. *TSO 5b.* List the various post processing techniques. *TSO 5c.* List the steps to perform post processing. *TSO 5d.* Explain the given Cleaning related post processing approach for 3D printed component. *TSO 5e.* Explain the given Surface finishing related post processing approach for 3D printed component. *TSO 5f.* Apply simple inspection and testing techniques on the given 3D printed component. *TSO 5g.* Identify the type of defect(s) in the given 3D printed component.	**Unit-5.0 Post Processing and Quality** 5.1 Need of post processing: Functional and Aesthetic reasons. 5.2 Steps of Post Processing: Cleaning/Support removal, Fixing, Curing or hardening, Surface finishing, Colouring. 5.3 Cleaning: Support Removal (FDM and Material Jetting); Powder Removal (SLS and Powder Bed Fusion); Washing (SLA and Photo polymerisation). 5.4 Fixing: Filling, Gluing, Welding. 5.5 Surface finishing: Sanding, Polishing, Tumbling, Hydro dipping, Epoxy coating, Electro Plating, Vapour smoothing-Acetone treatment. 5.6 Colouring, Coating, Priming and Painting. 5.7 Inspection and testing: Digital, Visual, Physical. 5.8 Defects and their causes.	**CO1, CO2, CO3, 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: P2400604E

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Use the available 3D printing software. *LSO 1.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 1.3.* Set printing process parameters. *LSO 1.4.* Produce a complex component using available FDM Printer.	1.	Develop the assigned digital single complex component using FDM based 3D Printer and available material.	CO1, CO2
LSO 2.1. Use the available 3D printing software. *LSO 2.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 2.3.* Set printing process parameters. *LSO 2.4.* Produce a complex component using available SLA Printer. *LSO 2.5.* Perform curing of the SLA based 3D printed component.	2.	Develop the assigned digital single complex component using SLA based 3D Printer and available material.	CO1, CO3
LSO 3.1. Use the available 3D printing software. *LSO 3.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 3.3.* Set printing process parameters. *LSO 3.4.* Produce a complex component using available SLS Printer.	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)
LSO 4.1. Use the available 3D printing software. *LSO 4.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 4.3.* Set printing process parameters. *LSO 4.4.* Produce a complex component using available FDM, SLA and SLS Printer. *LSO 4.5.* Perform Cost, Time, Surface finish and Strength estimations related to 3D printed components.	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
LSO 5.1. Use the available 3D printing software. *LSO 5.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 5.3.* Select appropriate tolerance, fit and printing process parameters. *LSO 5.4.* Produce an assembly using available SLA/SLS Printer.	5.	Print one digital assembly on SLA/SLS based 3D Printer.	CO2/CO3/ CO4
LSO 6.1. Use of available 3D scanner. *LSO 6.2.* Develop 3D digital model using scanning approach. *LSO 6.3.* Use the available 3D printing software. *LSO 6.4.* Produce a complex component using available SLA Printer.	6.	Scan the given real complex component and print it using FDM/SLA/SLS based 3D Printer.	CO2, CO3, CO4
LSO 7.1. Identify tools/devices/chemicals for post processing *LSO 7.2.* Perform post processing operations on printed component.	7.	Apply post processing techniques on the 3D printed component of experiment number 1 and/or 2 and/or 3.	CO5
LSO 8.1. Identify tools/devices/techniques for inspection and testing. *LSO 8.2.* Identify the defects in 3D printed components *LSO 8.3.* Apply remedial measures to bring soundness in the defective 3D printed component.	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.

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

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
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	7

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
		removal spatula, Needle file, Cutting mat, Glue stick, Wire stripper, Chemicals, Etching agents etc.	
10.	Inspection and Testing devices	• 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 strenght • 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
7.	3D Printing: A Practical Guide	Clay Martin	Larsen and Keller Education 2023 ISBN 9781641728323
8.	Fundamentals of 3D Printing	Elizah Brooks	Clanrye International 2023 ISBN 9781647290943
9.	Principles of 3D Printing	Brady Hunter	NY Research Press 2023 ISBN 9781632389549

(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=TQY2lF-sFaI
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 recourses 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 Schöffer, Brian Garret, 3D Hubs; 1st edition, 2017
3. https://www.improprecision.com/inspection-method-for-3d-printed-parts/
4. 3D Printer Users' Guide
5. 3D Printer Material Handbook
6. Lab Manuals

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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/ Developmen tof Solutions	**PO-4** EngineeringTools	**PO-5** Engineering Practices for Society, Sustainability and Environment	**PO-6** Project Managem ent	**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:

Legend:

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

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.	**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.	**CO-3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.3d Explain preventive maintenance procedure associated with PLC system to reduce environmental impact TSO.3e Identify faults in the given PLC system TSO.3f Explain the procedure for Troubleshooting PLC system TSO.3g Prepare preventive maintenance plan for the PLC system TSO.3h Use safety equipment's. TSO.3i Follow safe practices	3.2 Introduction to PLC Trouble shooting and maintenance, trouble shooting of hardware and software. 3.3 Diagnostic LED Indicators in PLCs 3.4 Common problems • 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 3.5 Troubleshooting of Specific Components of the PLC System • Power Supply Troubleshooting • I/O Modules Troubleshooting • Troubleshooting PLC Program Errors • Troubleshooting the Working Environment of a PLC • Replacement of CPU 3.6 PLC trouble shooting flowchart 3.7 PLC maintenance – PLC maintenance checklist, preventive maintenance procedure, maintenance plan for the PLC system. 3.8 Safety procedure and safety equipment's.	
TSO.4.a Describe the function of given element of a SCADA system. TSO.4.b Interface the given PLC with SCADA system using the given Open Platform Communications (OPC). TSO.4.c Describe the steps to develop a simple SCADA screen for the given industrial application. TSO.4.d Describe the procedure to maintain the SCADA based PLC system for the given application.	**Unit-4.0 SCADA and DCS** 4.1 Introduction, need, benefits and typical applications of SCADA and DCS 4.2 SCADA Architecture - Remote Terminal Units (RTUs), Master Terminal Units, Various SCADA editors, Communication protocols for SCADA 4.3 Comparison of SCADA with DCS 4.4 Interfacing SCADA system with PLC- Typical connection diagram, Object Linking and Embedding for Process Control (OPC) architecture 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. 4.6 Procedure to maintain the SCADA based PLC system.	**CO-3**
TSO.5a Identify different components used for automation in the given system TSO.5b Select automation components for a given situation TSO.5c In the given manufacturing or service industry Identify the areas where automation is possible.	**Unit-5.0 Applications of Industrial Automation** 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.	**CO-5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.5d Prepare plan for sustainable automation as per the requirement.	5.2 **Health Care-** microscopic robots for medical diagnosis, automated medication dispensing devices, AESOP, ZEUS, RP_7(remote presence 7th generation), DaVinci 5.3 **Defense- guided rockets and missiles,** counter measures, UAV drones, launcher, radar antenna, engagement control system 5.4 **Automobile –B**reak 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 5.5 **Agriculture-** harvesters, irrigation systems, plowing machines, self-driving tractors, grain yield sensor **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	

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)
LSO 1.1	Data communication from PLC to PC and vice versa	1.	Transfer the control data from PLC to PC and vice versa	CO1
LSO 1.2	Establish Communication channels between PLC s.	2.	Transfer the control data from PLC to PLC	CO1
LSO 1.3	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
LSO 1.4	Interface the given PLC with a PC or a Laptop	4.	Interface the given PLC with a PC or a Laptop	CO1
LSO 2.1	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
LSO 2.2	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
LSO 2.3	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
LSO 2.4	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
LSO 2.5	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
LSO 2.6	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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 2.7 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
LSO 2.8 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
LSO 3.1 Use hygrometer to measure the humidity inside the panel *LSO 3.2* Use thermometer to measure ambient temperature inside the panel *LSO 3.3* Use tester to determine the voltage fluctuation at the power supply terminals is within specifications *LSO 3.4* Test the ground connections of the given PLC. *LSO 3.5* 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 *LSO 3.6* Investigate the cause of Noise in the given PLC *LSO 3.7* PLC goes on blackout out by losing its operating power. Troubleshoot the cause of failure. *LSO 3.8* Troubleshoot the corrupted PLC memory. *LSO 3.9* Replace CPU and power supply fuses in a given PLC system.	13.	Troubleshooting of PLC system	CO3
LSO 4.1 Download any open source SCADA software and install the same. *LSO 4.2* Interpret the available components in symbol factory of SCADA software *LSO 4.3* Create simple SCADA HMI applications and apply dynamic properties. (Select any Three from the given list) 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. *LSO 4.4* Create historical and real time trends for the given automation	14.	Develop simple SCADA HMI applications using any one open source SCADA software and apply dynamic properties	CO4
LSO 5.1 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.	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)
LSO 5.2 Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application *LSO 5.3* 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. *LSO 5.4* Develop a Automation system to Open and close the door in the shop *LSO 5.5* Develop a line following robot with RFID sensor for supplying materials and automating workflow. *LSO 5.6* 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. *LSO 5.7* Develop smart automated railway crossing system to detect train arrival and departure and send appropriate signals to the microcontroller.			

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		
			Performance		Viva-Voce (%)
			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		
			Performance		Viva-Voce (%)
			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

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
5.	Hand tools	Screwdrivers, Hammers, Hand saws, Hex Key Allen Wrench Set Inch and Metric, relay puller, Multi-Tool Wire Stripper/Crimper/Cutter	13
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 -0.1egree 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
11.	Industrial Automation: Systems and Engineering	Geoffrey Williamson	States Academic Press , 2022 ISBN 9781649649270

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
12.	Industrial Automation Technologies	Jane Taylor	States Academic Press 2023 ISBN 9781649649255
13.	Introduction to Industrial Automation	Kian Pearson	Willford Press 2023, ISBN 9781682860864

(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)					
		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

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)	
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 • 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.	**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.	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
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. TSO 3j. Describe the Mechanism of Gear and Differential Assembly.	**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	
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.	• 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.	• Testing of Motors	
LSO 2.4 Test the continuity of the automotive wiring system in the EV	3.	• Testing of the automotive wiring system.	

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
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 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.	4.	• Testing of Batteries used in EVs	CO2, CO3
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.	• 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.	• 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.	• Impacts of G2V and V2G	CO 5
LSO 5.2 Prepare a layout of a charging station	8.	• 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:

1. Design and build a physical model of an EV motor and powertrain components from scratch.
2. Build and simulate communication systems of EVs using some software tools.
3. Prepare a report on "the way carbon credit works and companies utilize it to reduce their emission values".
4. 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 (Cl) 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. N.	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		60	30	10
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
10.	Electric Vehicle Engineering	Liana Walker	lanrye International2023, ISBN-978164729097
11.	Electric Vehicles: Current Progress & Technologies	Vanessa Jones	Murphy & Moore Publishing 2023, ISBN 9781649872746
12.	Electric and Hybrid Vehicles: Principles, Design and Technology	Mary Murphy	Larsen and Keller Education 2023 ISBN 9781641728520

(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 recourses before use by the students.

(c) Others:

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

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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.	**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	**CO2, CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
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.	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	
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.	1.5 Robot Industrial applications: • Welding Robots-Welding Guns, Welding Electrodes, Welding Power Sources, shielding gases, Robot interfacing • Spray painting Robots, assembly operation, cleaning.	
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. TSO 4e. Select a robot on the basis of cycle time analysis. TSO 4f. Conduct an economic analysis for use of robots. TSO 4g. Follow testing methods and acceptance rules for industrial robots.	**Unit– 4.0 Robot Programming and Economics of Robotization** 4.1 Characteristics of task level languages through programming methods 4.2 Motion interpolation 4.3 Artificial intelligence: Goals of artificial intelligence, AI techniques, problem representation in AI 4.4 Problem reduction and solution techniques. 4.5 Application of AI and KBES in Robots 4.6 Selection of Robots; Factors influencing the choice of a robot, selection of robot components, robot performance testing, work cycle time analysis 4.7 Economics analysis for robotics, cost data required for the analysis 4.8 Methods of economic analysis; Pay	**CO1, CO4, CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	back method, equivalent uniform annual cost method, return on investment method. 4.9 Testing methods and acceptance rules for industrial robots	
TSO 5a. Describe applications of robots in healthcare and medicine. TSO 5b. Describe applications of robots in Construction industry. TSO 5c. Describe applications of robots in Underground coal mining. TSO 5d. Describe applications of robots in uutilities, military & firefighting operations. TSO 5e. Describe applications of robots in undersea and space TSO 5f. Describe applications of robots in brief in logistics, retail and hospitality, and smart cities. 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	**Unit–5.0 Applications in Non-manufacturing Environments** 5.1 Applications of Robots in • Healthcare and medicine • Construction industry • Underground coal mines • Utilities, military & firefighting operations • Undersea • Space • Logistics, • Retail and Hospitality • Smart Cities • Farming and Agriculture 5.2 Overview of Microrobots, nano robots, soft robots, humanoid robots	**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.	6.	Design a PC controlled wireless Multipurpose robot for simple engineering applications.	CO2, CO4, CO5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 6.2 Integrate the components for the required application.			
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 14.1Develop a program for an industrial application. LSO 14.2Execute 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 (Cl) 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 beprepared 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	• 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)
		  • J1 Axis Rotation7.85 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 17.45ras/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-m^2 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	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: ±0.2Tip Velocity range: 500 mm / minPay load capacity: 2 kg (including griper) 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/O8 Programmable digital inputs8 Programmable digital outputs	8, 9, 14
3.	A mounted vision system with software (Free open source Robot simulation software)	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 12C); Motor interface PCB includes a 13-Bit temperature-to-digital converter with a temperature range from −40°C to 125°C (Analog Devices ADT7302)	3, 4, 5, 11

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
4.	6-axis Robotics Trainer	Programmable robotic arm with an interactive front panel. Software to demonstrates functioning of the 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 PL**C;** Touch operated ON/OFF Switch**;** Auto set to home position**;** Applications can be developed**;** Data acquisition using USB	3, 4, 5, 13
5.	E-Yantra Firebird kit	• 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

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
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
11.	Mechatronics: Engineering Fundamentals	Allie Weaver	Murphy & Moore Publishing 2022 ISBN 9781649872758
12.	Elements of Robotics	Greg Scott	States Academic Press 2022 ISBN 9781649649261
13.	Robotics: Design, Construction and Applications	Allie Weaver	Willford Press 2022 ISBN 9781682860944
14.	Modern Robotics: Mechanics, Systems and Control	Julian Evans	Larsen and Keller Education 2022 ISBN 9781641728515
15.	Introduction to Mechatronics	Randy Dodd	Larsen and Keller Education 2022 ISBN 9781641728493
16.	Introduction to Robotics	Julian Evans	Larsen and Keller Education 2022 ISBN 9781641728503

(b) Online Educational Resources:

1. https://web.iitd.ac.in/~saha/ethiopia/appln.pdf
2. https://nptel.ac.in/courses/112105249
3. https://www.robotsscience.com/industrial/industrial-robots-types-applications-benefits-and-future/
4. https://www.marian.ac.in/public/images/uploads/pdf/online-class/MODULE-6%20ROBOTICS%20INDL_APPLNS-converted.pdf
5. https://forcedesign.biz/blog/5-common-industrial-robot-applications
6. https://www.hitechnectar.com/blogs/top-industrial-robotics-applications-role-of-robots-in-manufacturing/
7. https://en.wikipedia.org/wiki/Industrial_robot
8. https://www.youtube.com/watch?v=fH4VwTgfyrQ
9. https://www.youtube.com/watch?v=aW_BM_S0z4k
10. https://www.automate.org/industry-insights/smarter-robot-grasping-with-sensors-software-the-cloud
11. https://robots.ieee.org/robots/?t=all
12. 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/9a0dacfdec8aa03dc12578ca003bfd2a/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

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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-6 Analyze the materials used in transformer manufacturing.
CO-7 Assemble the transformer based on specific requirements.
CO-8 Design using software based on specific requirements.
CO-9 Analyze the working conditions of transformers.
CO-10 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)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+ SL)	Total Credits (C)
		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.

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: T2400604I

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1d. Explain the use of different materials in transformers. *TSO 1e.* List the various types of materials used in transformers. *TSO 1f.* Explain the insulating materials. *TSO 1g.* Explain the winding material. *TSO 1h.* Explain the magnetic materials.	**Unit-1.0 Transformer Materials** 1.5 Review of basic materials and their processing 1.6 Insulating oil, insulating paper, pressboard, wood 1.7 Insulated copper conductor for windings, crepe paper, sealing materials 1.8 cold–rolled grain oriented electrical steel sheet, structural steel, future trends 1.9 Magnetic Circuit Materials	**CO1**
TSO 2f. Explain the basic concept of transformer design. *TSO 2g.* List the various parameters to be considered during design. *TSO 2h.* Choose the number of turns, the core diameter. *TSO 2i.* Select the winding wires and strips. *TSO 2j.* Choose the size of HV and LV conductors.	**Unit-2.0 Transformer Design** 2.5 Basic Concept of Design. 2.6 Selection of number of turns. 2.7 Selection of core diameter. 2.8 Selection of winding wires and strips. 2.9 Size HV and LV conductors. 2.10 Transposition	**CO1, CO2**
TSO 3e. Explain the concept of computer aided design. *TSO 3f.* Learn the programming skills, *TSO 3g.* Modify the programming considering other aspects. *TSO 3h.* Validate and print the design. *TSO 3i.* Use software to design.	**Unit-3.0 Transformer Design – Using CAD** 3.5 Computer aided design: Basic concept, specification needs. 3.6 Computer programming, variable inputs, program convergence. 3.7 Design output, design modification, other aspects of design. 3.8 Design validation, design package, computer design printout. 3.9 Software application for design.	**CO3, CO4**
TSO 4e. Explain the testing of Transformer oil. *TSO 4f.* Use of Transformer oil. *TSO 4g.* List the causes of oil ageing. *TSO 4h.* List the various tests to monitor the working conditions of a transformer.	**Unit-4.0 Transformer Condition Monitoring** 4.5 Transformer oil testing and Interpretation 4.6 Introduction, mineral insulating oil. 4.7 Four functions of transformer oil. 4.8 Causes of oil ageing. 4.9 Various tests on transformer oil such as power factor, moisture, neutralization number, interfacial tension, relative density, color, visual examination, breakdown voltage, dissolved gas analysis.	**CO3, CO4**
TSO 5a. Apply the concepts for practical use. *TSO 5b.* Design a practical power transformer.	**Unit-5.0 Transformer Design - Practical Applications** 5.1 Design of a 100 KVA transformer. 5.2 Design of 630 KVA transformer. 5.3 Design of 5 MVA, 33/11 KV transformer	**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)
LSO 1.1. Knowledge of knowing the various components of a power transformer. *LSO 1.2.* Explain the use of those components in the power transformer.	1.	Dismantling a power transformer and understanding various components.	**CO1**
LSO 2.1. Design a transformer using computer programming considering various aspects.	2.	Designing a transformer using computer programming.	**CO1**
LSO 3.1. Use of a commercial software to design a transformer.	3.	Application of software for transformer design.	**CO1**
LSO 4.1. Understand the breakdown voltage (BDV) of transformer oil.	4.	Breakdown voltage test of transformer oil.	**CO2**
LSO 5.1. Explain the practical applications of power transformers. *LSO 5.2.* 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.

d. 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.

e. 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.

f. Other Activities:

4. 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.

5. 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.

6. 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 (Cl) 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 beprepared 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:

(b) 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:

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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-11 Analyze various 5G radio-access technologies.

CO-12 Identify different components of GSM architecture.

CO-13 Describe the channel and channel behavior of the wireless channel.

CO-14 Analyze different mitigation techniques.

CO-15 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.

III) 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)
TSO 1i. Highlight the need for 5G communication system. *TSO 1j.* Describe the radio spectrum andchannel model with the help of suitable sketch and tables. *TSO 1k.* Describe the working of the 5G physical layer with the help of a suitable sketch. ~~*TSO 1l.*~~ Describe 5G network slicing with an example. *TSO 1m.* Explain the mobility and hands-off management in 5G environment.	**Unit-1.0 5G Radio Access Technology** 1.10 5G Radio Spectrum 1.11 5G Channel Model 1.12 Radio Interface Architecture 1.13 5G Physical Layer 1.14 5G Radio-Access Technologies 1.15 Introduction To 5G Network Slicing 1.16 Mobility and Handoff Management In 5G	**CO1**
TSO 2k. Describe the architecture and key components of basic GSM (Global System for Mobile Communications) networks. *TSO 2l.* List the components of the GSM(LTE) system. *TSO 2m.* Describe the working of the various components and their functions of the given type of wireless communication network *TSO 2n.* Analyze the functions of base station subsystems (BS)	**Unit-2.0 Study of GSM Architecture** 2.11 GSM System Architecture (LTE) 2.12 Explain the different components of Wireless Communication Network 2.13 Operation of base station (BS) subsystems	**CO2**
TSO 3j. Explain different principles and various factors affecting radio wave propagation in different environments. *TSO 3k.* Apply the free space propagation model to estimate signal strength and coverage. *TSO 3l.* Explain how reflection, scattering, and diffraction impact radio wave behaviour and signal quality. *TSO 3m.* Use the given type of path loss models to predict signal degradation over distance. *TSO 3n.* Differentiate between large-scale and small-scale fading and their effects on wireless communication. *TSO 3o.* Analyze the characteristics and behaviour of wireless channels, including their impact on signal transmission. *TSO 3p.* List the noise sources present in the wireless channel. *TSO 3q.* Describe the effects of noise on signal propagation through wireless channels and its impact on signal quality. *TSO 3r.* Calculate the capacity of channels with Additive White Gaussian Noise (AWGN).	**Unit-3.0 Channel and channel behavior** 3.10 Analysis of radio wave propagation 3.11 Free Space Propagation Model 3.12 Reflection, Scattering, Diffraction of Radio Waves 3.13 Path Loss Models 3.14 Study of Fading (Large, small-scale fading) 3.15 Analysis of Wireless Channel 3.16 Analysis of Noise, types of noise 3.17 Capacity of AWGN and Fading Channel (only formula and its variable parameters)	**CO3**
TSO 4i. Describe various diversity techniques to improve signal reliability and performance in wireless communication. *TSO 4j.* Describe receiver diversity methods and their impact on enhancing signal quality and reducing errors. *TSO 4k.* Describe transmitter diversity techniques and their role in mitigating fading and improving communication robustness. *TSO 4l.* Describe the principles and applications of Multiple Input Multiple Output (MIMO) technology. *TSO 4m.* Suggest the techniques to correct distortions and mitigate inter-symbol interference in wireless communication systems.	**Unit-4.0 Mitigation Techniques** 4.10 Diversity techniques 4.11 Analysis of various receiver diversity techniques 4.12 Analysis of various transmitter diversity techniques 4.13 MIMO technology advantages in communication systems 4.14 Equalization techniques and their importance in communication systems	**CO4**
TSO 5c. Discuss the various types of dispersion in optical fibre design *TSO 5d.* Explain the optimization technique of single mode fibre.	**Unit-5.0 Advanced Optical Fiber Communication and Emerging Technologies**	**CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5e. Describe the working and characteristics of different optical networks. *TSO 5f.* Explain the nonlinear effect on network performance of optical fibre systems. *TSO 5g.* Explain multicarrier modulation techniques to enhance data transmission and system performance. *TSO 5h.* Describe the principles and advantages of Orthogonal Frequency Division Multiplexing (OFDM) in improving bandwidth efficiency and reducing interference. *TSO 5i.* Analyze given emerging technologies.	5.4 Advanced Optical Fiber: Dispersion issues, Dispersion shifted, Dispersion flattened, Dispersion Compensating fibre 5.5 Design and optimization of single-mode fibers 5.6 Optical Networks- Basic Networks SONET, SDH- wavelength-routed networks 5.7 Nonlinear effect on Network Performance, performance of various systems (WDM, DWDM + SOA) 5.8 Multicarrier Modulation Technique 5.9 Orthogonal Frequency Division Multiplexing (OFDM) 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	

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)
LSO 1.3. Noise Modelling and its effect on Wireless Data Transmission	1.	Characterization and Impact of Noise on Wireless Data Transmission: A Comprehensive	**CO1**
LSO 2.2. Effect of fading on wireless data transmission in terms of outage probability	2.	Evaluating Fading Effects on Wireless Data Transmission: Outage Probability Analysis	**CO2**
LSO 3.2. Capacity of Wireless Channel (AWGN v/s Fading)	3.	Comparative Study of Channel Capacity: AWGN versus Fading Channels	**CO3**
LSO 4.2. Implementation of receiver diversity technique.	4.	Practical Implementation and Evaluation of Receiver Diversity Techniques in Wireless Communication	**CO4**
LSO 5.3. Implementation of transmitter diversity technique.	5.	Practical Implementation and Performance Analysis of Transmitter Diversity Techniques	**CO4**
LSO 6.1 Implement the (2X2) of MIMO system.	6.	Design and Implementation of MIMO Technology	**CO4**
LSO 7.1 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.

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

h. Micro Projects:

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.

i. Other Activities:

j. 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"

k. 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 (Cl)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 beprepared 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 recourses 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

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A) Course Code : 2425606(P2425606/S2425606)

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, 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 sessional 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 6^{th}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.

A) 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 relevanttechnical skills.
- **CO-4** Develop thecapabilities 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/ Developmen tof 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 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				
2425606	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)	
2425606	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 been 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

******

A) Course Code : **2400107 (T2400107)**

B) Course Title : Professional Ethics
(CE, CSE, ELX, ELX (R), FTS, ME, ME (Auto), AIML, MIE, CHE, CRE, FPP, GT)

C) Pre- requisite Course(s) : General awareness about moral values and different workplaces

D) Rationale :

One of the programme outcomes of the diploma course incorporates ethical practices in application of appropriate technology in context of society, sustainability, environment. It is of great importance to distinguish between the terms values and ethics. Ethics are norms of behaviour that are set by authorities at workplace. The persons belonging to that workplace are expected to follow the norms. Ethical behaviour at workplace affects the person's relation to people, creates a positive impact on business processes and environment. It is very important that a person has not only understanding of ethical behavior but also the responsibility to set ethical practices in own area of work.

While values are personal preferences or choices, they may sometimes contradict with ethics at his workplace. The values of a person affect behavior and his decision making.

This course is meant to sensitize the student to ethics in profession and motivate them to demonstrate ethical behavior in day to day activities and be aware of ethics in profession.

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 Demonstrate good values and ethics in the day to day activities and at workplace.

CO-2 Identify a set of values and ethics related to fair professional practice.

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	3	3	3	3	3		
CO-2	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:

Cousre Code	Course Title	Scheme of Study (Hours/Week)				
		Classroom Instruction (CI)		Notional Hours (TW/ Activities+ SL)	Total Hours (CI+TW/ Activities)	Total Credits (C)
		L	T			
2400107	Professional Ethics	01	-	-	01	01

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)	
2400107	Professional Ethics	25	-	-	-	-	-	25

Legend:

PTA: Progressive Theory Assessment in the 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:

- 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 assignments, micro-projects, seminars, 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 for internal as well as external assessment may vary as per the requirement of the respective course. For valid and reliable assessment, the internal faculty should prepare a 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: T2400107

Major Theory Session Outcomes (TSOs)	Units	*TSO 2o.* Relevant COs Number(s)
TSO 1a. Define concepts-values and ethics and attitude, development of attitudes *TSO 1b.* Identify situations depicting values such as humanity, honesty, punctuality, respect, peace, empathy *TSO 1c.* Identify situations depicting ethics, healthy competition, integrity, truthfulness,	**Unit-1.0 Values and Ethics in Day to Day Life** 1.1. Values- Definition and examples, Ethics- definition and examples, Concept of attitude and development of attitude 1.2. Importance of values and ethics in day to day activities and at workplace- Ethical ways of communication, environmental considerations in engineering processes, Basic concept of Carbon footprint, ethics at workplace 1.3. Examples of situations depicting values- based decisions and ethical behavior in day to Day life	**CO1**
TSO 2a. Identify the relevance of profession to society and environment *TSO 2b.* Identify the need of values and ethics in profession related activities *TSO 2c.* Identify Ethical conflicts	**Unit-2.0 Values and Ethics in Profession** 2.1 Relevance of profession to society 2.2 ethical principles such as respecting others and ourselves, respecting the rights of others, keeping promises, avoiding unnecessary problems to others, avoiding cheating and dishonesty, showing gratitude towards others and encouraging them to work 2.3 Identification of activities and related ethical and unethical behavior for professional activities in their area of work 2.4 Examples of situations depicting values- based decisions and ethical behavior	**CO1, CO2**

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

K) Suggested Activities and Self-Learning: Reading books related to values and ethics/Epics/ Daily news and discussions in group

a. Assignments: Preparation for group discussion, panel discussion, role play, case study, seminar, skits

a. Micro Projects: Skits development and performance, poster making,

b. Activities: Role Play, Case studies, Debates, Group Discussion

c. Suggested Seminar/ Debates on Topics such as:

i. charters of professions
ii. Importance of Values and ethics in identified profession
iii. Issues of ethical conflicts- Professional rivalry,
iv. Identified issues from Chanakya Neeti
v. Ethics in scriptures such as Kabir ke Dohe etc.
vi. Lessons on ethics from religious scriptures
vii. Issued based on Happenings reported in Daily news

L) 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, Case Method, Group Discussion, seminar, Role Play, Live Demonstrations in Classrooms, Lab, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

M) List of Major Laboratory Equipment, Tools and Software: (Not Applicable)

N) Suggested Learning Resources:

(c) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Professional Ethics and Human Values	D. R. Kiran	McGraw-Hill Education Pvt. Ltd. 2007 ISBN: 9780070633872
2.	A Textbook On Professional Ethics And Human Values	Dr. R S Naagarazan	New Age International (P) Ltd., Publishers, 2017 ISBN: 9789386173768
3.	Ethics, Integrity and Aptitude – **Hindi** (Paperback) (एथिक्स, सत्यनिष्ठा एवं अभिवृत्ति)	P.D Sharma	Rawat Publications, 2019 ISBN: 978-8131609941
4	Chanakya - Niti (Sutra Sahit) (Hindi)	Chanakya	Maple Press. 2014 ISBN 978-9350335529

(b) Online Educational Resources:

1. Free Ethics & Compliance Toolkit - Ethics and Compliance Initiative (https://www.ethics.org/resources/free-toolkit
2. Free & open source tools for ethics practitioners (https://www.cityethics.org/harvard-lab)
3. Microsoft Word - KPTI XII - Indian Ethics 03-05-13 (https://cbseacademic.nic.in/web_material/doc/ktpi/30_KPTI%20XII%20-%20Indian%20Ethics_old.pdfcbseacademic.nic.in)
4. Knowledge Traditions & Practices of India (cbseacademic.nic.in) (ps://cbseacademic.nic.in/web_material/Circulars/2012/68_KTPI/Module_5.pdf)

(c) Others: -

A) Course Code : 2400408(T2400408)

B) Course Title : Employability Skills Development (Common for all Programmes)

C) Pre- requisite Course(s) :

D) Rationale :

Education may only be enough to qualify for a job, but employability skills are the major criteria to be considered for a job role. Employability skills are building blocks of any career and they equip one to carry out roles in the company to the best of their ability. Employers usually check these employability skills before hiring. These sets of job-readiness skills are behaviors that are necessary for every job and are essential attitudes that enable students to grow in their careers. Employers value employability skills because they regard these as indications of how their employees will get along with other team members and customers, and how efficiently they will be able to handle the job performance and career success. Employers like to hire a technical expert who also displays well-rounded employability skills.

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 Build resume and showcase portfolio for placement activity.
CO-2 Face interviews and participate effectively in Group Discussions.
CO-3 Apply engineering tools in work situations and societal processes.

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/ Developmentof 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		
CO-2	3	-	-	-	2	2	3		
CO-3	3	-	-	3	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				
2400408	Employability Skills Development	01	-	-	-	01	01

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)	
2400408	Employability Skills Development	25	--	--	--	--	--	25

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: T2400408

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Perform SWOT analysis and reflect. *TSO 1b.* Develop skills in carrier planning & goal setting *TSO 1c.* Build a Resume using Internet formats. *TSO 1d.* Develop and Design portfolios. *TSO 1e.* Maintain good grooming attire. *TSO 1f.* Introduce oneself to others. *TSO 1g.* Develop a personal website.	**Unit-1.0 Goal Setting** 1.1 Career planning, SWOT 1.2 Resume using Internet formats. 1.3 Showcase portfolios. 1.4 Personal grooming. 1.5 Self-Introduction. 1.6 Website Development.	**CO1**
TSO 2a. Face interviews and E- Interviews confidently *TSO 2b.* Participate in group discussions. *TSO 2c.* Use Social media for personal enrichment &Netiquette *TSO 2d.* Manage self for higher growth. *TSO 2e.* Use body language for effective communication *TSO 2f.* Manage Emotions for personal growth	**Unit-2.0 Capacity Development** 2.1 Interview Skills 2.2 Group Discussion – Do's & don'ts, leadership, Teamwork, how to interrupt, synthesis, and analysis of topics. 2.3 Social Media for Personal Enrichment 2.4 Body language 2.5 Self-Management. 2.6 Emotional Intelligence	**CO2**
TSO 3a Develop & Maintain Social Contacts. TSO 3b Engage in Social Service projects. TSO-3c Collaborate for mutual advantage. TSO 3d Apply QC-Tools in work situations. TSO 3e Practice Lean Manufacturing Techniques for Production and Operations	**Unit-3.0 Utilizing Potential** 3.1 Social Networking 3.2 Social Engagements, Volunteering 3.3 Collaboration& Team-work. 3.4 QC-Tools – Check sheets, Fishbone Diagram, Histogram, Pareto chart, Control-chart, Scatter Diagram, Stratification, 3.5 Lean Manufacturing, Kanban, Kaizen, Five S, Poka-yoke, Quality Circle	**CO3**

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: - (Not Applicable)

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

a. Assignments:

1 Build a resume for Placement Activity.

2 Prepare letters for job applications.

b. Micro Projects:

1. Prepare collage for personal grooming.
2. Develop a showcase portfolio.
3. Prepare a collage of different gestures and postures of Body Language.
4. Apply Five-S in a work situation.
5. Arrange Mock Interviews, appear, and video record. Reflect on your performance.
6. Organize Group discussions on current topics and video record. Reflect on your performance

c. Other Activities:

1. Seminar Topics:
   - Emotional Intelligence.
   - 21st Century Skills.
   - Multitasking
2. Visits: Visit nearby Job Fairs, Career Guidance Fairs, etc.
3. Self-Learning Topics:
   - Use of social media.
   - Self-introduction.
   - Self-grooming.
   - QC Tools.
   - Lean Manufacturing,
   - Emotional Intelligence.

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	30%	-	-	-	-	-	-
CO-2	40%	-	-	-	-	-	-
CO-3	30%	-	-	-	-	-	-
Total Marks	**25**	**-**	-	-	-	**-**	**-**
			-				

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: (Not Applicable)

O) Suggested Assessment Table for Laboratory (Practical): (Not Applicable)

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
1.	Group Discussion Tables and chairs	Round Table with seating arrangement for 15 person
2..	Mock Interviews infrastructure	2 parallel mock interview set up with recording facility.
3.	Ear phones	Compatible with mobile phones
4	Headphones	Compatible with laptop/desk top
5	Blue tooth	Compatible with mobile phones.
7.	CC TV Camera	Compatible to record presentations and addresses.
8.	Podium	For presentations on stage.
9.	Public address system	For public meetings.
10.	Full Glass Mirrors	For monitoring Body Language

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Employability Skills Skills for Employability	Dr. M. Sen Gupta	Innovation Publication Pvt Ltd, 2020 ISBN: 978-81-933819-1-5
2.	Employability Skills	Dr. Nishith Rajaram Dubey, Anupam Singh	Indra Publishing House, 2023 ISBN - 978-93-93577-68-9
3.	Organizational Behavior	A. K. Chitale, Rajendra Prasad Mohanty and Dr Nishith Dubey	PHI Learning Pvt Ltd ISBN 978-81-203-4696-3
4.	Managerial Skills	Dr Nishith Dubey & Prof Gitanjali Shrivastava	Shiva Prakashan, Indore, India,2010, ISBN 81-7677-100-7,
5.	Body Language	Allan Pease	Pease International PTY. Ltd Australia

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
6.	Production and Operations Management Goods & Services approach	Dr S.V Deshmukh, Dr A. K. Chitale and Dr Nishith Dubey	Archers & Elevators publishing house, Bangalore, ISBN 9789386501197
7.	Emotional Intelligence	Daniel Goleman	Word Press.Com, 9789382563792
8.	How to win friends and influence people	Dale Carnegie	Srishti Publishers & Distributors, Delhi, India

(b) Online Educational Resources:

1. 4-Year Plan For Career Success: https://eng.umd.edu/sites/clark.umd.edu/files/4%20Year%20Plan%20For%20Career%20Success_Categorized_1.pdf

2. CAREER DEVELOPMENT GUIDE https://www.engineersaustralia.org.au/sites/default/files/content-files/2016-12/career_development_guide_may_2014.pdf

3. Tips for successful career planning tips://www.aryacollege.in/tips-for-successful-career-planning-in-2021/

4. Career Planning – Complete Guidehttps://www.mygreatlearning.com/blog/what-is-career-planning/

5. Build Resume: https://www.themuse.com/advice/how-to-make-a-resume-examples

6. Build Resume https://resumegenius.com/blog/resume-help/how-to-write-a-resume

7. Body Language: https://ubiquity.acm.org/article.cfm?id=3447263

8.Group Discussions: https://brightspeaking.com/en/how-to-effectively-participate-in-a-group-discussion/

9.Carrier planning & goal setting: https://www.hays.com.au/career-advice/career-development/setting-career-goals

10. Carrier planning & goal setting: https://www.thebalancemoney.com/step-by-step-guide-to-setting-career-goals-2059883

11. Collaboration & teamwork: https://www.indeed.com/career-advice/career-development/teamwork-and-collaboration

12. Interview skills: https://www.youtube.com/watch?v=lKCTS9dY4h4

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: -

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