

Curriculum of Diploma Programme

in

Chemical Engineering



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

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

Semester – VI

Teaching & Learning Scheme

Course Codes	Category of course	CourseTitles	Teaching & Learning Scheme (Hours/Week)					
			Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
			L	T				
2414601	PCC	Process Control & Instrumentation	03	-	04	02	09	06
2414602	PCC	Mass Transfer Operation	03	-	04	02	09	06
2414603	PEC	Programme Electives* - Any One	03	-	04	02	09	06
2400604	OEC	Open Electives** /COE (Advanced – Any One)	03	-	04	02	09	06
2414605	PSI	Major Project (Common for all programmes)	-	-	08	04	12	06
Total			12	-	24	12	48	30

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

Legend:

- CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)
- LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)
- Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.
- TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)
- SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.
- C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)
- *: Petrochemical Technology/ Polymer Technology/ Fertilizer Technology
- ** : 3D Printing & Design/ Artificial Intelligence (AI)/ Drone Technology / Electric Vehicle / Industrial Automation & Control/ Robotics/ Internet of Things/ 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)	
2414601	PCC	Process Control & Instrumentation	30	70	20	30	20	30	200
2414602	PCC	Mass Transfer Operation	30	70	20	30	20	30	200
2414603	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
2414605	PSI	Major Project (Common for all programmes)	-	-	20	30	50	100	200
Total			120	280	100	150	130	220	1000

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

Legend:

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

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

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

*: Petrochemical Technology/ Polymer Technology/ Fertilizer Technology

**.: 3D Printing & Design/ Artificial Intelligence (AI)/ Drone Technology / Electric Vehicle / Industrial Automation & Control/ Robotics/ Internet of Things/ 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 activities.

- A) **Course Code** : 2414601(T2414601/P2414601/S2414601)
- B) **Course Title** : Process Control & Instrumentation
- C) **Pre- requisite Course(s)** :
- D) **Rationale** :

As a diploma chemical engineer, one is responsible for monitoring & controlling chemical processes in the chemical industry. Additionally, they must be knowledgeable to handling instruments related to various process variables such as temperature, pressure, level & flow. This course is developed in the way by which chemical process control can be performed and related instruments can be handled in a safe and efficient manner, as they have to handle various instruments used in various chemical engineering processes.

- 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 the appropriate measuring instruments & understand their characteristics.
- CO-2** Apply temperature measuring instruments in the chemical industry to ensure accuracy.
- CO-3** Recommend an appropriate pressure measuring instruments to monitor pressure in the chemical industry.
- CO-4** Use multiple measuring instruments to measure liquid flow & level in the chemical industry.
- CO-5** Choose an appropriate control system for different control action in the chemical industry.

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

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

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

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)				
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)
		L	T			
2414601	Process Control & Instrumentation	03		4	2	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)	
2414601	Process Control & Instrumentation	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: T2414601**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Calibrate and apply the measurement techniques. <i>TSO 1b.</i> Describe the sketches the direct and indirect method of measurement of given processes. <i>TSO 1c.</i> Classify instruments according to their function in chemical industry. <i>TSO 1d.</i> Evaluate static and dynamic characteristics of an instrument.	Unit-1.0 Measurement and Measuring instrument Characteristics 1.1 Measurement and calibration: definition and application. 1.2 Measurement methods- direct and indirect method. 1.3 Functional elements- primary, secondary, manipulating element, data transferring element. 1.4 Static characteristics: Accuracy & static error, span, range, static correction true value, calibration & calibration curve, reproducibility & drift, zero span & point drift, sensitivity & dead zone, hysteresis, linearity, overall system sensitivity. 1.5 Dynamic characteristics: Standard test inputs, Speed of response & lag, Fidelity & dynamic error, Order of an instrument.	CO1
<i>TSO 2a.</i> Choose the relevant instrument to measure temperature of the given system with justification, working and sketches. <i>TSO 2b.</i> Operate pyrometer for given application.	Unit-2.0 Temperature measurement 2.1 Expansion thermometer: principle, construction and application, spiral bimetallic thermometer, mercury in glass thermometer. 2.2 Electrical temperature sensor: principle, construction and application, Resistance temperature detector, Thermocouple and thermistor, Thermocouple lead wires, Thermal well. 2.3 Pyrometer: principle, construction, and application of optical, radiation & photoelectric pyrometer	CO2
<i>TSO 3a.</i> Describe the construction & working of given type of pressure gauge. <i>TSO 3b.</i> Explain the use of given type of low - pressure (Vacuum) measurement.	Unit-3.0 Pressure Measurement 3.1 C type Bourdon tube, bellows, and metallic diaphragm gauge: principle, construction, and application.	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	3.2 Vacuum measurement- principle, construction and application, McLeod gauge, Pirani gauge Ionization gauge.	
<i>TSO 4a.</i> Classify flow measurement instrument based on given characteristics. <i>TSO 4b.</i> Describe the principal, construction & working of the given flow measuring devices. <i>TSO 4c.</i> Compare direct and indirect method of level measurement with their principle, construction, and application.	Unit-4.0 Flow viscosity and Level Measurement. 4.1 Variable area flow meter (Rotameter), venturi meter, orifice meter, pitot tube: principle, construction, working and application. 4.2 Direct method for level measurement: principle, construction, and application of high-pressure site glass level indicator. 4.3 Indirect method for level measurement: principal, construction, and application of hydrostatic measurement (pressure gauge, differential pressure, and air purge)	CO4
<i>TSO 5a.</i> Describe with sketches the function of the components of the given control systems. <i>TSO 5b.</i> Compare servo & regulatory problem. <i>TSO 5c.</i> Draw the block diagram of the given control system. <i>TSO 5d.</i> Describe the characteristics of given valve.	Unit-5.0 Process control system and control valve 5.1 Control system classification- open loop and close loop. 5.2 Servo and regulatory process, comparison. 5.3 Automatic control system: block diagram. 5.4 Control action-ON-OFF, P, PI, PID (only pneumatic controller). 5.5 Types of control valve- air to open, air to close valve characteristics- linear.	CO5

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2414601

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Calibrate temperature measuring devices such as expansion thermometer and resistance thermometer.	1	Calibration of temperature measuring devices. (Expansion thermometer /resistance thermometer.)	CO2
<i>LSO 2.1.</i> Measure temperature by using Thermocouple and find their static and dynamic characteristics.	2	Measurement of temperature by using Thermocouple and find their characteristics.	CO2
<i>LSO 3.1.</i> Calibrate the given Thermocouples and plot the calibration curve.	3	Calibration of the given Thermocouples and to plot the calibration curve.	CO2
<i>LSO 4.1.</i> Measure the temperatures high, medium, and low with the help of pyrometers.	4	Measurement of high temperature by Radiation Pyrometer.	CO2
<i>LSO 5.1.</i> Measure the vacuum created by pump with the help of McLeod gauge.	5	Measurement of the vacuum pressure by McLeod gauge.	CO3
<i>LSO 6.1.</i> Measure of vacuum created by pump by Pirani gauge.	6	Measurement of vacuum by Pirani gauge.	CO3
<i>LSO 7.1.</i> Measure level of liquid in a tank by Float type Level Meter.	7	Measurement of level by Float type Level Meter.	CO4
<i>LSO 8.1.</i> Determine the density of the given sample.	8	Measurement of density-by-Density Bottle Method.	CO4

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 9.1. Determine Moisture of given sample of oil/lubricants by Karl-Fisher apparatus.	9	Determination of Moisture by Karl-Fisher.	CO4
LSO 10.1. Determine the transient response of a liquid flow system for a step change in the set point using Proportional–Integral–Derivative (PID) controllers respectively.	10	Determination of transient response using a proportional-integral-derivative (PID) controller for a step change in the set point.	CO5

L) **Suggested Term Work and Self Learning: S2414601** 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 list of high-pressure measuring devices with their range used in chemical industry.
- Prepare a list of vacuum measuring devices with their range used in chemical industry.
- Expound examples of different types of control systems.
- Enumerate the examples of Block diagram of open loop and closed loop control systems used in chemical industries.

b. **Micro Projects:**

1. Prepare working models of resistance temperature detectors & submit a brief report.
2. Develop an air pressure monitoring system to measure the pressure of different objects like cycle, motorcycle, four wheelers' tubes of your institute along with the project report on the same.
3. Prepare a setup for applications of measurements and control in dryers & submit a report on the same.
4. Prepare a model along with the project report to classify Basic elements of closed loop system.
5. Perform a market survey for availability of temperature measurement devices in the local market & prepare a brief report on the same.

c. **Other Activities:**

1. Seminar Topics:

- Different temperature measuring devices used in chemical industries.
- Applications of resistance temperature detectors (RTD).
- Application of pneumatic electrical and hydraulic controllers.

2. Visits:

- **Visit of chemical process plant:** Visit nearby chemical industry to observe working of different instrumentation & process control system to regulate industry operation via control room & prepare the report of it.

3. Self-Learning Topics:

- Laplace transformation.
- Thermocouple with different material combinations and their temperature measuring range.
- Comparison of different types of controllers.

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%	15%	-	-	20%	20%
CO-2	30%	30%	10%	25%	-	10%	20%
CO-3	20%	20%	15%	25%	33%	15%	20%
CO-4	10%	10%	30%	25%	33%	15%	20%
CO-5	30%	30%	30%	25%	34%	40%	20%
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

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

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

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

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

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Measurement and Measuring instrument Characteristics.	6	CO1	07	4	3	-
Unit-2.0 Temperature measurement.	12	CO2	21	4	9	8
Unit -3.0 Pressure Measurement.	12	CO3	14	4	2	8
Unit-4.0 Flow viscosity and Level Measurement.	6	CO4	07	4	3	-
Unit-5.0 Process control system and control valve.	12	CO5	21	4	10	7
Total	48	-	70	20	27	23

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.	Calibration of temperature measuring devices. (Expansion thermometer /resistance thermometer.)	CO2	30	60	10
2.	Measurement of temperature by using Thermocouple and find their characteristics.	CO2	40	50	10
3.	Calibration of the given Thermocouples and to plot the calibration curve.	CO2	30	60	10
4.	Measurement of high temperature by Radiation Pyrometer.	CO2	30	60	10
5.	Measurement of the vacuum pressure by McLeod gauge.	CO3	40	50	10
6.	Measurement of vacuum by Pirani gauge.	CO3	30	60	10
7.	Measurement of level by Float type Level Meter.	CO4	30	60	10
8.	Measurement of density by Density Bottle Method.	CO4	40	50	10
9.	Determination of Moisture by Karl-Fisher.	CO4	30	60	10
10.	Determination of transient response using a proportional-integral-derivative (PID) controller for a step change in the set point.	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	Bimetallic Thermometers.	Window: sheet glass Pointer: Micro Zero Adj. / Balanced Aluminum Stem Material: Brass Chrome Plated. SS 304, SS 316 Stem Length: From 50 mm to 500 mm Range: From -20°C to up to +300°C in standard ranges. Accuracy: $\pm 2\%$ of the span ($\pm 1\%$ optional) Over Range Protection Fittings: 20% of the span.	1,2,3
2	Setup of Thermocouples.	Heat Source: Provide with ceramic insulation.	2,3

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
		Temp. Controller: Digital Temperature Controller, 0-199.9°C Thermocouple: Standard 3 types of thermocouples a). Fe-Constantan (J-Type) b). CR / Al (K-Type) c). Cu-Constantan (T-Type).	
3	Radiation Pyrometer.	temperature ranges: 5 and 1300°C Short response time: min. 1.5 ms Extremely small spot sizes: in 0.3 mm Built-in digital display with temperature indication	4
5	McLeod gauge.	Battery Life: Mechanical Display: Analog Material: Glass And Metallic Measuring Range: 0.01 TO 10 MM HG	5
6	Pirani gauge.	Type: M-350PG-SPT type with Set Point Pressure setting range: 5×10^{-2} to 1×10^5 (Pa) Accuracy (Pa): $\pm 50\%$: 5×10^{-2} to 1×10^{-1} Input voltage: +14 to 30VDC Operating temperature range: Operating temperature range	6
7	Float type Level Meter.	The Specific Gravity of the fluid: more than 0.6 Float material: SS/PP/Teflon Type: Analog	7
8	Setup of Density Bottle method.	Density bottle of 50 ml capacity Digital balance of accuracy 0.001g vacuum desiccator Vacuum pump Oven Constant temperature water bath (27 °C)	8
9	Karl-Fisher apparatus.	Method: Volumetric Titration Water content measuring range: 100 PPM to 100% End Point Confirmation Time: 20 sec. Fixed Dispensing resolution: 0.01 ml Memory Storage: 100 Test Methods (User Programmable). Display: 16-character x 2 Line LCD Backlit Display Input: Mechanical Knob + Push Buttons Dimensions: 42 x 33 x 33 cm. Weight: 15 kg approx. Power Supply: 230 $\pm$ 10V AC, 50 Hz, Power 50 W Max.	9
10	Temperature Control Trainer With on –off and PID controller.	Type of control SCADA Control unit Digital indicating controller with Ethernet communication Make Yokogawa, model UT35 Temperature sensor Type RTD, PT100 Heating control Proportional power controller (SSR), Input 4-20 mA, Capacity 20 A. Heater Type Electrical 2 coil, Capacity 3 KW Rotameter 6-60 LPH, Make Eureka Process tank SS304, Capacity 0.5 lit	10

R) Suggested Learning Resources:

(a) Books:

S. No.	Title	Author	Publisher and Edition with ISBN
1	Industrial Instrumentation.	D.P. Eckman	Wiley Eastern Ltd. New Delhi, First edition & 2004 ISBN-10: 8123908105
2	Process Control.	Peter Harriott	Tata McGraw Hill New Delhi, 1964 ISBN-10: 0070267855
3	Instrumentation.	F.W. Kirk N.R. Rimboi	D.B. Taraporewala Sons & Co. Mumbai, Third Edition & 1975
4	Process Instrumentation and Control.	A.P. Kulkarni	Nirali Publication Nagpur, 2013 ISBN-10: 9381237069
5	Process Systems Analysis and Control.	Donald R. Coughanowr	Tata McGraw Hill New Delhi, Third edition & 2017, ISBN: 9781259098437

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc22_ch60/preview.
2. https://onlinecourses.nptel.ac.in/noc19_de04/preview.
3. <https://en.wikipedia.org/wiki/Thermocouple>- Thermocouple.
4. https://en.wikipedia.org/wiki/Pressure_measurement-Pressure measurement devices.
5. https://www.slideshare.net/Attiya_Rehman/level-measuring-instruments-Level-measuring-instruments.
6. <https://www.electrical4u.com/types-of-controllers-proportional-integral-derivative-con>.Types of Controller.
7. nptel.ac.in/courses/112103174/14-Control system.

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

(c) Others:

- A) **Course Code** : 2414602(T2414602/P2414602/S2414602)
- B) **Course Title** : Mass Transfer Operations
- C) **Pre- requisite Course(s)** :
- D) **Rationale** :

The course has been designed for diploma in chemical engineering students. In this course student will deal with transport of a species in a mixture in a single phase or across a phase boundary in the presence of a concentration driving force. The application of the principles of mass transfer is a common phenomenon in both non-living & living world. The concept of mass transfer is used in the refining of petroleum product by using distillation equipment, gas purification such as removing carbon dioxide from natural gas or pollutants from flue gases by using absorption equipment. Extraction equipment is used in pharmaceutical industries to extract active compounds from plants and in food industries for flavor extraction and many more applications exist in the industries and daily life. Therefore, this course is one of the important courses since it attempts to develop the skills in students to handle this industrial equipment necessary for the production and purification of petroleum products (hydrocarbon).

- 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 different diffusion theories to determine overall mass transfer coefficient.

CO-2 Use various distillation methods to determine the product rate and calculate the number of trays for a binary distillation column used in chemical industry.

CO-3 Use gas absorption operation and relevant equipment in chemical industries.

CO-4 Calculate the percentage of separation achieved in an extraction process.

CO-5 Calculate the time required for drying process & various terms associated with humidity.

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

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

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

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2414602	Mass Transfer Operation	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)
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- 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)	
2414602	Mass Transfer Operation	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: T2414602**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Describe importance of mass transfer operation TSO 1b. Distinguish between mass flux & molar flux. TSO 1c. Explain the Fick's law of diffusion & diffusivity. TSO 1d. Distinguish between steady state equimolar counter diffusion & molecular diffusion in a steady state diffusion of A through non-diffusing B. TSO 1e. Relate between individual & overall mass transfer coefficient for two phase system. TSO 1f. state different theories of mass transfer.	Unit-1.0 Fundamentals of Mass Transfer & Diffusion. 1.1 Definition of diffusion, Concept of mass concentration, molar concentration, mass fraction, mole fraction. 1.2 Local and average velocity with respect to stationary and movable coordinate system for diffusing species. 1.3 Concept of mass flux & molar flux. 1.4 Definition and mathematical statement of Fick's law of diffusion, definition, and unit of diffusivity. 1.5 Relation between mass flux and molar flux. 1.6 Molecular diffusion in a steady state equimolar counter diffusion, molecular diffusion in a steady state diffusion of A through non-diffusing B. 1.7 Concept of mass transfer coefficient, individual & overall mass transfer coefficient. Relation between individual & overall mass transfer coefficient. 1.8 Theories of mass transfer: Two film theory, Penetration theory, Surface renewal theory.	CO1
TSO 2a. Plot equilibrium curve on x-y axis for a binary mixture with the help of relative volatility data. TSO 2b. Explain the use of relevant distillation column for a particular industrial application. TSO 2c. Calculate number of equilibrium stages (plate) in distillation column for a given situation. TSO 2d. Use relevant reflux ratio to obtain required purity of product in the given situation. TSO 2e. Explain types of packing used in a distillation column.	Unit-2.0 Distillation 2.1 Concept of distillation, boiling point diagram, vapour liquid equilibria, Henry's Law, Raoult's Law, Computing x — y data, Volatility, relative volatility. 2.2 Methods of distillation, Simple or Differential distillation, Rayleigh's equation, Flash or Equilibrium distillation, Rectification or Fractionation, Azeotropic distillation, Steam distillation. 2.3 Material balance on distillation column, derivation of operating line for rectifying and stripping section, McCabe — Thiele method, derivation of q line, effect of feed conditions on slope of q line, Reflux ratio — minimum, total, and optimum. 2.4 Plate column, packed column, Bubble cap plate, Sieve plate, Valve plate, Downcomers, and weirs.	CO2

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	2.5 Simple numerical based on the position of the number of plates and feed plate.	
<i>TSO 3a.</i> Apply concept of absorption of gas in liquids with the help of solubility concept. <i>TSO 3b.</i> Explain Raoult's law. <i>TSO 3c.</i> Select appropriate solvent. <i>TSO 3d.</i> Apply material balance in different condition. <i>TSO 3e.</i> Select liquid-gas ratio for absorber. <i>TSO 3f.</i> Define various efficiencies. <i>TSO 3g.</i> Explain tray tower and packed tower. <i>TSO 3h.</i> Calculate absorption based on material balance.	Unit-3.0 Gas Absorption 3.1 Industrial application of absorption, equilibrium solubility of gases in liquids and effect of temperature and pressure on solubility. 3.2 Ideal solution and Raoult's law. 3.3 Types of solvent used for absorption. 3.4 Material balance for one component transfer for counter current flow, co-current flow & counter current multistage operation. 3.5 Concept of absorption factor & stripping factor with minimum liquid-gas ratio for absorber. 3.6 Real Tray & Tray efficiency- point efficiency, Murphy efficiency, Overall tray efficiency. 3.7 Tray tower and packed tower, HETP. 3.8 Simple numerical based on material balance for gas absorption.	CO3
<i>TSO 4a.</i> Compare application of different separation equipment. <i>TSO 4b.</i> Define various term related to liquid extraction. <i>TSO 4c.</i> Explain triangular diagram for used liquid-liquid extraction. <i>TSO 4d.</i> Select a proper solvent for in a extraction process. <i>TSO 4e.</i> Calculate percentage of extraction achieved in an extraction process.	Unit 4.0 Liquid-Liquid Extraction 4.1 Definition & basic concept of liquid-liquid extraction. 4.2 Comparison among distillation, absorption & extraction process. 4.3 Application of liquid extraction, steps, and terminology of of liquid extraction. 4.4 Definition & concept of distribution coefficient & ternary system. 4.5 Basic concept & application of triangular diagram. 4.6 Selection criteria for solvent in extraction. 4.7 Different types of industrial extraction equipment. 4.8 Numerical on liquid-liquid extraction.	CO4
<i>TSO 5a.</i> Define drying operation and related terms. <i>TSO 5b.</i> Calculate different moisture content. <i>TSO 5c.</i> Explain some basic terms of air water system(humidification). <i>TSO 5d.</i> Describe drying rate characteristics for batch drying with sketches. <i>TSO 5e.</i> Derive equation of drying time for constant rate period and falling rate period. <i>TSO 5f.</i> Classify drying equipment. <i>TSO 5g.</i> Describe construction and working of Drier equipment. <i>TSO 5f.</i> Calculate drying time.	Unit 5.0 Drying & Humidification 5.1 Definition & needs of drying operation. 5.2 General definition of some basic terms: Moisture content on wet & dry basis, equilibrium moisture content, bound moisture content, unbound moisture content, free moisture content, critical moisture content, constant rate period, falling rate period. 5.3 Properties & some basic terms of air water system (Humidification): Relative humidity, absolute humidity, relation between relative humidity and absolute humidity, saturation humidity, dry bulb temperature & wet bulb temperature. 5.4 Drying rate curve for batch drying. 5.5 Derivation of equation for drying time for constant period and falling rate period.	CO5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	5.6 Construction, working & application of different types of dryers used in chemical industries: Tray dryer, Rotary dryer, Spray dryer, Fluidized bed dryer, Tunnel dryer. 5.7 Simple numerical based on drying & humidification process.	

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2414602

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Know the Diffusion characteristics for gas-liquid system at room temperature.	1.	Determination of diffusivity of gas-liquid system at room temperature.	CO1
<i>LSO 1.2.</i> Determine diffusivity of gas-liquid system at room temperature.			
<i>LSO 2.1.</i> Determine diffusivity of gas-liquid system at different temperature.	2.	Determination of diffusivity of gas-liquid system at different temperature.	CO1
<i>LSO 2.2.</i> Compare diffusivity of gas-liquid system at different temperature with room temperature.			
<i>LSO 3.1.</i> Know the Diffusion characteristics for liquid-liquid system at room temperature.	3.	Determination of diffusivity of liquid-liquid system at room temperature.	CO1
<i>LSO 3.2.</i> Calculate diffusivity of liquid-liquid system at room temperature.			
<i>LSO 4.1.</i> Plot diffusivity chart for liquid-liquid system at different temperature.	4.	Determination of diffusivity of liquid-liquid system at different temperature.	CO1
<i>LSO 4.2.</i> Compare diffusivity chart of different system with respect to temperature			
<i>LSO 5.1.</i> Plot vapour-liquid equilibria curve at atmospheric pressure for Benzene-Xylene.	5.	Preparation of vapour-liquid equilibria curve at atmospheric pressure for Benzene-Xylene.	CO2
<i>LSO 5.2.</i> Determine relative volatility for benzene-xylene binary mixture at room temperature.			
<i>LSO 6.1.</i> Perform distillation operations.	6.	Determination of product rate and number of trays for a binary mixture in a simple distillation in glass assembly.	CO2
<i>LSO 6.2.</i> Calculate the product rate and number of trays for binary distillation.			
<i>LSO 7.1.</i> Calculate rate of absorption in a tray or packed tower.	7.	Measurement of rate of absorption in a tray or packed tower	CO3
<i>LSO 8.1.</i> Determine number of stages for liquid-liquid extraction.	8.	Determination of stage efficiency /performance characteristics for liquid- liquid counter current extraction setup.	CO4
<i>LSO 9.1.</i> Calculate various terms associated with humidity.	9	Determination of property of atmospheric air with the help of wet bulb and dry bulb temperature.	CO5
<i>LSO 10.1.</i> Calculate drying time of wet solid for given set of condition.	10.	Determination of equilibrium moisture content and drying time of wet solid.	CO5

L) **Suggested Term Work and Self Learning: S2414602** 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.

Q→A mixture of 40 mole % isopropanol in water is to be batch-distilled at 1 atm until 70 mole % of the charge has been vaporized. Calculate the composition of the liquid residue remaining in the still pot, and the average composition of the collected distillate. VLE data for this system, in mole fraction of isopropanol, at 1 atm are :

Temp.(K)	366	357	355.1	354.3	353.6	353.2	353.3	354.5
y	0.220	0.462	0.524	0.569	0.593	0.682	0.742	0.916
x	0.012	0.084	0.198	0.350	0.453	0.679	0.769	0.944

Q→CO₂ is diffusing through a non-diffusing of air under steady state conditions at a total pressure of 1 atm and temperature of 300 k. The partial pressure of CO₂ is 20Kpa at one point and 5Kpa at other point. The distance between the two points is 5cm. Calculate the flux of CO₂ and at 300k and 1 atm the diffusivity of CO₂ to air is $2 \times 10^{-5} \text{m}^2/\text{s}$. [01; 04].

b. **Micro Projects:**

- Perform absorption of CO₂ in a packed bed absorption tower by varying flow rate of solvent and find optimum flow rate required for maximum absorption. Prepare a report on the same.
- Make a known solution of quarterly mixture consisting of ethyl alcohol, methyl alcohol, carbon tetrachloride and water and perform fractional distillation to separate each component. Find the composition of each fraction & make a brief report on it.
- Construct a mini dryer/model to find the drying time of a given known sample & submit a report on the same.
- Collect the five sample of wet solid (cake form) from institute campus and calculate the total drying time of them with the help of tray dryer in the lab & compare the drying time with the brief report on the same.

c. **Other Activities:**

1. Seminar Topics:

- Ethanol blending in petrol.
- Comparison of middle east crude oil with Russian crude oil & required change in the distillation column operation.
- Importance of vacuum distillation.
- Heat pump dryer.

2. Visits:

- **Visit of chemical process plant:** Visit nearby refinery industry to observe working of different mass transfer operations equipment (distillation, absorber etc.) used in the refinery and prepare the report of it.

3. Self-Learning Topics:

- Overall mass transfer coefficient.
- Internal reflux ratio & external reflux ratio.
- Comparison among different separation equipment.
- Industrial applications of crystallization.

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%	30%	35%	35%	20%	20%	20%
CO-2	30%	30%	35%	35%	25%	20%	20%
CO-3	10%	10%	10%	10%	25%	20%	20%
CO-4	10%	10%	10%	10%	15%	20%	20%
CO-5	20%	20%	10%	10%	15%	20%	20%
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

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

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

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

N) Suggested Specification Table for End Semester Theory Assessment: 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	Remember (R)	ETA (Marks) Understanding (U)	Application & above (A)
Unit-1.0 Fundamentals of Mass Transfer & Diffusion.	12	CO1	21	4	10	7
Unit-2.0 Distillation.	12	CO2	21	6	5	10
Unit-3.0 Gas Absorption.	7	CO3	7	2	2	3
Unit-4.0 Liquid-Liquid Extraction.	7	CO4	7	2	2	3
Unit-5.0 Drying & Humidification.	10	CO5	14	6	4	4
Total	48	-	70	20	23	27

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

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		Viva-Voce (%)
			Performance PRA* (%)	PDA** (%)	
1.	Determination of diffusivity of gas-liquid system at room temperature.	CO1	40	50	10
2.	Determination of diffusivity of gas-liquid system at different temperature.	CO1	30	60	10
3.	Determination of diffusivity of liquid-liquid system at room temperature.	CO1	40	50	10
4.	Determination of diffusivity of liquid-liquid system at different temperature.	CO1	30	60	10
5.	Preparation of vapour-liquid equilibria curve at atmospheric pressure for Benzene-Xylene.	CO2	30	60	10
6.	Determination of product rate and number of trays for a binary mixture in a simple distillation in glass assembly.	CO2	40	50	10
7.	Measurement of rate of absorption in a tray or packed tower.	CO3	30	60	10
8.	Determination of stage efficiency /performance characteristics for liquid- liquid counter current extraction setup.	CO4	40	50	10
9.	Determination of property of atmospheric air with the help of wet bulb and dry bulb temperature.	CO5	30	60	10
10.	Determination of equilibrium moisture content and drying time of wet solid.	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.	Diffusivity apparatus.	Stefan Tube, hot plate, temperature indicator, blower.	1,2,3 & 4
2.	Fractionation column with reflux provision.	Reboiler of capacity minimum 1000ml, Plate / packed column, condenser, and receiver.	5
3.	Simple Distillation Set up.	Reboiler of capacity minimum 1000ml, condenser and receiver.	6
4.	Absorption column.	Column with provisions for measuring pressure drop and flow rate, compressor.	7
5.	Extraction column.	Column with provisions for measuring pressure drop and flow rate, pump.	8

S. No.	Name of Equipment, Tools, and Software	Broad Specifications	Relevant Experiment/Practical Number
6.	Tray Dryer.	Drying compartment with weight and temperature indicator and blower.	9
7.	Drum Dryer.	300mm Dia X 200mm long, coolant provision, Steam Provision, Feeding provision.	10

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

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Mass Transfer Operations.	Robert E. Treybal	Mc Graw- Hill, 3rd Edition, 1981, ISBN-13 : 978-1259029158
2.	Unit Operation of Chemical Engineering.	McCabe, Warren L., Julian C. Smith	McGraw Hill Publication, New York 2004, 7th Edition, ISBN-13 : 978-8184959635
3.	Unit Operations-II.	K. A. Gavhane	Nirali Prakashan, Pune, ISBN: 9788196396121
4.	Unit Operations of Chemical Engineering, Volume-I.	P. Chattopadhyay	Khanna Publishers, New Delhi, 1995, ISBN-13 : 978-8174091758
5.	Chemical Engineering, Volume-2.	Coulson and Richardson	Butterworth-Heinemann; 5th Edition, 2002, ISBN: 9788181471444
6.	Introduction to Chemical Engineering.	L. Badger, Julius T. Banchero	McGraw Hill Publication, New York, 7th Edition, 2004, ISBN-13 : 978-0074630501

(b) Online Educational Resources:

- 1) www.unitoperation.com
- 2) <http://nptel.ac.in/courses/index.php?subjectId=103103035>
- 3) https://en.wikipedia.org/wiki/Molecular_diffusion-Molecular_diffusion
- 4) <http://www.msubbu.in/ln/mt/>
- 5) <https://byjus.com › Chemistry › Chemistry Articles-Types of Distillation>
- 6) https://en.wikipedia.org/wiki/Vapor%E2%80%93liquid_equilibrium-Phase_equilibrium

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

(c) Others:

- A) **Course Code** : 2414603A(T2414603A/P2414603A/S2414603A)
- B) **Course Title** : Petrochemical Technology
- C) **Pre- requisite Course(s)** :
- D) **Rationale** :

Petroleum is a mixture of hydrocarbon in different form like liquid and gas, which is complex in nature as well as structure. Mainly it is found in liquid form known as crude oil. Crude oil is black in color, which is mixture of many hydrocarbons. Crude oil is formed millions of years ago from remains of plant and animals. The remains of these animals and plants were covered by layers of sand, silt, and rock. Heat and pressure from these layers turned the remains into what we now call crude oil or petroleum. Refining of crude oil gives many products like gasoline, diesel, jet fuels and many more. To convert crude oil to these products, process such as desalting, catalytic cracking & reforming are done. Petrochemicals are generally chemicals obtained from petroleum and natural gas. A variety of petrochemicals are obtained like olefins & aromatics.

- 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 different sources of crude oil with properties.

CO-2 Use suitable method for treatment of crude oil.

CO-3 Apply suitable method for cracking & reforming.

CO-4 Enumerate the properties of different petrochemicals obtained from Methane & Ethane.

CO-5 Illustrate the properties & manufacturing process of different chemicals obtain from C3 & C4.

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

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2
CO-1	2	-	-	-	-	-	1		
CO-2	3	2	2	2	1	-	1		
CO-3	3	1	2	2	2	-	1		
CO-4	2	1	1	2	1	2	-		
CO-5	1	-	-	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				
2414603A	Petrochemical Technology	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)	
2414603A	Petrochemical Technology	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: T2414603A**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Describe history of petroleum. <i>TSO 1b.</i> List sources of petroleum. <i>TSO 1c.</i> Classify crude oil. <i>TSO 1d.</i> List fraction of crude oil. <i>TSO 1e.</i> Identify refining industries in India.	Unit-1.0 History of Petroleum 1.1 History and Formation of petroleum. 1.2 Reserves of Crude oil in India and abroad. 1.3 Exploration & drilling of crude oil in india. 1.4 Classification and properties in India and worldwide crude oil. 1.5 Important fraction obtained from crude oil with their boiling range, properties, and testing methods. 1.6 Petroleum refining industries in India. 1.7 Application of petroleum fractions (products).	CO1
<i>TSO 2a.</i> Identify treatment method used for crude oil. <i>TSO 2b.</i> Describe fractionation methods. <i>TSO 2c.</i> Describe Sulphur recovery process. <i>TSO 2d.</i> Apply treatment methods to gasoline. <i>TSO 2e.</i> List properties of crude oils. <i>TSO 2f.</i> Describe properties of crude oil.	Unit-2.0 Treatment of Crude Petroleum 2.1 Primary Treatment: Dehydration & Desalting of crude oil. 2.2 Crude oil fractionation: Atmospheric and Vacuum distillation. 2.3 Sweetening (Sulphur recovery) process for petroleum product. 2.4 Treatment methods of gasoline. 2.5 Properties of products viz. octane number, cetane number, pour point, flash point, fire point, aniline point, drop point, cloud point. 2.6 Detail of Cloud & pour point apparatus, Pensky Marten apparatus, smoke point apparatus, Conradson apparatus, Abel' apparatus.	CO1, CO2
<i>TSO 3a.</i> Describe cracking process. <i>TSO 3b.</i> Identify cracking process for crude oils. <i>TSO 3c.</i> Identify reforming process for crude oils. <i>TSO 3d.</i> Describe different technology used in petroleum industry.	Unit-3.0 Thermal & Catalytic Cracking Process. 3.1 Basic of thermal & catalytic cracking process. 3.2 Visbreaking & delayed coking for petroleum product. 3.3 Fixed & fluidized bed catalytic cracking of heavier product. 3.4 Catalytic reforming to increase the octan/ cetane number of petrol/diesels. 3.5 Hydrogenation, alkylation & isomerization process of petroleum product.	CO3, CO4

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 4a.</i> Identify various chemicals obtained from petroleum. <i>TSO 4b.</i> List chemicals obtained from methane & ethane. <i>TSO 4c.</i> Describe manufacturing process of various chemicals, obtained from CH ₄ & C ₂ H ₅	Unit-4.0 Petrochemical from Methane & Ethane. 4.1 Petrochemical industries in India. 4.2 Chemicals obtained from Methane & ethane. 4.3 Manufacturing of Methanol, formaldehyde, Methylamine from methane/ethane. 4.4 Manufacturing of ethanol, vinyl chloride, acetylene.	CO3, CO4
<i>TSO 5a.</i> Describe manufacturing process of propylene oxide. <i>TSO 5b.</i> Describe manufacturing process of Isopropanol. <i>TSO 5c.</i> Explain manufacturing process of Phenols from Cumene. <i>TSO 5d.</i> Describe manufacturing process of Benzene, Toluene, and xylene.	Unit-5.0 Petrochemical from C3, C4 & Aromatics. 5.1 Manufacturing of propylene oxide, 5.2 Manufacture of Isopropanol. 5.3 Phenols from cumene. 5.4 Chemicals obtained from aromatics. 5.5 Production of Benzene, Toluene & Xylene. 5.6 Manufacture of Benzoic acid from toluene.	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: P2414603A

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Understand the concept of Specific gravity. <i>LSO 1.2.</i> Prepare solution of different specific gravity.	1.	Measurement of API gravity of given product by using Specific gravity bottle.	CO1
<i>LSO 2.1.</i> Describe flash point <i>LSO 2.2.</i> Explain Penske Martin apparatus <i>LSO 3.2.</i> Prepare list of samples with different flash point	2.	Determination of Flash point of given sample using Penske Martens Apparatus	CO1
<i>LSO 3.1.</i> Explain fire point <i>LSO 3.2.</i> Prepare list of samples with different fire points.	3.	Determination of Fire point of given sample using Pesky Martens Apparatus	CO1
<i>LSO 4.1.</i> Describe Abbey's apparatus <i>LSO 4.2.</i> Compare Penske Martin Apparatus & Abbey's apparatus.	4.	Determination of Flash point & Fire point of given sample by using Abbey's apparatus.	CO2
<i>LSO 5.1.</i> Explain cloud point <i>LSO 5.2.</i> Prepare list of samples with different Cloud Point	5.	Determination of Cloud Point of given sample	CO3, CO4, CO5
<i>LSO 6.1.</i> Explain smoke point <i>LSO 6.2.</i> Prepare list of chemicals with different smoke point	6.	Determination of smoke point of given sample	CO3, CO4, CO5
<i>LSO 7.1.</i> Describe Drop point	7.	Determination of Drop point of given sample	CO3, CO4, CO5
<i>LSO 8.1.</i> Describe Conrandson carbon residue apparatus	8.	Determination of the Conradson carbon residue of given petroleum sample	CO3, CO4, CO5
<i>LSO 9.1.</i> Describe ASTM Distillation <i>LSO 9.2.</i> Compare different types of distillation <i>LSO 9.3.</i> List out fractions obtained from ADU	9.	Determination of the ASTM distillation curve for given petroleum product.	CO4, CO5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 10.1. Describe Aniline point LSO 10.2. List out Aniline point of different samples.	10.	Determination of aniline point of given sample by aniline point apparatus	CO5

L) Suggested Term Work and Self Learning: S2414603A Some sample suggested assignments, micro project and other activities are mentioned here for reference.

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

- 1.1 The students are advised to make a survey of the world energy demand and availability of crude oil and then prepare a report there of.
- 1.2 Students are required to mention different hydrocarbons found in crude oil.
- 1.3 Analyze the different cracking processes and differentiate among them.
- 1.4 Explain any sweetening process in petroleum refining.
- 1.5 Write in detail about catalytic reforming.

b. Micro Projects:

1. Construct a working model of small scale distillation column to separate binary mixture of ethanol water. Also write a brief report on it.
2. Find out the flash & fire point of the petrol obtained from four different petrol pump near your localities. Compare the result, discuss the reason in variation of flash point & fire point & write a report on it.
3. Prepare list of Petroleum & Petrochemical industry in your area. Enlist make a brief report of all products obtained from it.
4. Prepare safety report of Petroleum Industry.
5. Write short report on storage & transportation of petroleum product.

c. Other Activities:

1. Seminar Topics:
 - Sources of petroleum.
 - Properties of Petroleum product.
 - Waste water treatment from petroleum industry.
2. Visits:

Visit a nearby petroleum industry and prepare a report of the process and safety measures adopted in the industry.
3. Self-Learning Topics:
 - Crude oil formation.
 - Import/Export policy of Government of India for Petroleum.
 - Advancement in petroleum industry.

- 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%	15%	-	-	10%	10%
CO-2	30%	30%	20%	25%	-	20%	20%
CO-3	30%	30%	25%	25%	33%	30%	30%
CO-4	10%	10%	20%	25%	33%	20%	20%
CO-5	20%	20%	20%	25%	34%	20%	20%
Total Marks	30	70	20	20	10	20	30
			50				

Legend:

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

** : Mentioned under point- (N)

: Mentioned under point-(O)

Note:

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

- N) Suggested Specification Table for End Semester Theory Assessment:** 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 History of Petroleum	8	CO1	7	3	4	-
Unit-2.0 Treatment of Crude Petroleum	10	CO1, CO2	21	6	8	7
Unit-3.0 Thermal & Catalytic Cracking Process.	10	CO2, CO3, CO4	21	6	7	8
Unit- 4.0 Petrochemical from Methane & Ethane.	10	CO2, CO3, CO4	7	3	2	2
Unit-5.0 Petrochemical from C3, C4 & Aromatics.	10	CO4, CO5	14	2	6	6
Total	48	-	70	20	27	23

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.	Measurement of API gravity of given product using Specific gravity bottle.	CO1	30	60	10
2.	Determination of Flash point of given sample using Penske Martens Apparatus.	CO1	40	50	10
3.	Determination of Fire point of given sample using Pesky Martens Apparatus.	CO1	30	60	10
4.	Determination of Flash point & Fire point of given sample by using Abbey's apparatus.	CO2	30	60	10
5.	Determination of Cloud Point of given sample.	CO3, CO4, CO5	30	60	10
6.	Determination of smoke point of given sample.	CO3, CO4, CO5	30	60	10
7.	Determination of Drop point of given sample.	CO3, CO4, CO5	30	60	10
8.	Determination of the Conradson carbon residue of given petroleum sample.	CO3, CO4, CO5	40	50	10
9.	Determination of the ASTM distillation curve for given petroleum product.	CO3, CO4, CO5	30	60	10
10.	Determination of aniline point of given sample by aniline point apparatus.	CO3, CO4, 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.	Flash Point Apparatus.	Electrical Heating, Range: 19° C and 49° C.	CO1
2.	Fire Point Apparatus.	Electrical Heating, Range: 19° C and 49° C.	CO1
3.	Cloud Point Apparatus.	Cloud and Cour apparatus (Corrosion Resistance: Yes Frequency: 50 Hz Material: Stainless Steel).	CO1
4.	Pensky Martin Apparatus.	Pensky martens Flash point (Accuracy: +/- 0.50 C, Display Led).	CO2

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
5.	Smoke Point Apparatus.	Dimension: 7cm × 21cm × 19cm; weight: 2 to 4 kg.	CO3, CO4, CO5
6.	Drop Point Apparatus.	Voltage: 230V; Power: 1 KW; External Diameter: 16 MM; Size: 6 HOLE; Temperature: 400 C MAXIMUM.	CO3, CO4, CO5
7.	Conradson carbon residue.	Material: Mild Steel; Shape: Rectangular; Automation Type: Automatic; Phase: Single Phase.	CO3, CO4, CO5
8.	ASTM Distillation Unit.	Electrically heated, Vapor and liquid line; Power required: 220-240V 1 KW, single phase.	CO3, CO4, CO5
9.	Aniline Point Apparatus.	Aniline point (Aniline Point Apparatus as per IP-2, IS-1448, P-3, ASTM D-611, thin film method, electrically heated model with motorized stirrer, pumping system.).	CO4, CO5

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	A text on Petrochemicals.	B.K. Bhaskarrao	2nd Ed, Khanna publishers, New Delhi, ISBN: 978-81-7409-044-7
2.	Advanced Petrochemicals.	G.N. Sarkar	1st Ed, Khanna Publishers, New Delhi, ISBN-10: 8174090967
3.	Modern Petroleum Technology.	Hobson G. D	Volume – II' John Wiley & Sons 1986, ISBN-10: 9780471984115
4.	Petroleum Refinery Engineering.	W.L. Nelson	McGraw –Hill, 1964, ISBN-10: 0070462682

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc23_ch64/preview
2. <https://nptel.ac.in/courses/103107082>
3. https://igitsarang.ac.in/assets/documents/coursematerial/pre_lecture_note_module_1_7th_sem__1600932959.pdf
4. <https://archive.nptel.ac.in/courses/103/102/103102022/>
5. https://sist.sathyabama.ac.in/sist_coursematerial/uploads/SCH1308.pdf

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

(c) Others:

- A) **Course Code** : 2414603B(T2414603B/P2414603B/S2414603B)
- B) **Course Title** : Polymer Technology
- C) **Pre- requisite Course(s)** :
- D) **Rationale** :

Diploma chemical engineers are responsible for identifying and characterizing the raw materials used in the production of polymer to ensure the quality of the final product and must be familiar with the range of processing techniques. Polymers consist of many repeating sub units called monomers & have unique physical properties due to their large molecular mass including high elasticity, toughness & visco – elasticity. They are extensively used in the commercial production of plastics such as elastomers, fibers, coatings and adhesives.

- 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 appropriate techniques of polymerization.
- CO – 2** Use the techniques and their characteristics/limitations of synthesis of polymers.
- CO – 3** Illustrate the structure-processing-property relationship of polymers.
- CO – 4** Apply the various processing and manufacturing techniques.
- CO – 5** Enumerate the basic issues involved in polymer blends, composites, and nano composites.

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

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

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

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2414603B	Polymer Technology	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)	
2414603B	Polymer Technology	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: T2414603B**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Describe techniques of polymerization. TSO 1b. Explain impact of properties on polymer. TSO 1c. Describe the salient properties of plastics. TSO 1d. Describe the salient properties of Rubber. TSO 1e. Describe the salient properties of Fibers.	Unit-1.0 Properties of Polymer 1.1 Techniques of polymerization, Bulk polymerization, Solution polymerization. 1.2 Suspension polymerization, Emulsion polymerization. 1.3 Molecular weight, Crystalline and Glass transition temperature. 1.4 Properties of Plastics: Electrical Resistance, Chemical Resistance, Thermal Stability, Biodegradability. 1.5 Properties of Rubbers: Elasticity, Electric Conductivity, Resistance to fatigue. 1.6 Properties of Fibers: Resiliency, Elongation, Strength.	CO1
TSO 2a. Explain the types of polymerization process with their reaction mechanism. TSO 2b. Compare step growth & chain growth polymerization. TSO 2c. Explain the polymers reactions.	Unit 2.0 - Polymerization Reaction and Techniques 2.1 Types of polymerization reaction – chain and step polymers with examples – various steps in chain polymerization, initiation, propagation and termination, mechanism, propagation and termination mechanism of free radical, ionic and coordination polymerization, living polymer, initiators, inhibitors, chain transfer agents with examples. 2.2 Step growth polymerization, ring opening polymerization and interfacial polymerization with examples correlate with step growth and chain growth polymerization. 2.3 Reactions of polymers - Difference between reactions of polymers and simple molecules, behavior of functional groups in polymers, various reactions like hydrolysis, acidolysis, aminolysis, addition, substitution, reactions of various groups like hydroxyl, aldehyde, and ketone, carboxylic, cyclization reaction.	CO2
TSO 3a. Explain the degradation process with their suitable examples. TSO 3b. Select the methods apply of polymer degradation in chemical process. TSO 3c. Describe various factor affecting the stability of polymers.	Unit 3.0 - Polymer Degradation 3.1 Types of degradation, chain and random degradation, examples of degradation due to thermal, mechanical, high-energy radiation, oxidative degradation/reactions, rubber oxidation, ozone degradation, oxidation of saturated polymers.	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 3d.</i> Explain the methods used for modification of chemical & physical properties of polymers.	3.2 Hydrolytic degradation - degradation of PVC, advantages, and disadvantage of degradation. 3.3 Factors affecting thermal stability– polymer stabilization various additives incorporated in polymer to prevent degradation. 3.4 Various methods to study polymer degradation – TGA, DSC, DTA, IR, etc. Methods of modification of polymers Physical and chemical modification - physical means - blends, alloys, and composites - Chemical methods – co-polymerization, grafting, cross-linking, and interpenetrating network (IPN). Additives, and mechanism of addition of materials in polymer – common additives – curatives accelerators, antioxidants, activators, plasticizers – internal and external, reinforcing filler, extenders, stabilizers, and special purpose additives – function of each.	
<i>TSO 4a.</i> Describe different processing techniques of polymers.	Unit 4.0 – Processing of Polymers 4.1 Mastication, Mixing, Moulding, Extrusion, Calendaring, Vulcanization, Compounding Coating.	CO4
<i>TSO 5a.</i> List the composite materials and define their role in the chemical process.	Unit 5.0 - Composite Materials. 5.1 Ceramic and other fiber reinforced plastics, Polymer degradation - Thermal, Mechanical, Ultrasonic, Photo, High energy radiation, Ecology, and environmental aspects of polymer industries. Rheological Sciences Equations, Unico elastic models - Maxwell.	CO5

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2414603B

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 1.1.</i> Prepare polymer in the lab.	1.	Polymer Preparation and Determine the Yield of Following:	CO1, CO4
<i>LSO 1.2.</i> Determine the yield of the listed polymers.		1.1 Preparation of Phenol – formaldehyde. 1.2 Preparation of Urea –formaldehyde. 1.3 Preparation of Polystyrene by bulk, solution, and emulsion. 1.4 Preparation of PMMA. 1.5 Preparation of graft natural rubber. 1.6 Preparation of Nylons. 1.7 Preparation of Polyesters. 1.8 Preparation of alkyl resins. 1.9 Regenerated Cellulose. 1.10Determination of gel time of UP resins.	

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 2.1. Determine the purity of given raw polymer.	2.	Determination Of Purity of Raw Polymer and Polymer Additives: 2.1 Purity of MBT. 2.2 Purity of DPG. 2.3 Purity of ZnO.	CO2, CO4

L) Suggested Term Work and Self Learning: S2414603B 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 list of typical additives used in polymer products?
- Prepare a note on Glass Transition Temperature.
- Prepare a note of showing advantages of blow molding as compared to injection molding.
- Prepare a note on different types of screw zones in an extrusion machine.
- In molding process, the polymer material will try to stick to the wall of the mold (container). How can you prevent it?
- Apply your knowledge in Chemical Engineering and prepare a note on problem, one may encounter in polymerization processes.

b. Micro Projects:

- Make natural plastic from dairy. Do the properties of the polymer change depending on what you used for the dairy source (percent of milk fat in milk or sour cream, etc.)? Prepare a brief on it.
- Prepare Glyptal resin, analyze the property of Glyptal resin and compare it with decron. Make a brief report on it.
- Prepare thermo-plastics PMMA (Poly Methyl Methacrylate), analyze the property of PMMA and compare it with transparent glass. Make a brief report on it.
- Make gelatin plastic. Examine the properties of the plastic as it goes from fully hydrated with water to fully dried out. Prepare a brief on it.

c. Other Activities:

- Seminar Topics:
 - Biodegradable Polymers: A Sustainable Alternative to Conventional Plastics.
 - Application of Polyethylene (PE) and Polypropylene (PP) Blends.
 - Polybutylene Adipate Terephthalate (PBAT): uses as a biodegradable alternative in packaging films and bags.
 - Starch-Based Polymers: uses & applications like packaging and disposable cutlery.
- Visits: Visit nearby chemical industries. Prepare report of visit with special comments of technique used, material used, single component/batch production/mass production and cost of printed component.

3. Self-Learning Topics:

- Techniques for pressure less processing.
- Compression molding: polymer processing under pressure.
- Injection Molding: polymer processing under pressure.
- Rolling and Calendaring: polymer processing under pressure.

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%	30%	40%	25%	34%	40%	20%
CO-2	20%	20%	10%	25%	33%	10%	20%
CO-3	20%	20%	15%	25%	-	10%	20%
CO-4	20%	20%	20%	25%	33%	30%	20%
CO-5	10%	10%	15%	-	-	10%	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 Properties of Polymer	12	CO1	21	7	7	7
Unit-2.0 Polymerization Reaction & Techniques	8	CO2	14	3	6	5
Unit-3.0 Polymer Degradation	8	CO3	14	3	5	6
Unit-4.0 Processing of Polymers	12	CO4	14	3	6	5
Unit-5.0 Composite Materials	8	CO5	7	4	3	-
Total	48	-	70	20	27	23

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.	Polymer preparation and determine the yield of following 1.11Preparation of Phenol – formaldehyde. 1.12Preparation of Urea –formaldehyde. 1.13Preparation of Polystyrene by bulk, solution, and emulsion. 1.14Preparation of PMMA. 1.15Preparation of graft natural rubber. 1.16 Preparation of Nylons. 1.17Preparation of Polyesters. 1.18Preparation of alkyl resins. 1.19Regenerated Cellulose. 1.20Determination of gel time of UP resins.	CO1, CO4	30	60	10
2.	Determination of Purity of Raw Polymer and Polymer additives 2.1 Purity of MBT. 2.2 Purity of DPG. 2.3 Purity of ZnO.	CO2, CO4	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.	Glassware: Conical flasks, burettes, pipettes, RBFs, measuring cylinders, beakers.	Standard and as per requirements as these are mainly glassware's not so complicated equipment.	All experiments.
2.	Glass Assembly: RBF, reaction vessel, condenser, separating vessel.		
3.	Burner		
4.	Weight balance	Range: - Minimum 0.1 gm to Maximum 5kg (with accuracy of ± 0.1 gm)	
5.	Heating and cooling bath	Material: SS (304/316) with Temperature range from -28 °C to 150 °C.	

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

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Outlines of Chemical Technology,	Rao, M. Gopal, Sittig, Marshall	Affiliated East West Press (Pvt) Ltd, New Delhi 3 rd Edition, ISBN: 9788185938790
2.	Chemical Technology, Vol. I & II	Pandey, G. N. and Shukla	Vani books company, Hyderabad 2 nd Edition, ISBN: 9780706986884, 9780706986877
3.	Shreve's Chemical Process Industries,	Austin, G.T.	McGraw Hill publication, New Delhi 5 th edition, ISBN: 9781259029455
4.	Polymer Science	Gowarikar, V.R., Viswanathan, N.V. Sreedhar, Jayadev	New Age International Pvt. Ltd., New Delhi, ISBN: 9789389802511
5.	Polymer Science and Technology	Joel R.; Fried	PHI Learning, New Delhi, 2007, 2 nd Edition, ISBN-13: 978-0137039555
6.	Text on Petrochemicals	Rao, B. K. Bhaskar	Khanna Publishers, Delhi, 1998, 2 nd Edition, ISBN: 978-81-7409-044-7

(b) Online Educational Resources:

- 1) <https://nptel.ac.in/courses/116102010>
- 2) <https://nptel.ac.in/courses/104105039>
- 3) <https://archive.nptel.ac.in/courses/113/105/113105028/>
- 4) <https://archive.nptel.ac.in/courses/104/105/104105124/>
- 5) www.zorge.com/assets/Documents/Rubber-technology.pdf

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

(c) Others: -

- A) **Course Code** : 2414603C(T2414603C/P2414603C/S2414603C)
- B) **Course Title** : Fertilizer Technology
- C) **Pre-requisite Course(s)** :
- D) **Rationale** :

To provide comprehensive understanding of essential ingredients of fertilizers and the production processes of different fertilizers. Indian economy is dominated by agriculture sector. Synthetic fertilizers are essential for producing high yield of good crops. It is therefore vital for chemical engineers to understand the basic properties of each fertilizer & its flowdiagram for Industrial production. The course content and curriculum should be implemented with the aim to develop required skills in the students, so that they are able to acquire the competency i.e. Supervise the different stages in fertilizer production.

- 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 the relevant fertilizers for the different types of crops.
- CO-2** Justify the need for mixed & complex fertilizers.
- CO-3** Analyze the soil fertility and level of nutrients in soil.
- CO-4** Apply the techniques used in fertilizer.
- CO-5** Use bio-fertilizers over conventional fertilizers for increasing productivity & retaining the health of the soil.

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

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

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

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2414603C	Fertilizer Technology	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)	
2414603C	Fertilizer Technology	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: T2414603C**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Justify the need for synthetic fertilizer TSO 1b. Categorize fertilizers TSO 1c. Explain role of essential elements for plant growth.	Unit-1.0 Overview of Fertilizers 1.1 Definition and classification of nutrient required for growth of plant. 1.2 Synthetic fertilizers, classification of fertilizers. 1.3 Role of essential elements in plant growths. 1.4 Macro elements and microelements application of fertilizers considering nutrient. 1.5 Balance of fertilizer and types of crops.	CO1
TSO 2a. Explain the manufacturing of complex fertilizers with flow diagram. TSO 2b. Select the techniques of manufacturing potassium fertilizers. TSO 2c. Explain the manufacturing of ammonium fertilizers with flow diagram.	Unit -2.0 Mixed and Complex Fertilizer. 2.1 Chemical fertilizers: classification, composition, and properties of major nitrogenous, phosphatic, potassic fertilizers, secondary & micronutrient fertilizers, complex fertilizers, nano-fertilizers, soil amendments. 2.2 Secondary & micronutrient fertilizers: Types, composition, reaction in soil and effect on crop growth. 2.3 Potassium fertilizers, mixed and NPK fertilizers. Methods of production, specification, characteristics of potassium sulphate, potassium chloride, potassium nitrate compound fertilizers and complex fertilizers. 2.4 Raw materials: Methods of production, characteristics, and specifications of ammonium phosphates: SAP, DAP. 2.5 Methods of production, characteristics, storage and handling specifications of ammonium nitrate, calcium ammonium nitrate, ammonium chloride, ammonium sulphate.	CO2
TSO 3a. Explain the role of liquid fertilizer in the chemical industry. TSO 3b. Classify the application and benefits of green manure in today's world scenario. TSO 3c. Select the relevant methods for fertilizer recommendation to the crops.	Unit 3.0 - Introduction to New Variety of Fertilizers: 3.1. Liquid fertilizers: Methods of production, specification, characteristics etc. 3.2. Classification and importance of organic manures, properties, and methods of preparation of bulky manures. Green/leaf manuring. Transformation reactions of organic manures in soil and importance of C: N ratio in rate of decomposition. Integrated nutrient management.	CO3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	3.3. History of soil fertility and plant nutrition, Criteria of essentiality. Role, deficiency and toxicity symptoms of essential plant nutrients, Mechanisms of nutrient transport to plants, factors affecting nutrient availability to plants. Critical levels of different nutrients in soil. Forms of nutrients in soil. 3.4. Methods of fertilizer recommendations to crops. Factor influencing nutrient use efficiency (NUE) in respect of N, P, K, S, Fe and Zn fertilizers, methods of application under rainfed and irrigated conditions. Micronutrient fertilizers, their type, composition, reaction in soils and effect on crop growth.	
<i>TSO 4a.</i> Describe different techniques used in fertilizer. <i>TSO 4b.</i> Analyze the environmental impact of fertilizer plants on Ecosystem. <i>TSO 4c.</i> Apply the soil testing method to determine the critical levels of different nutrients in soil. <i>TSO 4d.</i> Explain the plant analysis methods.	Unit 4.0 - Fertilizer Application Techniques: 4.1. Different soil-controlled release fertilizers. Effluent treatment methods for various fertilizer plants. Environmental impact of fertilizer plants on Ecosystem. Indian fertilizer industry – production Economics and future plans. 4.2. Mechanism of nutrient transport to plants: Factors affecting nutrient availability to plants. 4.3. Handling and storage of fertilizers: Fertilizer control order. 4.4. Soil Testing (Available nutrients): Chemical methods and critical levels of different nutrients in soil. 4.5. Plant analysis methods: Critical levels of nutrients, DRIS approach, Lesson Topic Weight age rapid tissue test, indicator plants. Soil test-based fertilizer recommendations to crops. 4.6. Methods and scheduling of nutrient applications for different soils and crops grown under rain fed and irrigated conditions.	CO4
<i>TSO 5a.</i> Explain the impact of fertilizers on the environment. <i>TSO 5b.</i> Justify the need for bio fertilizers and its benefits. <i>TSO 5c.</i> Explain preparation of bio fertilizers.	Unit 5.0- Fertilizers and Environment: 5.1. Environmental issues related to the use of fertilizers, impact of fertilizers on the environment, Solid, Liquid and Gaseous pollution from fertilizer industries, Bio fertilizers, and green fertilizers. 5.2. Biofertilizers and their role in crop production. Introduction to Bio-fertilizer, Advantages of bio-fertilizers over conventional fertilizers. Manufacturing of bio-fertilizers.	CO5

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2414603C

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1 Prepare chart in the lab.	1	Prepare chart for fertilizer classification with chemical formula and nutrient content.	CO 1
LSO 2.1 Determine % nutrient content in the fertilizer.	2	Estimate nutrient content (% N, %P ₂ O, % K ₂ O) in different fertilizers from their chemical formula.	CO 1, CO 2
LSO 3.1 Determine the % of nitrogen in the given sample.	3	Estimate percentage of Nitrogen in Ammonium chloride by substitution method.	CO 1, CO 2
LSO 4.1 Determine the % of nitrogen in the given sample.	4	Estimate percentage of Nitrogen in Ammonium sulfate by substitution method.	CO 1, CO 2
LSO 5.1 Determine the % of nitrogen in the given sample.	5	Estimate percentage of Nitrogen in Ammonium chloride by back titration.	CO 1, CO 2
LSO 6.1 Determine the % of nitrogen in the given sample.	6	Estimate percentage of Nitrogen in Ammonium sulphate by back titration.	CO 1, CO 2
LSO 7.1 Test method of fertilizer.	7	Fertilizer Adulteration test / Identification of Adulteration in fertilizer / Detection of adulteration in fertilizers (Rapid test).	CO 2, CO 3, CO 4
LSO 8.1 Determine the % of nitrogen in the given sample.	8	Estimate percentage of Nitrogen in Ammonium Chloride/Sulphate by Kjeldhal's method.	CO 1, CO 2
LSO 9.1 Determine the bio fertilizer in the lab.	9	Analysis of bio-fertilizer.	CO 5
LSO 10.1 Determine the % of nitrogen in the given sample.	10	Estimate percentage of Nitrogen in DAP by Formaldehyde method.	CO 2
LSO 11.1 Determine the % of nitrogen in the given sample.	11	Estimate percentage of Nitrogen in DAP by Kjeld Hal's method.	CO 2
LSO 12.1 Prepare the potassium compound in the lab.	12	Prepare potassium sulphate, potassium chloride, potassium nitrate.	CO 2

L) Suggested Term Work and Self Learning: S2414603C 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 showing comparison of the properties of synthetic fertilizer and bio fertilizer.
- Enumerate the requirement of utilities and overheads for setting up a Complex NPK Fertilizer plant?
- Prepare a list of various fertilizer plants present in India with their products and production capacities.
- How many phosphatic fertilizer manufacturing units are present in India? Prepare a list with their production capacity.

b. Micro Projects:

- Prepare Ammonium sulphate in the laboratory, find yield and measure problems associated with it. Write a brief report on the same.
- Develop a prototype fertilizer plant and prepare a report on various unit operation, unit processes involved in manufacturing process, its main product and by product data.
- Prepare a report to control water pollution arising from fertilizer industries.
- Visit nearby agriculture land, study the consumption pattern of synthetic and bio-fertilizer & make a detail report on consumption pattern of fertilizer & its effect on the health of the soil.

c. Other Activities:

1. Seminar Topics:

- Elements present in the soil.
- Comparison of synthetic & bio fertilizer.
- Importance of green fertilizer.
- Advantages of bio-fertilizers over conventional fertilizers.

2. Visits:

Arrange Visit to nearby fertilizer production plant (HURL Bihat) & prepare a brief report on it.

3. Self-Learning Topics:

- Difference between organic manures and chemical fertilizer.
- Application of different nitrogen fertilizers.
- Comparison the properties of Single superphosphate and Triple superphosphate.

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%	10%	-		-	-
CO-2	20%	20%	20%	30%	30%	35%	30%
CO-3	30%	30%	30%	35%	35%	20%	30%
CO-4	20%	20%	20%	35%	35%	35%	30%
CO-5	20%	20%	20%	-	-	10%	10%
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 is 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 Overview of Fertilizers.	8	CO1	7	3	4	-
Unit-2.0 Mixed & Complex Fertilizer.	10	CO2	14	4	5	5
Unit-3.0 Introduction to new Variety of Fertilizers.	10	CO3	21	5	12	4
Unit-4.0 Fertilizer Application & Techniques.	12	CO4	14	4	5	5
Unit-5.0 Fertilizers & Environment.	8	CO5	14	4	5	5
Total	48	-	70	20	31	19

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.	Prepare chart for fertilizer classification with chemical formula and nutrient content.	CO 1	30	60	10
2.	Estimate nutrient content (% N, %P ₂ O ₅ , % K ₂ O) in different fertilizers from their chemical formula.	CO 1, CO 2	40	50	10
3.	Estimate percentage of Nitrogen in Ammonium chloride by substitution method.	CO 1, CO 2	40	50	10
4.	Estimate percentage of Nitrogen in Ammonium sulfate by substitution method.	CO 1, CO 2	30	60	10
5.	Estimate percentage of Nitrogen in Ammonium chloride by back titration.	CO 1, CO 2	40	50	10
6.	Estimate percentage of Nitrogen in Ammonium sulphate by back titration.	CO 1, CO 2	30	60	10
7.	Fertilizer Adulteration test / Identification of Adulteration in fertilizer / Detection of adulteration in fertilizers (Rapid test).	CO 2, CO 3, CO 4	40	50	10
8.	Estimate percentage of Nitrogen in Ammonium Chloride/Sulphate by Kjeldhal's method.	CO 1, CO 2	40	50	10
9.	Analysis of bio-fertilizer.	CO 5	30	60	10
10.	Estimate percentage of Nitrogen in DAP by Formaldehyde method.	CO 2	40	50	10
11.	Estimate percentage of Nitrogen in DAP by Kjeld Hal's method.	CO 2	30	60	10
12.	Prepare potassium sulphate, potassium chloride, potassium nitrate.	CO 2	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.	Glassware: Conical flasks, burettes, pipettes, RBFs, measuring cylinders, beakers.	Standard and as per requirements as these are mainly glassware's not so complicated equipment.	All experiments.
2.	Glass Assembly: RBF, reaction vessel, condenser, separating vessel.		
3.	Burner		
4.	Weight balance (minimum 0.1gm)	Range: - Minimum 0.1 gm to Maximum 5kg (with accuracy of ± 0.1 gm)	
5.	Heating and cooling bath	Material: SS (304/316) with Temperature range from -28 °C to 150 °C.	
6.	Kjeld Hal Assembly	Material: 304 Grades Stainless Steel; Flask capacity: 30 ML, 50 ML & 100ML; Heating element: Kanthal A-1 Heater watt: 200 watts; Maximum temperature: 350 °C; Power supply: 220 volts.	

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Dryden's Outlines of Chemical Technology,	M. Gopala RaoSitting Marshall	Affiliated East West Press (Pvt) Ltd, 3 rd Ed., New Delhi, ISBN: 9788185938790
2.	Shreve's Chemical Process Industries, 5 th edition.	Austin G.T.	McGraw Hill publication, New Delhi, ISBN: 9781259029455
3.	Chemical Technology -Vol. I and II, 2 nd edition.	Pandey G.N. andShukla	Vani Books Company - Hyderabad, ISBN-13: 978-0706986877
4.	Biofertilizers in Agriculture, 2 nd edition.	N. S. Subba Rao	Oxford & IBH Publishing Company, New Delhi 1988, ISBN-10 : 9789386800039

(b) Online Educational Resources:

- 1) <https://nptel.ac.in/courses/103107086>
- 2) <https://nptel.ac.in/courses/103106108>
- 3) <https://www.youtube.com/watch?v=gzeo1dmKvuw>
- 4) <https://digimat.in/nptel/courses/video/126105024/L44.html>
- 5) https://sist.sathyabama.ac.in/sist_coursematerial/uploads/SCH1604.pdf
- 6) www.fnca.mext.go.jp/bf/bfm/pdf/Biofertilizer_Manual.pdf

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

(c) Others:

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

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

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

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

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

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

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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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	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,	CO-4

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

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

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

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

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

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

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

b. Micro Projects:

Use python programming for the solutions of Microproject problems

- (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.
- (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.
- Conduct performance analysis of Classification Algorithms (any 2) on a specific dataset.

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

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

Legend:

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

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

Legend:

PRA*: Process Assessment

PDA*: Product Assessment

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

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

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

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
1.	Computer Systems	Desktop Computers with i3 processor, 16 GB RAM, 512 GBHDD	S. No. 1 to 10
2.	Online Python IDE	https://www.online-python.com/	S. No. 1 to 10
3.	Jupyter Notebook	Download from https://jupyter.org/	S. No. 1 to 10
4.	Pip Python package manager	Download Pip 22.3 From https://pypi.org/project/pip/	S. No. 1 to 10
5.	Google colab	https://colab.research.google.com/github/tensorflow/docs/blob/master/site/en/tutorials/quickstart/beginner.ipynb#scrollTo=DUNzJc4JTj6G	S. No. 1 to 10
6.	Various modules, Libraries and Packages	Tens or flow, NumPy, Pandas, package	S. No. 1 to 10

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

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

(b) Online Educational Resources:

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

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

(c) Others:**Data Source:**

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

- A) **Course Code** : 2400604C(T2400604C/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-

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

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

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.1. a. Write the steps to install Python. TSO.1. b. Explain given types of variables in python. TSO.1. c Explain use and importance of Tuple, Dictionary, operators in python TSO.1. d. Explain use of array in python. TSO.1. e. Explain use of 2-Dimensional Array in python TSO.1. f Explain uses of given type of Conditional statement in python.	Unit-1.0 Python Basics: - 1.1 Installation of Python 1.2 Variables, Print () function, Escape character sequence and run python Program 1.3 Python Tuple, Dictionary, operators 1.4 Python arrays, create, reverse and append data into it. 1.5 Python 2 Dimensional arrays. 1.6 Python Conditional statement.	CO-1 and CO-5
TSO.2. a. Explain uses of given type of do & while loops in python TSO.2. b. Explain working of break, continue and pass statement in python TSO.2. c. Write the benefits of using OOP methodology in python. TSO.2. d. Explain given type of string operation related to python. TSO.2. e. Explain given function in python TSO.2. f Explain use of Lambda function in python.	Unit 2. Python Advance: - 2.1 Python Do & while loops 2.2 Python break, continue, pass statements 2.2 Python OOPs Class, Object, Inheritance and Constructor 2.4 Python Strings Replace, Join, Split, Reverse, Uppercase, Lowercase, count, find, split and length 2.5 Python Functions, Built-in functions and user defined functions 2.6 Lambda function and uses	CO-1 and CO5
TSO.3. a. Differentiate between Cloud and IoT cloud. TSO.3. b. Explain features of Cloud in IoT environment TSO.3. c. List features of various types of Cloud TSO.3. d. List features of cloud services like SaaS, PaaS and IaaS TSO.3. f List advantages of cloud data storage. TSO.3. g Explain Arduino architecture and its applications. TSO.3.h Explain Raspberry pi architecture and its applications.	Unit-3.0 Cloud Features: - 3.1 Cloud computing and IoT cloud 3.2 Benefits of cloud in IoT 3.3 Types of Cloud public, private and hybrid 3.4 Cloud services like SaaS, PaaS and IaaS 3.5 Cloud connectivity and Data storage on Cloud. 3.6 Arduino: Architecture, Programming, and Applications 3.7 Raspberry Pi Architecture, Programming, and Application basic level for IoT applications	CO-1, CO-2 and CO-5
TSO.4. a. Explain wired network TSO.4. b. Explain short range wireless network TSO.4. c. Explain M2M communication TSO.4. d. Explain various generation of wireless network TSO.4. e. Explain the importance of LWPAN in IoT TSO.4. f Differentiate between SigFox & LoRaWAN TSO.4. g Explain use of NB-IOT (Narrow Band IOT) TSO.4.h Create heterogenous network using RFID.	Unit.4 IoT Networking and Application: - 4.1 Wired and short-range wireless network 4.2 M2M – 2G, 3G, 4G & 5G networks 4.3 LPWAN – Low Power Wide Area Networks 4.4 SigFox & LoRaWAN. 4.5 NB-IOT (Narrow Band IOT) 4.6 RFID and Bar code basics- Components of an RFID system-Data -Tags-Antennas- Connectors- Cables- Readers- encoder/ printers for smart labels- Controllers software 4.7 RFID advantages over Bar codes.	CO-1 and CO-4
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.	Unit. 5 IoT App Development: - 5.1 Framework selection for IoT app development 5.2 Identify stages of app to be developed. 5.3 Develop, Implement, and Deploy the App 5.4 Testing and Integration	CO-4 and CO-5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.5. d. Implement and deploy the app TSO.5. e Maintain and improve the app based on the feedback	5.5 Maintain and improve	

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

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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1 Python installation LSO 1.2 Prepare and run python program on given problem LSO 1.3 Prepare python program on Dictionary, Tuple and operators. LSO 1.4 Prepare program on arrays LSO 1.5 Prepare a program on 2-dimensional array LSO 1.6 Create program on conditional statement	1.	1.1 Install given version of Python on the computer system. 1.2 Prepare a python program using print() function and run it. 1.3 Access given value from the tuple 1.4 Print the given value of key from the dict. 1.5 Write a Python program to create an array of 5 integers and display the array items. Access individual element through indexes 1.6 Write a Python program which takes two digits m (row) and n (column) as input and generates a two-dimensional array. 1.7 Write a python program to check whether person is eligible for voting or not. (accept age from the user) 1.8 Write a python program to check whether the entered number is even or odd. 1.9 Write a python program to check whether entered number is divisible by another entered number. 1.10 Write a python program to display "Yes" is entered number is divisible by 5 otherwise display "No"	CO-1
LSO 2.1 Prepare python program on Do & while loops LSO 2.2 Prepare python program on break and continue statement. LSO 2.3 Prepare Python program using break and continue statements LSO 2.4 prepare python program using OOP LSO 2.5 Prepare Python program using functions	2.	2.1 Prepare a python program which can print first 10 even and odd numbers using while statement 2.2 Write a python program which can print first 10 integers and its square using while/for loop. 2.3 Write a python program which can print sum of first 10 natural numbers using while/for loop. 2.4 Write a python program which can identify the prime number between the range given using while/for loop. 2.5 Consider a situation where you want to iterate over a string and want to print all the characters until a letter 'e' or 's' is encountered. It is specified that you have to do this using loop and only one loop is allowed to use. 2.6 Consider the situation when you need to write a program which prints the	CO-2

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

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

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

b. Micro Projects:

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

c. Other Activities:

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

d. Self-Learning Topics:

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

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

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

Legend:

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

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

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

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

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

R) Suggested Learning Resources:

(a) Books:

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

(b) Online Educational Resources:

1. nptel.iitm.ac.in/courses/.../IIT.../lecture%2023%20and%2024.htm
2. en.wikipedia.org/wiki/Shear_and_moment_diagram
3. www.freestudy.co.uk/mech%20prin%20h2/stress.pdf

4. www.engineerstudent.co.uk/stress_and_strain.html
5. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf
6. <https://www.veritis.com/blog/aws-vs-azure-vs-gcp-the-cloud-platform-of-your-choice/>
7. <https://wiki.python.org/moin/TimeComplexity>
8. www.engineerstudent.co.uk/stress_and_strain.html
9. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf
Amini, P. (2014). Sulley: Pure Python fully automated and unattended fuzzing framework.
<https://github.com/OpenRCE/sulley>

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

(c) Others:

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

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

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

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

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

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

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

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number (s)
TSO 1a. Draw free body diagram of quadcopter drone. TSO 1b. Determine centroid of given drone structure. TSO 1c. Determine center of gravity of different drone structure. TSO 1d. Analyze different types of force acting drone system. TSO 1e. Differentiate between static and dynamic force analysis. TSO 1f. Explain how gyroscopic motion keeps drone balanced and hovering.	Unit-1.0 Engineering mechanics for Drone Technology 1.1 Drone Mechanics - 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 drone 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
TSO 3a. Identify features and specifications of FCB use in different application	Unit-3.0 Advance flight controller Board (FCB) 3.1 Specification and ports of FCB	CO-3

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number (s)
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.	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	
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 drone structure.	CO-1
LSO 2.1 Develop skills of observation and interpreting phenomenal changes on Drone model for stability and hovering.	2.	Demonstrate gyroscopic effect on a drone model	CO-1
LSO 3.1 Draw various frame to be required in designing drone structure.	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 3.2 Use Measuring instrument in designing drone frame.			
LSO 3.3 Choose suitable materials for making drone frame			
LSO 4.1 Identify and measure the condition of sensors.	4.	Test Tilt and LiDAR sensors and their characteristics with Microcontroller based Flight controller board.	CO-2
LSO 4.2 Interface Tilt and LiDAR sensors in drone.			
LSO 5.1 Identify different component of GPS module	5.	Demonstrate the interfacing of GPS module to drone navigation.	CO-2, CO-3
LSO 5.2 Measure and use signals from GPS module to determine latitude & longitude.			
LSO 5.3 Diagnose problems using appropriate instruments/tools related to GPS navigation.			
LSO 6.1 Measure characteristics of HD and thermal Image camera.	6.	Test HD and thermal Image camera and their characteristics.	CO-2
LSO 6.2 Diagnose common problems related to HD and thermal Image camera.			
LSO 7.1 Identify the characteristics of RF circuit blocks like amplifier, and filters.	7.	Identify, configure and operate 433MHz and 2.4 GHz RC transmitter and receiver.	CO-2
LSO 7.2 Identify different antennas used.			
LSO 7.3 Operate drone using RC transmitter and receiver.			
LSO 8.1 Test the different peripheral interconnections with FCB	8.	Programming and configure of parameters in flight control board (FCB).	CO-3
LSO 8.2 Troubleshoot advance Flight control board (FCB)			
LSO 9.1 Configure radio communication device to control drones.	9.	Test and perform communication of advance Flight control board with RF transceiver.	CO-3, CO-2
LSO 9.2 Operate drone using RC transmitter and receiver.			
LSO 10.1 Measure various parameters of GPS system	10.	Test and perform communication of Flight control board (FCB) with GPS	CO-3, CO-2
LSO 10.2 Interface GPS system with flight controller board.			
LSO 11.1 Configure HD and thermal image camera with drone.	11.	Test and troubleshoot HD and thermal image camera with advance FCB in drone.	CO-3, CO-2
LSO 11.2 Demonstrate use of HD and thermal image camera with FCB			
LSO 12.1 Measure voltage, current frequency using Digital Multimeter	12.	Measure various electric parameters in drone hardware	CO-4
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.			

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	13.	Perform preventive maintenance of drone components	CO-4
LSO 13.2 Diagnose drone problems after flying of 50 and 100hrs			
LSO 14.1 Perform dismantle process of drone.	14.	Dismantle and service of different parts of drone system	CO-4
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.			

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	Remember (R)	ETA (Marks) 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		Viva-Voce (%)
			Performance PRA* (%)	PDA** (%)	
1.	Determine Centre of gravity of different drone structure.	CO-1	50	40	10
2.	Demonstrate gyroscopic effect on a drone model	CO-1	40	50	10
3.	Compare different types of airframe structure like quadcopter frame (plus shape, cross shape and H-shape), hexacopter frame (hexa + and hexa S).	CO-2	50	40	10
4.	Test Tilt and LiDAR sensors and their characteristics with Microcontroller based Flight controller board.	CO-2	50	40	10
5.	Demonstrate the interfacing of GPS module to drone navigation.	CO-2, CO-3	50	40	10
6.	Test HD and thermal Image camera and their characteristics.	CO-2	50	40	10
7.	Identify, configure and operate 433MHz and 2.4 GHz RC transmitter and receiver.	CO-2	60	30	10
8.	Programming and configuration of parameters in flight control board (FCB).	CO-3	60	30	10
9.	Test and perform communication of advance Flight control board with RF transceiver.	CO-3, CO-2	60	30	10
10.	Test and perform communication of Flight control board (FCB) with GPS	CO-3, CO-2	60	30	10
11.	Test and troubleshoot HD and thermal image camera with advance FCB in drone.	CO-3, CO-2	60	30	10
12.	Measure various electric parameters in drone hardware	CO-4	40	50	10
13.	Perform preventive maintenance of drone components	CO-4	60	30	10
14.	Dismantle and service of different parts of drone system	CO-4	60	30	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

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

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

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

(b) Online Educational Resources:

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

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

(c) Others:

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

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

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

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

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

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

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

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

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

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

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

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 1a.</i> Explain various forms of 3D printing raw material. <i>TSO 1b.</i> Select material for the given popular 3D printing processes with justification. <i>TSO 1c.</i> Select various Polymer based 3D printing raw materials with justification. <i>TSO 1d.</i> Explain procedure of Powder preparation for the given 3D printing material. <i>TSO 1e.</i> Explain properties of the given Metal/Ceramics 3D printing material. <i>TSO 1f.</i> 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
<i>TSO 2a.</i> Explain working of a typical FDM based 3D Printer. <i>TSO 2b.</i> Justify use of FDM based 3D printing process and material for the given component. <i>TSO 2c.</i> Explain the Laminated Object Manufacturing process. <i>TSO 2d.</i> 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
<i>TSO 3a.</i> Explain the phenomenon of Photo Polymerization. <i>TSO 3b.</i> Explain the working of a typical Stereo Lithography based 3D Printer. <i>TSO 3c.</i> Explain procedure of 3D Scanning of the given component. <i>TSO 3d.</i> Justify use of SLA based 3D printing process and material for the given component. <i>TSO 3e.</i> Estimate the cost and time of the given SLA based 3D printed component. <i>TSO 3f.</i> 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
<i>TSO 4a.</i> Explain powder fusion mechanism. <i>TSO 4b.</i> Explain working of a typical SLA based 3D Printer. <i>TSO 4c.</i> Justify use of SLA based 3D printing process and material for the given component. <i>TSO 4d.</i> Explain Net shape process. <i>TSO 4e.</i> Explain Binder Jet 3D printing process. <i>TSO 4f.</i> Justify use of Binder Jet 3D printing process and material for the given component. <i>TSO 4g.</i> 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.	
<i>TSO 5a.</i> Justify the need of post processing in the given 3D printed component. <i>TSO 5b.</i> List the various post processing techniques. <i>TSO 5c.</i> List the steps to perform post processing. <i>TSO 5d.</i> Explain the given Cleaning related post processing approach for 3D printed component. <i>TSO 5e.</i> Explain the given Surface finishing related post processing approach for 3D printed component. <i>TSO 5f.</i> Apply simple inspection and testing techniques on the given 3D printed component. <i>TSO 5g.</i> 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)
<i>LSO 1.1.</i> Use the available 3D printing software. <i>LSO 1.2.</i> Select printing process parameters based on the type/make of Printer and raw material <i>LSO 1.3.</i> Set printing process parameters. <i>LSO 1.4.</i> 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
<i>LSO 2.1.</i> Use the available 3D printing software. <i>LSO 2.2.</i> Select printing process parameters based on the type/make of Printer and raw material <i>LSO 2.3.</i> Set printing process parameters. <i>LSO 2.4.</i> Produce a complex component using available SLA Printer. <i>LSO 2.5.</i> 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
<i>LSO 3.1.</i> Use the available 3D printing software. <i>LSO 3.2.</i> Select printing process parameters based on the type/make of Printer and raw material <i>LSO 3.3.</i> Set printing process parameters. <i>LSO 3.4.</i> 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.	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 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.			
LSO 5.1. Use the available 3D printing software.	5.	Print one digital assembly on SLA/SLS based 3D Printer.	CO2/CO3/CO4
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.			
LSO 6.1. Use of available 3D scanner.	6.	Scan the given real complex component and print it using FDM/SLA/SLS based 3D Printer.	CO2, CO3, CO4
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.			
LSO 7.1. Identify tools/devices/chemicals for post processing	7.	Apply post processing techniques on the 3D printed component of experiment number 1 and/or 2 and/or 3.	CO5
LSO 7.2. Perform post processing operations on printed component.			
LSO 8.1. Identify tools/devices/techniques for inspection and testing.	8.	Check the soundness of the 3D printed component of experiment number 1 and/or 2 and/or 3 using available devices/techniques.	CO5
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.			

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

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

b. Micro Projects:

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

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

c. Other Activities:

1. Seminar Topics:

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

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

3. Self-Learning Topics:

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

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

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

Legend:

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

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
1.	High end computers	Processor Intel Core i7 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10	All
2.	Parametric Computer Aided Design software	CATIA/Solid works/NX/Creo OR Available with CoE	1 to 5
3.	FDM based 3D printer	Fused Deposition Modelling system with complete accessories; Build Volume-300 x 300 x 300mm or Higher; Layer Thickness-0.1 – 0.4 OR Available with CoE	1,4,5,6
4.	SLA based 3D printer	Printing Technology: SLA, 145 x 145 x 175mm build volume, Common layer thickness 25–100 μ m, Dimensional Accuracy $\pm$ 0.5% (lower limit: $\pm$ 0.10 mm), cure time of only 1-3s per layer, Material type: UV-sensitive liquid resin, Curing unit.	2,4,5,6
5.	SLS based 3D printer	Printing Technology: SLS., Build Volume: 130 x 130 x 180 mm, Recommended min. wall thickness: 0.8 mm, Powder Diameter: 60 Microns, Material Type: Nylon, TPU, Light Source: Laser Diode	3,4,5,6
6.	3D Printing Material	ABS/PLA, Resin based Photosensitive material, Polymer/metal/ceramic powder OR Available with CoE	1,2,3,4,5,6
7.	3D Printing software	Latest version of software like: Cura/PrusaSlicer/ideaMaker/Meshmixer/MeshLab OR Available with CoE	1 to 6
8.	3D Scanner and Processing software	Handheld 3D scanner, Accuracy up to 0.1 mm, Resolution up to 0.2 mm, Real time onscreen 3D model projection and processing, Wireless technology with an inbuilt touch screen and battery, Extended field of view for capturing both large and small objects, Processing Software OR Available with CoE	6
9.	Post processing equipments and tools	Deburring tools (tool handle & deburring blades), Electronic Digital Caliper, Cleaning Needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removal spatula, Needle file, Cutting mat, Glue stick, Wire stripper, Chemicals, Etching agents etc.	7
10.	Inspection and Testing devices	- Visual inspection, Devices related to: - Scanning electron microscopy (SEM), CT system, X-ray, - Penetration testing, - Infrared thermography, - Leak or pressure testing for complex structures, - Eddy current, - Mechanical property inspection to measure tensile, yield, shear, fatigue, hardness, density, impact strength - Metallography (Microstructure testing)	8

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

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

(b) Online Educational Resources:

1. https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. <https://archive.nptel.ac.in/courses/112/104/112104265/>
3. <https://bigrep.com/post-processing/>
4. <https://www.mdpi.com/2227-7080/9/3/61>
5. <https://all3dp.com/2/best-3d-printing-books/>
6. <https://www.youtube.com/watch?v=TQY2lF-sFal>
7. <https://www.youtube.com/watch?v=Oz0PoS5LPxg>
8. <https://www.youtube.com/watch?v=6ejjh0GdyDc>

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

(c) Others:

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

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

D) **Rationale** :

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

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

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

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

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

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
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	3.4 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. TSO.5d Prepare plan for sustainable automation as per the requirement.	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. 5.2 Health Care- microscopic robots for medical diagnosis, automated medication dispensing devices, AESOP, ZEUS, RP_7(remote presence 7th generation), DaVinci	CO-5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	5.3 Defense- guided rockets and missiles , counter measures, UAV drones, launcher, radar antenna, engagement control system 5.4 Automobile –Break monitoring system, Vehicle tracking system, Rear-view alarm to detect obstacles behind, Four-wheel drive, Traction control system, Dynamic steering response, Anti-lock braking system (ABS) Adaptive cruise control, Adaptive headlamps, Intelligent Parking Assist System, Driverless/Autonomous Cars 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)
<i>LSO 1.1</i> Data communication from PLC to PC and vice versa	1.	Transfer the control data from PLC to PC and vice versa	CO1
<i>LSO 1.2</i> Establish Communication channels between PLC s.	2.	Transfer the control data from PLC to PLC	CO1
<i>LSO 1.3</i> Transfer data from sensors to PLC and from PLC to PC.	3.	Transfer the sensor data from sensor to PLC to PLC and PC	CO1
<i>LSO 1.4</i> Interface the given PLC with a PC or a Laptop	4.	Interface the given PLC with a PC or a Laptop	CO1
<i>LSO 2.1</i> Identify Different parts and front panel indicators of a PLC	5.	Identify the various parts and front panel status indicators of the given PLC.	CO2
<i>LSO 2.2</i> Develop Ladder logic program for different arithmetic operations	6.	Develop/Execute ladder logic program for different arithmetic operations such as Addition, subtraction, multiplication, division increment, decrement, trigonometric in a given PLC	CO2
<i>LSO 2.3</i> Develop Ladder logic program for different logical operations	7.	Develop/Execute ladder logic program for logical operations such as AND, OR, NOT, NAND, NOR, X-OR, X-NOR gate along with truth table	CO2
<i>LSO 2.4</i> Program Latch and Unlatch circuit in a PLC for motor operation	8.	Program the given PLC to start run and stop the given motor using latch circuit	CO2
<i>LSO 2.5</i> Create delay in operation using on delay, off delay and retentive timer function in a given PLC.	9.	Test the functionality of on delay, off delay and retentive timer for its correct operation in a given PLC.	CO2
<i>LSO 2.6</i> Count the number of objects/events using Up counter, Down counter and UP/Down counter in a PLC	10.	Test the functionality of Up, Down and Up-down counter for its correct operation in a given PLC.	CO2
<i>LSO 2.7</i> Program PLC using ladder logic to control a LED/Lamp	11.	Develop/Execute a ladder logic program to put LED/lamp in the blinking mode	CO2
<i>LSO 2.8</i> Program PLC using ladder logic to control a simple traffic light system	12.	Develop/Execute a ladder logic program to control a simple traffic light control system using PLC	CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
<i>LSO 3.1</i> Use hygrometer to measure the humidity inside the panel <i>LSO 3.2</i> Use thermometer to measure ambient temperature inside the panel <i>LSO 3.3</i> Use tester to determine the voltage fluctuation at the power supply terminals is within specifications <i>LSO 3.4</i> Test the ground connections of the given PLC. <i>LSO 3.5</i> A given PLC is not working as per the logic instructions investigate the PLC to identify the cause of failure to show the desired output <i>LSO 3.6</i> Investigate the cause of Noise in the given PLC <i>LSO 3.7</i> PLC goes on blackout out by losing its operating power. Troubleshoot the cause of failure. <i>LSO 3.8</i> Troubleshoot the corrupted PLC memory. <i>LSO 3.9</i> Replace CPU and power supply fuses in a given PLC system.	13.	Troubleshooting of PLC system	CO3
<i>LSO 4.1</i> Download any open source SCADA software and install the same. <i>LSO 4.2</i> Interpret the available components in symbol factory of SCADA software <i>LSO 4.3</i> 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. <i>LSO 4.4</i> 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
<i>LSO 5.1</i> Develop a smart irrigation device to detect the change in moisture level in the soil and controls the flow of water accordingly with a DC pump. <i>LSO 5.2</i> Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application <i>LSO 5.3</i> Develop a PLC program to control the robot in such a way that the	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)
		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	Remember (R)	ETA (Marks) 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		Viva-Voce (%)
			Performance 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
13.	Use hygrometer to measure the humidity inside the panel	CO3	50	40	10

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		Viva-Voce (%)
			Performance PRA* (%)	PDA** (%)	
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 the intensity of the sunlight at that particular time of the day.	CO5	60	30	10

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

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

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

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

R) Suggested Learning Resources:

(a) Books:

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

(b) Online Educational Resources:

1. Software: - www.fossee.com
2. Software: - www.logixpro.com
3. Software: - www.plctutor.com
4. Software; - www.ellipse.com
5. PLC lecture: - <https://www.youtube.com/watch?v=pPiXefBO2qo>
6. PLC tutorial: http://users.isr.ist.utl.pt/~jag/aulas/apil3/docs/API_I_C3_3_ST.pdf

7. <https://www.youtube.com/watch?v=277wwYWolpw>-PLC system troubleshooting and repair. Industrial control panel. PLC system repair.
8. <https://www.youtube.com/watch?v=5Jmtvrch5Jg>
9. <https://www.youtube.com/watch?v=peyV9bwEaLY>
10. <https://www.youtube.com/watch?v=QdJhRmtKpxk&list=RDCMUCke36Liq-w5fboMHkq1APZw&index=3>
11. <https://www.youtube.com/watch?v=ygrrRwalz3M>

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

(c) Others:

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

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

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

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

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

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

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

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

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

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

G) Teaching & Learning Scheme:

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

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain the vehicle movement process TSO 1b. Derive various equations for the movement of Vehicles TSO 1c. Compute different resistances affecting Vehicle movement. TSO 1d. Explain the dynamics of the given type of EV system.	Unit-1.0 Vehicle Dynamics 1.1 Vehicle Movement 1.2 Rolling Resistance: Equation, Coefficient, factor affecting rolling resistance, typical values of rolling resistance 1.3 Grading resistance 1.4 Road resistance 1.5 Acceleration resistance 1.6 Total driving resistance 1.7 Aerodynamic drag: Equation, typical values of the drag coefficient. 1.8 Vehicle dynamics - Hybrid and Electric Vehicles - DC Motor Dynamics and Control - AC Motor Dynamics and Control	CO1
TSO 2 a. Identify the given elements of Automobile Systems. TSO 2 b. Describe the functions of the given elements of Automobile Systems. TSO 2 c. Explain the dynamic characteristics of the Disc Braking System for the given braking steps. TSO 2 d. Describe the Procedure for testing the given AC/DC motors. TSO 2 e. Describe the Procedure of Installation and Testing of the given EV Charging Stations. TSO 2 f. Describe the Procedure for Commissioning EV Charging Stations. TSO 2 g. Explain the functions of the EV Control Unit.	Unit-2.0 Elements of Automobile 2.1 Suspension and Damping systems 2.2 Brake system: Half-step braking, Full step Braking 2.3 Transaxle 2.4 Elements of Noise Vibration and Harshness Control 2.5 Body balancing 2.6 Tyre Technology 2.7 AC/DC motor 2.8 Air-conditioning and Heating System 2.9 Lighting System 2.10 Automotive wiring system 2.11 Earthing and Insulation 2.12 Charging stations – Installation and Commissioning 2.13 Vehicle control unit	CO2
TSO 3a. Compare different power transmission systems in EVs. TSO 3b. List the main Components of the EV Power Train. TSO 3c. Explain the functions of the given EV Power Train component. TSO 3d. Describe the testing procedure of the given EV Power Train component. TSO 3e. Explain the regenerative braking operation in the given EV motor. TSO 3f. Describe the speed control mechanism of the given motor. TSO 3g. Explain various parameters of the given battery. TSO 3h. Select the suitable battery for the given EV application. TSO 3i. Describe the assembling and dismantling procedure of the given battery.	Unit-3.0 EV Power Transmission System 3.1 Transmission System: Single and Multi-transmission system 3.2 EV Power Train 3.3 EV Power Train Components: Battery Pack, DC-AC Converter, Electric Motor, On-Board Charger. 3.4 Battery Parameters: Voltage, Current, Charging rate, efficiency, energy density, power density, State of Charge (SoC), Depth of Discharge (DoD), State of Health (SoH), Operating Temperature, specific energy, specific power, life cycle and cost. 3.5 Battery Assembly and Dismantling. 3.6 Gear and Differential Assembly 3.7 Safe disposal of used battery	CO3

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

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

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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 2.1 Test the operation of the Control Disc Braking system and control the regenerative braking system using a test rig.	1.	Testing of Control Disc Braking system and Control Regenerative Braking system.	CO2
LSO 2.2 Test the performance (Speed v/s Braking Torque) of the Disc Braking System in Half step and Full step braking modes.			
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.	
LSO 3.1 Test the performance of a new set of batteries and aged batteries.	4.	Testing of Batteries used in EVs	CO2, CO3
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			

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
b. Specific energy c. Life span and d. Cost parameters			
LSO 3.4 Evaluate the State of Health (SoH) of the given EV Battery after several charge/discharge cycles.			
LSO 3.5 Test the dynamic performance of the given motor;	5.	• Speed control of Electrical Motors	
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			
LSO 4.1 Connect the components of the EC Units with EV subsystems.	6.	• Connection of Electronic Control Unit components	CO4
LSO 4.2 Troubleshoot basic faults in the electronic control unit of EV.		• Troubleshooting of electronic control unit	
LSO 5.1 Evaluate the impact of the Grid on Vehicle Charging and Vehicle Charging on the Grid.	7.	• Impacts of G2V and V2G	CO5
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 (CI) Hours	Relevant COs Number (s)	Total Marks	Remember (R)	ETA (Marks)		Application & above (A)
					Understanding (U)		
Unit-1.0 Vehicle Dynamics	8	CO1	12	4	5		3
Unit-2.0 Elements of Automobile.	10	CO2	15	5	6		4
Unit-3.0 EV Power Transmission System.	14	CO3	20	4	10		6
Unit-4.0 Vehicle Control Unit (VCU)	10	CO4	15	4	6		5
Unit-5.0 Charging Technologies	6	CO5	8	3	3		2
Total Marks	48		70	20	30		20

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

O) Suggested Assessment Table for Laboratory (Practical):

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

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved

Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Portfolio Based Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field, Information and Communications Technology (ICT) Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Sessions, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

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

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

R) Suggested Learning Resources:

(a) Books:

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

(b) Online Educational Resources:

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

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

(c) Others:

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

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

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

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

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

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Define the need and scope of industrial robots. TSO 1b. Describe the concept of robot dynamics with regards to methods for orientation and location of objects. TSO 1c. Analyse robot direct kinematics for the given 2 DOF planar manipulator. TSO 1d. List types of robots TSO 1e. List safety steps while handling the given robot. TSO 1f. Interface robots with the given welding machine. TSO 1g. Interface robots with the given painting machine. TSO 1h. Interface robots with the given assembly machine.	Unit-1.0 Robot Kinematics, Dynamics and Industrial Applications 1.1 Definition need and scope of Industrial robots 1.2 Robot dynamics – Methods for orientation and location of objects 1.3 Planar Robot Kinematics – Direct and inverse kinematics for 2 Degrees of Freedom. 1.4 Safety while operating and handling robot 1.5 Robot Industrial applications: - Welding Robots-Welding Guns, Welding Electrodes, Welding Power Sources, shielding gases, Robot interfacing - Spray painting Robots, assembly operation, cleaning.	CO2, CO3
TSO 2a. Explain the techniques to control robot motion. TSO 2b. Describe the given robot drive system. TSO 2c. Describe the types of grippers. TSO 2d. Design grippers for specific application. TSO 2e. Test the designed gripper for the application. TSO 2f. Use Bar code technology for robotic applications. TSO 2g. Integrate radio frequency identification technology in robotic applications. TSO 2h. Assemble an automated guided vehicle for the given situation using standard components. TSO 2i. Assemble a simple automated storage and retrieval systems (ASRS) for the given situation using standard components.	Unit- 2.0 Robot Drives, Control and Material Handling 2.1 Controlling the Robot motion. 2.2 Position and velocity sensing devices. 2.3 Drive systems – Hydraulic and Pneumatic drives 2.4 Linear and rotary actuators and control valves 2.5 Electro hydraulic servo valves, electric drives, motors 2.6 End effectors – Vacuum, magnetic and air operated grippers 2.7 Material Handling; automated guided vehicle systems, automated storage and retrieval systems (ASRS) 2.8 Bar code technology 2.9 Radio frequency identification technology.	CO2, CO3
TSO 3a. Differentiate between various work cell layouts. TSO 3b. Select work cell for specific robot with justification. TSO 3c. Analyse robot cycle time. TSO 3d. Explain industrial applications of robotic cell. TSO 3e. Follow safety procedures in robotic cell.	Unit- 3.0 Robot Cell Design and Application 3.1 Robot work cell design, control and safety 3.2 Robot cell layouts 3.3 Multiple Robots and machine interference 3.4 Robot cycle time analysis 3.5 Industrial application of robotic cells	CO3
TSO 4a. List different programming languages for the robots	Unit- 4.0 Robot Programming and Economics of Robotization	CO1, CO4, CO5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
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.	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 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 utilities, 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. LSO 6.2 Integrate the components for the required application.	6.	Design a PC controlled wireless Multipurpose robot for simple engineering applications.	CO2, CO4, CO5
LSO 7.1 Identify the components required for an unmanned arial photography LSO 7.2 Integrate the components for the required application.	7.	Design an unmanned arial photography system.	CO3, CO5
LSO 8.1 Develop a program LSO 8.2 Simulate palletizing and depalletizing operations through robots.	8.	Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots.	CO5
LSO 9.1 Develop a program LSO 9.2 Simulate direction control and step control logic for robotization	9.	Develop TPP / Offline program for vision-based inspection for robots.	CO4, CO5
LSO 10.1 Develop a program LSO 10.2 Simulate robotising an inspection and part assembly.	10.	Program and simulate coordinated identification, inspection and part assembly for robots.	CO1, CO5
LSO 11.1 Develop a program. LSO 11.2 Simulate obstacle avoidance of robots.	11.	Develop obstacle avoidance robot Programming	CO1, CO5
LSO 12.1 PLC programming. LSO 12.2 Simulate robotising of welding operation.	12.	Program and simulate welding operation using robot simulation software.	CO1, CO5
LSO 13.1 Simulate robotising of drilling operation.	13.	TPP / Offline program for drilling operation.	CO1, CO5
LSO 14.1 Develop a program for an industrial application. LSO 14.2 Execute the robot programme.	14.	Program to execute an industrial robot application using a given configuration.	CO1, CO5
LSO 15.1 Use robot simulation software for Direct Kinematic analysis upto 4-axis robots	15.	Analyse Direct Kinematics of 4-axis robot using available software.	CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 15.2 Correlate the simulated results with respective mathematical calculations.			

L) Suggested Term Work and Self Learning: S2400604H Some sample suggested assignments, micro project and other activities are mentioned here for reference.

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

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

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

Legend:

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

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Identify different wireless sensor network in robotics viz. ZigBee, LoRa.	CO1, CO3	40	50	10
2.	Use different Radio Frequency (RF) Controlled Wireless Robots.	CO1, CO2	40	50	10
3.	Examine different voice operated robot with speaker identification technology.	CO1, CO3	40	50	10
4.	Design a computer-controlled pick and place robot (wireless)	CO1, CO4	40	50	10
5.	Design a Zigbee controlled Boat with wireless video and voice transmission.	CO2, CO3	40	50	10
6.	Design a PC controlled wireless Multipurpose robot for simple engineering applications.	CO3, CO4	40	50	10

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
7.	Design an unmanned aerial photography system.	CO3, CO5	40	50	10
8.	Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots.	CO5	40	50	10
9.	Develop TPP / Offline program for vision-based inspection for robots.	CO4, CO5	40	50	10
10.	Program and simulate coordinated identification, inspection and part assembly for robots.	CO1, CO5	40	50	10
11.	Develop Obstacle avoidance robot Programming	CO1, CO5	40	50	10
12.	Program and simulate welding operation using robot simulation software.	CO1, CO5	40	50	10
13.	TPP / Offline program for drilling operation.	CO1, CO5	40	50	10
14.	Program to execute an industrial robot application using a given configuration.	CO1, CO5	40	50	10
15.	Analyse Direct Kinematics of 4-axis robot using available software.	CO2, CO3	40	50	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
1.	6 Axis Articulated Robot (Material Handling)- 1 No	- 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 Rotation 7.85 rad/s - J2 Axis Rotation 6.63 rad/s - J3 Axis Rotation 9.08 rad/s - J4 Axis Rotation 9.60 rad/s - J5 Axis Rotation 9.51 rad/s - J6 Axis Rotation 17.45 rad/s - Max. load capacity Wrist: 4Kg	1, 2, 3, 12

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
		- Allowable Load moment 16.6 N-m at wrist J4 Axis, J5 Axis, J6 Axis - Allowable Load inertia).47 kg-m² at wrist J4 Axis J5 Axis, J6 Axis - Repeatability: +/- 0.05mm - Mass: 21 Kg Minimum - Installation environment: Ambient temperature: 0 – 45°C - Ambient humidity: Normally 75%RH or less. No dew, nor frost allowed. - Vibration Acceleration: 4.9 m/s² (0.5G or less)	
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: ±0.2 Tip Velocity range: 500 mm / min Pay load capacity: 2 kg (including gripper) J1 - Waist: ± 140° J2 - Shoulder: - 100 - 60° J3 - Elbow: - 70 + 10° J4 - Wrist rotate: ± 70° J5 - Wrist pitch: ± 35° J6 - Wrist roll: ± 180° External I/O 8 Programmable digital inputs 8 Programmable digital outputs	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 I2C); Motor interface PCB includes a 13-Bit temperature-to-digital converter with a temperature range from -40°C to 125°C (Analog Devices ADT7302)	3, 4, 5, 11
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 PLC; 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	1, 3, 5, 6, 7, 10

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
		- 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)	
6.	Robot simulator for Robotics	Educational networking licensed Robotic system with simulation software	2, 8, 10
7.	Assorted sensors	Optical encoders, Acoustic sensors ,IR, Potentiometer, RTD, Thermistor, strain gauge, piezoelectric, etc.	4
8.	Vision equipment	Camera, Imaging Components: Point, Line, Planar and Volume Sensors	1, 4, 10
9.	Raspberry Pi kit	1.2GHz quad-core Broadcom BCM2837 CPU with 1GB DDR2 RAM with in-built Wi-Fi & Bluetooth Video Core IV 3D graphics core 40 pin extended pins - with 27 GPIO pins Micro SD slot Multiple ports: Four USB ports, full sized HDMI, four pole stereo output and composite video port, CSI camera port and DSI display port 10/100 BaseT Ethernet Micro-USB, power source 5V, 2A	7, 9

R) Suggested Learning Resources:

(a) Books:

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

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
9.	Essentials of Robotics Process Automation	S. Mukherjee	Khanna Publication, First Edition, 978-9386173751
10.	Robotics	R R Ghorpade, M M Bhoomkar	Nirali Prakashan 978-9388897020

(b) Online Educational Resources:

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/9a0dacfddec8aa03dc12578ca003bfd2a/Learn%20with%20ABB.%20Robotic%20package%20for%20education.pdf>

2. Users' Guide:

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

3. Lab Manuals:

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

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

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

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

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

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

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

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

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

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

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

Course Code	Course Title	Scheme of Study (Hours/Week)					
		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.

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

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

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

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

1. 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.

2. 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.

3. Other Activities:

1. Seminar Topics:

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

2. Visits:

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

3. Self-learning topics:

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

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

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

Legend:

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

**.: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

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

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

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

(b) Online Educational Resources:

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

(c) Others:

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

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

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

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

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

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

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

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

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

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

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

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

Legend:

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

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

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

Note:

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

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

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

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
<i>TSO 5c.</i> Discuss the various types of dispersion in optical fibre design <i>TSO 5d.</i> Explain the optimization technique of single mode fibre. <i>TSO 5e.</i> Describe the working and characteristics of different optical networks. <i>TSO 5f.</i> Explain the nonlinear effect on network performance of optical fibre systems. <i>TSO 5g.</i> Explain multicarrier modulation techniques to enhance data transmission and system performance. <i>TSO 5h.</i> Describe the principles and advantages of Orthogonal Frequency Division Multiplexing (OFDM) in improving bandwidth efficiency and reducing interference. <i>TSO 5i.</i> Analyze given emerging technologies.	Unit-5.0 Advanced Optical Fiber Communication and 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	CO5

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

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

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

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

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

5. 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.

6. Other Activities:**7. 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"

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

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

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

Legend:

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

Note:

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

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

Unit Title and Number	Total Classroom Instruction (CI)Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 5G Radio Access Technology	8	CO1	12	4	4	4
Unit-2.0 Study of GSM Architecture	8	CO2	12	4	4	4
Unit-3.0 Channel and channel behavior	8	CO3	12	4	4	4
Unit-4.0 Mitigation Techniques	12	CO3	14	4	4	6
Unit-5.0 Advanced Optical Fiber Communication and Emerging Technologies	12	CO2	20	6	6	8
Total	48	-	70	22	22	26

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

O) Suggested Assessment Table for Laboratory (Practical): Kindly change this table as per the list of experiment in the above list

Sl. No	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
6.	Characterization and Impact of Noise on Wireless Data Transmission: A Comprehensive	CO1	30	60	10
7.	Evaluating Fading Effects on Wireless Data Transmission: Outage Probability Analysis	CO2	40	50	10
8.	Comparative Study of Channel Capacity: AWGN versus Fading Channels	CO3	30	60	10
9.	Practical Implementation and Evaluation of Receiver Diversity Techniques in Wireless Communication	CO4	30	60	10
10.	Practical Implementation and Performance Analysis of Transmitter Diversity Techniques	CO4	30	60	10
11.	Design and Implementation of MIMO Technology	CO4	30	60	10
12.	Development and Performance Evaluation of Orthogonal Frequency Division Multiplexing (OFDM) in Wireless Systems	CO5	30	60	10

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

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

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

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

Please insert laboratory equipment in this format

Sl. No.	Name of Equipment, Tools, and Software	Relevant Experiment/ Practical Number
1.	Software-Defined Radio (SDR) kit : Allows for the implementation and testing of 5G communication protocols.	All
2.	5G NR Testbed: Complete test setups for developing and testing 5G NR systems.	All
3.	Vector Signal Analyzer (VSA) and Vector Signal Generator (VSG): For generating and analyzing complex modulated signals used in 5G communication.	All
4.	MIMO (Multiple Input Multiple Output) Test System (2X2, and more): For testing MIMO technology, which is essential for 5G networks.	All
5.	MATLAB/Mathematica	All

R) Suggested Learning Resources:

(a) Books

Here are some essential books for Optical Fiber and 5G Communication.

Sl. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Millimeter Wave Wireless Communications	Theodore S. Rappaport, Robert W. Heath Jr., Robert C. Daniels, and James N. Murdock	Cambridge University Press, 2024. ISBN 9781009489836
2.	5G NR: The Next Generation Wireless Access Technology	Erik Dahlman, Stefan Parkvall, and Johan Skold	Academic Press, 2020. ISBN-10. 0128143231; ISBN-13. 978-0128143230
3.	Wireless Communications	Andreas F. Molisch,	John Wiley & Sons, 2012. ISBN: 8126542322
4.	Wireless Communications	Andrea Goldsmith	Cambridge University Press, 2005. ISBN: 9780511841224

(b) Online Educational Resources:

Here are some valuable online references for a course in Optical Fiber and 5G Communication:

1. Prof. Aditya K. Jagannatham– NPTEL **Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications**
2. **Coursera** - Post Graduate Certificate in 5G Technology and IoT: This program covers the essentials of 4G and 5G systems, including key technical advancements and challenges. It also delves into topics such as massive MIMO, OFDM, and mm Wave communication, providing a solid foundation in modern wireless communication (Coursera).
3. **Coursera** - 5G and Beyond Wireless Technologies: This course provides an in-depth understanding of 5G New Radio standards, beam management, cell-free massive MIMO, and intelligent reflecting surfaces, making it an excellent resource for those looking to explore the cutting-edge aspects of 5G technology (Coursera).
4. **Coursera** - 5G for Everyone: Gain an in-depth understanding of how 5G is revolutionizing the way we do business in the 2020s with technologies that make 5G possible, including mm Wave, Massive MIMO, RAN, and more. Learn how companies can use 5G Private Networks and Industrial IoT to transform the way they operate daily. Gain the base-level knowledge of 5G you need to continue your wireless education and advance in the rapidly growing field of wireless technology.

MIT OCW - Principles of Wireless Communications: This course is an introduction to the design, analysis, and fundamental limits of wireless transmission systems. Topics to be covered include: wireless channel and system models; fading and diversity; resource management and power control; multiple-antenna and MIMO systems; space-time codes and decoding algorithms; multiple-access techniques and multiuser detection; broadcast codes and precoding; cellular and ad-hoc network topologies; OFDM and ultrawideband systems; and architectural issues.

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational 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

A)	Course Code	: 2414605(P2414605/S2414605)
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 Term work mentioned under different semesters. These projects are normally related to the developing skills in respective course of the specific programme.

In the context of diploma programme in Bihar, minor project work will be carried out in Semester 5 with emphasis on project planning.

Major project work is reflected as a course in the total programme structure, normally at 6th semester depending on the requirement of the programme. Through major project, students try to bring the industrial/real world problems in institutional setting, may be in collaboration/ networking with industries/field agencies/enterprises as per the requirement of different diploma programmes.

E) **Course Outcomes:** After completion of the major project work, students will be able to –

- CO-1** Integrate the knowledge (K), skills (S), attitudes (A) developed, in a new task or problem identified in the form of project work.
- CO-2** Develop higher level of cognitive, psychomotor and affective domain skills relevant to the course/programme.
- CO-3** Solve the industrial/real world problems/tasks by Integrating the generic skills/soft skills/employable skills with relevant technical skills.
- CO-4** Develop the capabilities and skills of innovativeness, creativity, resourcefulness, time management, problem solving abilities, interpersonal skills, pro-activeness, cost effectiveness, environment consideration and sustainability.
- CO-5** Prepare the project report.

F) Suggested Course Articulation Matrix (CAM):

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

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

* PSOs will be developed by 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				
2414605	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)	
2414605	Major Project	-	-	20	30	50	100	200

Legend:

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

Note:

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

I) Suggested Implementation of Major Project:

Under the minor project in fifth semester, project planning is almost over. The projects are identified and allocated to students. Teacher's role is important as they act as guide, facilitator, catalyser, motivator to promote brain storming, thinking, creativity, initiativeness and many other skills in the students. Teachers should help or guide continually to monitor whether the students are proceeding in the right direction as per outcomes to be attained.

It is also suggested that teachers are not supposed to guide and plan each and every step from the point of view of execution of the project, otherwise it will curb the creativity or thinking process of the students. Teachers have to see that he or she is able to create think tank for this fast-technological world of work for the growth of our country. Following points should be taken into consideration while implementing the major project work.

The following steps are undertaken under the major project-

1. Design, Development and Execution of the Major Project.
2. Quality of Project Report Writing and its Presentation.

1.0 Design, Development and Execution of Major Project:

Projects design, development, execution is done by the students under the guidance and feedback by respective teachers for attainment of courses specific outcomes, POs and PSOs.

Continual Monitoring, feedback and assessment mechanism on weekly progress/updates on action taken on different criteria and sub-criteria of the project work need to be planned for individual and team of students. Path breaking teachers who think out of the box are required to guide, monitor and evaluate the project work.

1.1 Unique Features of Major Project:

Following important characteristic features of project need to be given special emphasis during the implementation and evaluation of the major project work-

- Innovativeness
- Creativity
- Originality
- Pro-activeness
- Initiativeness
- Cost Effectiveness
- Resourcefulness
- Development of Soft Skills/Generic Skills
- Ethical Issues
- Environmental Considerations

- Simulated/Automated Industry's/Improvised Process
- Application or Utility in the World of Work.
- Relevance to the Curriculum
- Mapping of Outcomes of Project with Pos and PSOs (if applicable)
- Feasibility of Implementation of the Project

2.0 Quality of Project Report Writing and its Presentation:

Following points need to be taken care of during report writing, its implementation and evaluation-

- Report writing as per prescribed format
- Clarity of outcomes
- Innovativeness
- Presentation of Data
- Data Analysis, Interpretation and Result
- Quality of Product/Prototype

2.1 Project Report Writing:

The suggested format of the project report is mentioned below for teacher's and students' reference:

- i. Problem Statement/ Project Title
- ii. Abstract
- iii. Literature Review
- iv. Outcomes of the Project
- v. Project Planning, Design and Development
- vi. Methodology
- vii. Implementation and Testing
- viii. Result and its Interpretation
- ix. Summary
- x. References / Bibliography

2.2 Presentation & Discussion:

Quality of presentation of data need to be ensured using the following criteria -

- Clarity in Communication and Presentation
- Voice Audibility
- Use of Media and Methods
- Satisfying the Queries of Audience
- Attainment of Outcomes

2.3 Project's Potential:

Futuristic scope and recommendation for further studies related to project may be assessed from the following criteria -

- Papers Published or Award Received
- Exhibition or Display or Showcase of Project in Competition or Exhibition or Tech Fest
- Evaluation of Working/Testing of Projects or Prototype
- Relevance and Applications in the World of Work
- Recognition in any Form
- Related Areas/Sub Areas for Further Studies

J) Assessment of the Major Project:

For objective, valid and reliable assessment, different tools of assessment such as a checklist, rating scale, assessment rubric, observation schedule, portfolio assessment, incidental records etc. need to be prepared. Even the students may be encouraged 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	30
1.4	Clarity in Formulation of Outcomes of The Project	
1.5	Preparation of Synopsis	
1.6	Presentation of Synopsis	
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	25
3.2	Presentation & Discussion	
3.3	Project's Potential	
	TOTAL	100
