STATE BOARD OF TECHNICAL EDUCATION, BIHAR

Scheme of Teaching and Examinations for

VIth SEMESTER DIPLOMA IN ELECTRONICS (ROBOTICS)

(Effective from Session 2023-24 Batch)

THEORY

Sr. No.	SUBJECTS	SUBJECT CODE	TEACHING SCHEME	EXAMINATION – SCHEME							Credits
			Periods per Week	Hours of Exam.	Teacher's Assessment (TA) Marks (A)	Class Test(CT) Marks (B)	End Semester Exam. (ESE) Marks (C)	Total Marks (A+B+C)	Pass Marks ESE	Pass Marks in the Subject	
1.	Industrial Engineering and Management	2043601	03	03	10	20	70	100	28	40	03
2.	Process control	2043602	03	03	10	20	70	100	28	40	03
3.	Robotics	2043603	03	03	10	20	70	100	28	40	03
4.	Programmable logic Controllers	2043604	03	03	10	20	70	100	28	40	03
5.	Elective / COE		03	03	10	20	70	100	28	40	02
	Artificial Intelligence in Robotics (2043605A)			Artificial Intelligence **(Advance)** (2000605B)			Internet of Things **(Advance)** (2000605C)				
	Drone Technology **(Advance)** (2000605D)			3D Printing **(Advance)** (2000605E)			Industrial Automation **(Advance)** (2000605F)				
	Electric Vehicles **(Advance)** (2000605G)			Robotics **(Advance)** (2000605H)							
		Total: - 15					**350**	**500**			14

PRACTICAL

Sl. No.	SUBJECTS	SUBJECT CODE	TEACHING SCHEME	EXAMINATION – SCHEME					Credits
			Periods per Week	Hours of Exam.	Practical(ESE)		Total Marks (A+B)	Pass Marks in the Subject	
					Internal (A)	External (B)			
6.	Process Control Lab	2043606	04	04	15	35	50	20	02
7.	Robotics Lab	2043607	04	04	15	35	50	20	02
8.	Elective / COE Lab		04	04	20	30	50	20	02
	CAD Lab (2043608)	Artificial Intelligence **(Advance) Lab** (2000608B)			Internet of Things **(Advance)** Lab (2000608C)				
	Drone Technology **(Advance)** Lab (2000608D)	3D Printing **(Advance)** Lab (2000608E)			Industrial Automation **(Advance) Lab** (2000608F)				
	Electric Vehicles **(Advance) Lab** (2000608G)				Robotics **(Advance)** Lab (2000608H)				
	Total: - 12						**150**		06

TERM WORK

Sr. No.	SUBJECTS	SUBJECT CODE	TEACHING SCHEME	EXAMINATION – SCHEME				Credits
			Periods per week	Marks of Internal Examiner (X)	Marks of External Examiner (Y)	Total Marks (X+Y)	Pass Marks in the Subject	
9.	Project Work	2043609	06	30	70	100	40	03
10	Term Work		02	20	30	50	20	01
	Course under NPTEL/Moocs / others TW 2043611	Artificial Intelligence In Robotics TW (2043611A)	Artificial Intelligence **(Advance)TW** (2000611B)	Internet of Things **(Advance)TW** (2000611C)		Drone Technology **(Advance)** TW (2000611D)		3D Printing **(Advance)TW** (2000611E)
		Industrial Automation **(Advance)TW** (2000611F)		Electric Vehicles **(Advance)TW** (2000611G)		Robotics **(Advance) TW** (2000611H)		
	Total:- 08					**100**		**04**
Total Periods per week Each of duration one Hour **= 35**						**Total Marks = 750**		**24**

INDUSTRIAL ENGINEERING AND MANAGEMENT

Subject Code 2043601	Theory			No of Period in one session : 42			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

COURSE LEARNING OBJECTIVE:

Student must be trained not only in manufacturing process but also in managing activities of industries. Student must be trained to work as a good Manager. The knowledge about plant, safety, work study techniques, personnel Management and financial management will definitely mould the students as managers to the industries.

OBJECTIVES:

- To study the different types of Layouts.
- To study the safety aspects and its impacts on an organization
- To study different work measurement techniques.
- To study production planning and control and its functions.
- To study basic and modern management techniques.
- To study the staff selection procedure and training of them.
- To study capital and resources of capital.
- To study inventory control system.
- To study about organization and its behavior.

UNIT	CONTENTS: THEORY	HOURS
I	**PLANT ENGINEERING** Plant Engineering: Plant – Selection of site of industry – Plant layout – Principles of good layout – types – process, product and fixed position –- techniques to improve layout – Principles of material handling equipment – Plant maintenance – importance – Break down maintenance, preventive maintenance and scheduled maintenance.	06
II	**WORK STUDY, METHOD STUDY AND WORK MEASUREMENT** Work Study: Productivity – Standard of living – method of improving productivity – Objectives – Importance of good working conditions. Method Study: Definition – Objectives – Selection of a job for method study – Basic procedure for conduct of method study – Tools used – Operation process chart, Flow process chart, two handed process chart, Man machine chart. Work Measurement: Definition – Basic procedure in making a time study – Employees rating factor – Application of time allowances – Rest, Personal, Process, Special and Policy allowances – Calculation of standard time – Problems – Basic concept of production study – Techniques of work measurement.	10

III	**PRODUCTION PLANNING AND QUALITY CONTROL** Production Planning and Control: Introduction – Major functions of production planning and control – Pre planning – Methods of fore casting – Routing and scheduling – Dispatching and controlling –Concept of Critical path method (CPM) – Description only. Production – types –Mass Production, batch Production and job order production - Principles of product and process planning – make or buy decision. Quality Control: Definition – Objectives – Types of inspection – First piece, Floor and centralized inspection – Advantages and disadvantages. Quality control – Statistical quality control – Types of measurements – Method of variables – Method of attributes – Uses of X, R, p, and c Charts – Operating Characteristics curve (O.C curve) –	**08**
IV	**Principles, Modern Management Techniques** Principles of Management: Definition of management – Administration – Organization – F. W. Taylor's and Henry Fayal's Principles of Management – Functions of Manager – Directing – Leadership – Styles of Leadership – Qualities of a good leader – Motivation – Positive and negative motivation – Modern Management Techniques –Just in Time – Total Quality Management - Quality circle- Zero defect concept - 5S Concept – Management Information Systems – Strategic Management – SWOT Analysis – Business Process Reengineering (BPR) – Enterprises Resource Planning (ERP) – Supply Chain Management (SCM) – Activity Based Management (ABM) – Global Perspective – Principles and brief Description.	**10**
V	**Introduction to Industry 4.0** Introduction to Industry 4.0- The Various Industrial Revolutions, Comparison of Industry 4.0 Factory and Today's Factory, Road to Industry 4.0: Internet of Things (IoT) & Industrial Internet of Things (IIoT) & Internet of Services, Big data, Technologies for enabling Industry 4.0 Cyber Physical Systems, Robotic Automation and Collaborative Robots, Support System for Industry 4.0, Mobile Computing, Cyber Security, Augmented / Virtual reality, Artificial Intelligence, System integration, digital twin, 3D printing, Introduction to Industry 4.0 design principles, Impact of Industry 4.0 on – service and business models, Compelling Forces and Challenges in implementing Industry 4.0. .	**08**
	TOTAL	**42**

Text book:

1. "Industrial Engineering and Management", O.P Khanna Revised Edition Publications (P) Ltd., -2004 67/4 Madras House, Darya Ganj, New Delhi 110002.
2. "Engineering Economics and Management", T. R. Banga & S. C. Sharma, McGraw Hill Edition -2 2001, New Delhi.
3. Herald Koontz and Heina Weinrich, 'Essentials of Management, McGraw hill Publishing company, Singapore International Edition Latest

Reference books:

1. Management, A global Perspective, Heinz Weinrich, Harold Koontz, 10th Edition, McGraw International Edition Latest.
2. Essentials of Management,4th Edition, Joseph L Massie, Prentice Hall of India, New Delhi 2004
3. S Chandran, Organizational Behavior, Vikas Publishing House Pvt Ltd. Lates M. Govindrajan and S Natarajan, Principles of Management, Prentice Hall of India Pvt. Ltd., New Delhi Late

PROCESS CONTROL

Subject Code 2043602	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

COURSE LEARNING OBJECTIVE:

In process industries, controllers are used in controlling temperature, pressure, flow, liquid level, and other process variables. This is provided to get necessary knowledge that may help the students getting employed in process industries.

OBJECTIVES:

- Study the basic concepts of instrumentation.
- Compare the different types of sensors and transducers
- Explain the signal conditioning.
- Explain the working of digital display unit.
- Explain the functioning of recorders.
- Explain the measurement technique of strain, force torque and power.
- Explain the measurement technique of pressure, temperature and flow

UNIT	CONTENTS: THEORY	HOURS
I	**SIMPLE PROCESS CONTROL SYSTEMS AND TERMINOLOGY** Definition – Process – Functional block diagram of an Automatic process control system – Set point – Measured variable – Comparator – Error – Controller – Final control element. Controlled variable – Manipulated variable – disturbances – Advantages of Automatic control system – Simple Liquid level control system – Flow control system – Temperature control system with transportation Lag – Self Regulation – Capacitance and Capacity. Piping and Instrumentation flow Diagram (BIS standard) for the above system.	08
II	**CONTROLLER PRINCIPLES** Controller – Block diagram, Types, General properties – Reverse and Direct action, Controller modes – Discontinuous – On – Off Control with differential gap, without differential gap – Neutral zone– Continuous – Proportional controller – Proportional band (PB) – Effect of PB on a controller output – Offset –Integral control – PI – PD – PID – Definition, salient features, applications and limitations of the above controllers – Selection of control action – Electronic controllers – Error detector – Two position controller – P,I,D,PI,PD, PID controllers –reverse action – pneumatic controllers – Flapper – Nozzle mechanism, Pneumatic relay.	10

III	**TUNING OF CONTROLLERS** Concept of tuning – Criteria for controller tuning – Quarter decay ratio, IAE, ISE, ITAE – Methods of tuning – Open loop response method – Process reaction curve –Closed loop response method – Ultimate cycle method, Damped oscillation method.	**06**
IV	**FINAL CONTROL ELEMENTS:** Signal converters – P to I Converter, I to P Converter – Actuators – Electrical, Pneumatic, Hydraulic and Electro pneumatic – Valve Positioners – Control valve –Characteristics Quick opening, Linear, Equal percentage – Control valve sizing – Cv rating – Selection of a control valve – Effects of Cavitation and Flashing on control valve performance.	**10**
V	**COMPLEX CONTROL SYSTEMS** Cascade control system, Ratio control systems, feed forward control system, Comparison of feedback control system and feed forward control system. (One specific application for each of the above systems) – Introduction DCS and SCADA Block Diagram of Fuzzy logic controller – block diagram – typical application-washing machine	**8**
	TOTAL	**42**

Text books

1. Donald P Eckman, Process control, Wiley Eastern limited,1991
2. Peter Hariot, Process control, Tata McGraw Hill.
3. B. Sankara Gomathi, Process control (Principles and applications), J J Publications, 1981.

Reference books

1. George Stephanopoulos, Chemical process control.
2. Michael P Lukas, Distributed control system (Their evaluation and design), Van Nostrand Reinhold Company Inc, 1986.
3. James A Freeman / David M Skapura, Neural networks, Pearson Education, Eighth reprint, 2003.
4. C.D. Johnson, Process control instrumentation Technology, Prentice Hall of India Pvt, Ltd,
5. C.L. Smith, Digital computer process control. Douglas M. Considine, Process / Industrial Instruments Handbook, fourth edition, McGraw Hill, Inc.

ROBOTICS

Subject Code 2043603	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

COURSE LEARNING OBJECTIVE:

UNIT	CONTENTS: THEORY	HOURS
I	**Basic Configuration of Robotics and its Working** Introduction – definition – basic configuration of robotics and its working –robot components – manipulator, end effectors, drive system, controller, sensors –mechanical arm – degrees of freedom – links and joints – construction of links, types of joint – classification of robots – Cartesian, cylindrical, spherical, horizontal articulated (SCARA), vertical articulated – structural characteristics of robots –work envelope and work volume - robot work volumes and comparison – wrist rotations – mechanical transmission, pulleys, belts, gears, harmonic drive – conversion between linear and rotary motion and its devices.	**09**
II	**Robot controllers, servo systems** Robot controller – level of controller – open loop and closed loop controller –servo systems — robot path control – point to point – continuous path control – sensor-based path control – controller programming – actuators – dc servo motors – stepper motors – hydraulic and pneumatic drives - feedback devices – potentiometers – optical encoders – dc tachometers.	**09**
III	**Robot Motion Analysis and Vision System** Robot motion analysis – robot kinematics – robot dynamics - end effectors –grippers and tools - gripper design – mechanical gripper – vacuum gripper –magnetic grippers – sensors – transducers – tactile sensors – proximity sensors and range sensors – force and moment sensors and its applications and problems photoelectric sensors – vision system – image processing and analysis – robotic applications – robot operation aids – teach pendent – MDI and computer control	**10**
IV	**Robot Programming** Robot programming – lead through methods and textual robot languages – motion specification - motion interpolation - basic robot languages – generating of robot programming languages – On-Line & Off-Line programming - robot language structure – basic commands – artificial intelligence and robotics.	**07**
V	**Robot Application in Manufacturing** Robot application in manufacturing – material handling –assembly finishing –adopting robots to work station - requisite and non – requisite robot characteristics –stages in selecting robot for individual application – precaution for robot –future of robotics. Economics analysis for robotics – cost data required for the analysis – methods of economic analysis – pay back method – equivalent uniform annual cost method – return on investment method.	**07**
	TOTAL	**48**

In Recent days robots are used in automation industries. Knowledge & Familiarization of robots will be considered as an added advantage in the field of Automation.

OBJECTIVES:

- Explain different components of robot and compare various types of Robots.
- Study the working of various robot controller.
- Differentiate various robot controller.
- Explain the kinematics of robot.
- Explain the working of vision system
- Appreciate the application of robots in various industries.
- Compare the uses of various sensors & warning system

Text Books:

1. Mikkel P. Groover, Mite chell weiss, Rogern Negal and Nicholes G.Odress, Industrial Robotics Technology- Programming and Applications
2. R. K. Mittal, I. J. Nagrath, Robotics and controls, Tata McGraw Hill Education Pvt.

Reference Books:

1. Doughlaes –R. HAlcoojr, An Introduction to robotics.
2. Robotics – An Introduction – Doughales – R. Halconnjr.An Introduction to Robotics

PROGRAMMABLE LOGIC CONTROLLERS

Subject Code 2043604	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

Course Learning Objective:

Students will be able to

- Describe typical components of a Programmable Logic Controller.
- Explain the basic concepts of a Programmable Logic Controller.
- State basic PLC terminology and their meanings.
- Explain and apply the concept of electrical ladder logic, its history, and its relationship to programmed PLC instruction.
- Explain the concept of basic digital electronics and data manipulation.
- Use timer, counter, and other intermediate programming functions.
- Design and program basic PLC circuits for entry-level PLC application.
- Design and program a small, automated industrial production line.

UNIT	CONTENTS: THEORY	HOURS
I	**PLC BASICS** Programmable Logic Controllers (PLCs): Introduction; definition & history of the PLC; Principles of Operation; Various Parts of a PLC: CPU & programmer/ monitors; PLC input & output modules; Solid state memory; the processor; I/O modules; power supplies. PLC advantage & disadvantage; PLC versus Computers, PLC Application. Programming equipment; proper construction of PLC ladder diagrams; process scanning consideration; PLC operational faults.	**10**
II	**PLC Hardware Components** The I/O section, Discrete I/O Modules, Analog I/O Modules, Special I/O Modules, I/O specifications, The CPU, Memory design, Memory Types, Programming Devices, Selection of wire types and size.	**08**
III	**Various INPUT /OUTPUT Devices and its interfacing with PLC.** Different types of Input devices: Switches: Push button Switches, Toggle Switches, Proximity switches, Photo switches, Temperature Switch, Pressure Switch, and Level Switch, Flow Switches, manually operated switches, Motor starters, Transducers and sensors, Transmitters etc. Their working, specification and interfacing with PLC. Different types of Output devices: Electromagnetic Control Relays, Latching relays, Contactors, Motors, Pumps, Solenoid Valves etc. Their working, specification and interfacing with PLC.	**12**

IV	**Basics of PLC Programming** Processor Memory Organization, Program Scan, PLC Programming languages, Relay type instructions, Instruction addressing, Branch Instructions, Internal Relay Instructions, Programming Examine if Closed and examine If Open instructions, Entering the ladder diagram, Modes of operation. Creating Ladder Diagrams from Process Control Descriptions. Ladder diagram & sequence listing; large process ladder diagram construction, flow charting as programming method, Industrial Examples.	**12**
	TOTAL	**42**

Text Books:

1. Frank Petruzzula, Programmable Logic Controllers, Tata Mc-Graw Hill Edition
2. John W. Webb, Ronald A. Reis, Programmable Logic Controllers Principles and Applications, PHIpublication
3. Madhuchannd Mitra and Samerjit Sengupta, Programmable Logic Controllers Industrial Automation an Introduction, Penram International Publishing Pvt. Ltd.
4. J. R. Hackworth and F. D. Hackworth, Programmable Logic Controllers Principles and Applications, Pearson publication.

ARTIFICIAL INTELLIGENCE IN ROBOTICS

Subject Code 2043605A	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	02
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

Course Objectives:

1. Study the concepts of Artificial Intelligence.
2. Learn the methods of solving problems using Artificial Intelligence.
3. Introduce the concepts of Expert Systems and Machine learning.

Course Outcomes:

The student will be able to

1. Identify problems that are amenable to solution by AI methods.
2. Identify appropriate AI methods to solve a given problem.
3. Formalize a given problem in the language/framework of different AI methods.
4. Summarize the learning methods adopted in AI.
5. Design and perform an empirical evaluation of different algorithms on a problem formalization.
6. Illustrate the applications of AI in Robotic Applications.

UNIT	CONTENTS: THEORY	HOURS
1.	**Introduction** History, state of the art, Need for AI in Robotics. Thinking and acting humanly, intelligent agents, structure of agents.	6
2.	**Problem Solving** Solving problems by searching –Informed search and exploration–Constraint satisfaction problems– Adversarial search, knowledge and reasoning–knowledge representation – first order logic.	8
3.	**Planning** Planning with forward and backward State space search – Partial order planning – Planning graphs– Planning with propositional logic – Planning and acting in real world.	8
4.	**Reasoning** Uncertainty – Probabilistic reasoning–Filtering and prediction–Hidden Markov models–Kalman filters– Dynamic Bayesian Networks, Speech recognition, making decisions.	6

5.	**Learning** Forms of learning – Knowledge in learning – Statistical learning methods – reinforcement learning, communication, perceiving and acting, Probabilistic language processing, and perception.	8
6.	**AI in Robotics** Robotic perception, localization, mapping- configuring space, planning uncertain movements, dynamics and control of movement, Ethics and risks of artificial intelligence in robotics.	6
		42

Text Books:

1. Stuart Russell, Peter Norvig, "Artificial Intelligence: A modern approach", Pearson Education, India, 2016.
2. Negnevitsky, M, "Artificial Intelligence: A guide to Intelligent Systems",. Harlow: Addison Wesley, 2002.

Reference Books:

1. David Jefferis, "Artificial Intelligence: Robotics and Machine Evolution", Crabtree Publishing Company, 1992.
2. Robin Murphy, Robin R. Murphy, Ronald C. Arkin, "Introduction to AI Robotics", MIT Press, 2000.
3. Francis. X. Govers, "Artificial Intelligence for Robotics", Packt Publishing, 2018.
4. Huimin Lu, Xing Lu, "Artificial Intelligence and Robotics", Springer, 2017.

A) Course Code : 2000605B/2000608B/2000611B

B) Course Title : Artificial Intelligence (Advance)

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 subsetof 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				
2000605B/ 2000608B/ 2000611B	Artificial intelligence (Advance)	03	-	04	02	09	05

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)	
2000605 B/ 2000608B/ 2000611B	Artificial Intelligence (Advance)	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:

Major Theory Session Outcomes (TSOs)	Units	Relevant Cos Number(s)
TSO 1a. Describe the basic terminology of Machinelearning 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: 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 andvalidation sets, cross validation. Applicationsof Machine Learning, processes involved in Machine Learning	**CO-1**

TSO 2a. Identify the category or class of aparticular dataset using KNN algorithm TSO 2b. Use Linear regression for predictiveanalysis TSO 2c. Predict the categorical dependent variable using Logistic Regression TSO 2d. Use SVM for classification problems inMachine 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 unlabelled data set	**Unit 2: Supervised and unsupervised learning** **Supervised learning:** Introduction to Supervised Learning, K-Nearest Neighbour, Linear Regression, LogisticRegression, 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; PartitionalClustering - K-means clustering. Expectation-Maximization (EM) Algorithm	**CO-2**
TSO 3a. Explain Structure and working of BiologicalNeural Network. TSO 3b. differentiate between Artificial Neural Network and Biological Neural Network TSO 3c. State key historical points in development ofANN TSO 3d. Explain the architecture of an artificialneural network	**Unit 3: Introduction to neural networks** Structure and working of Biological Neural Network, Fundamentals of Artificial Neural Networks & Applications, Characteristics ofArtificial Neural Networks, History of neuralnetwork research, characteristics of neural networks terminology.	**CO-3**
TSO 4a. Use neuron McCulloch – Pitts model indesigning 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 trainingalgorithm TSO 4e. Use ART (Adaptive Resonance Theory)learning model TSO 4f: Implement Bidirectional Associative Memory (BAM) model in Artificial Neural Network	**Unit 4: Neural networks models and LearningMethods** Models of neuron McCulloch – Pitts model, Rosenblatt's Perceptron, Adaline model, Basic learning laws, Topology of neural network architecture, Multilayer Neural Networks, Learning Methods, Backpropagation, Counter propagation, Adaptive Resonance Theory (ART), Associative memories, BAM.	**CO-4**
TSO 5a. Illustrate the features of Tens or flow TSO 5b. Manipulate tensors TSO 5c. Explain features of Tens or Board visualization TSO 5d Explain the concept and features of Tens orflow playground	**Unit-5 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: (2000608B)

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 learningalgorithms LSO 2.2 Evaluate the performance of classification model	2	(a) Implement SVM for Iris Dataset- download thedataset from (https://gist.github.com/netj/8836201) (b) Find confusion matrix and evaluation matrix for SVM Hint: SVM model can be constructed using sklearn command, import pandas as pd from sklearn.svm import SVC from sklearn.model_selection import train_test_split from sklearn.metrics import confusion matrix from sklearn.metrics import classification report from sklearn.metrics import accuracy score 1. Read the csv Iris dataset file 2. Condition the data 3. Condition the training and Testing data 4. Construct the Linear model 5. Test the model with Linear kernel 6. Prepare confusion matrix 7. prepare Classification Report	**CO-2**
LSO 3.1 Perform clustering operations using k-meansalgorithm	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 EMalgorithm	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 c) 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 theBackpropagation 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**

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 9.1 Test artificial intelligence (AI) algorithms through the use ofGoogle's TensorFlow machinelearning 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 useof 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 (2000611B):** Some sample suggested assignments, micro project andother activities are mentioned here for reference.

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

b. **Micro Projects:**
Use python programming for the solutions of Microproject problems

1. (a) Create a Bar plot to get the frequency of the three species of the Iris data.
   (b) Create a Pie plot to get the frequency of the three species of the Iris data.
   (c) Write a Python program to create a graph to find relationship between the sepal length and width.

2. (a) Write a Python program to split the iris dataset into its attributes (X) and labels (y). The X variablecontains 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% testdata. Out of total 150 records, the training set will contain 120 records and the test set contains 30 ofthose records. Print both datasets.

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

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

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/MidSem 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 percentages 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	7	**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	8	**CO4**	14	3	3	8
Unit-5.0. Tensor flow	10	**CO5**	10	2	6	2
Total Marks	**45**		**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):

SN	Laboratory Practical Titles		Relevant COs Number(s)	PLA/ELA		
				Performance		Viva-Voce (%)
				PRA* (%)	PDA** (%)	
1.	Write a program to implement k-Nearest Neighbour algorithm toclassify the iris data set. Print both correct and wrong predictions. Python ML library classes can be used for this problem.		CO-2	-	80	20
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	-	80	20
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	-	80	20

5.	Build an Artificial Neural Network by implementing the Backpropagation algorithm and test the same using appropriate data sets.		CO-4	10	70	20
6.	Implement the perceptron algorithm from scratch in python.		CO-4	10	70	20
7.	Write a programme to implement two dimension and three-dimension Tensor.		CO-5	-	80	20
8.	Write a programme to add and multiply two 4x4 matrix, you can Import “tens or flow” and “numpy”.		CO-5	-	80	20
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	70	20

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 packagemanager	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., 2021ISBN-10: 9789386173423 ISBN-13: 978-9386173423
6.	Learn TensorFlow 2.0: Implement Machine Learning and Deep LearningModels with Python	Pramod Singh, Avinashmanure	Apress, 978-1484255605 ISBN-10: 1484255607 ISBN-13: 978-1484255605
7	Artificial Intelligence: Concepts, **Techniques and Applications**	Alexis Keller	States Academic Press, **2022 ISBN-** 9781649649245
8	**Artificial Intelligence:** An Introduction	**Jacob** Pearson	Willford Press 2022 ISBN 9781682860911
9	**Fundamentals of** Machine Learning	Mia Williams	Willford Press 2022 ISBN 9781682860920
10	Artificial Intelligence: A Modern Approach	Emilia Stones	Larsen and Keller Education 2022 ISBN 9781641728525

(b) Online Educational Resources:

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

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

(c) Others:

Data Source:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

- Dr. Sanjay Agrawal (Coordinator)
- Dr. R. K. Kapoor (Co-coordinator)

*****

A) Course Code : **2000605C/2000608C/2000611C**

B) Course Title : Internet of Things (Advance)

C) Pre- requisite Course(s) : IoT (Basics), Computer Networks

D) Rationale :

The 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 potentcombination 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 performvarious 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 SpecificOutcomes* (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 isoptional

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				
2000605C/ 2000608C/ 2000611C	IoT (Advance)	03	-	04	02	09	05

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)						
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		Total Marks (TA+TWA+LA)
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2000605C/ 2000608C/ 2000611C	IoT (Advance)	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 andsession 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 TheorySession 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 appropriate.

J) Theory Session Outcomes (TSOs) and Units:

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 Conditionalstatement 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 & whileloops in python TSO.2. b. Explain working of break, continue and pass statement in python TSO.2. c. Write the benefits of using OOPmethodology in python. TSO.2. d. Explain given type of string operation relatedto 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 Python Strings Replace, Join, Split, Reverse, Uppercase, Lowercase, count, find, split and length 2.5 Python Functions, Built-in functions and user defined functions 2.6 Lambda function and uses	**CO-1 and C05**
TSO.3. a. Differentiate between Cloud and IoT cloud. TSO.3. b. Explain features of Cloud in IoT environment TSO.3. c. List features of various types of Cloud TSO.3.d. List features of cloud services like SaaS, PaaS and IaaS TSO.3.f. List advantages of cloud data storage. TSO.3. g. Explain Arduino architecture and its applications. TSO.3.h Explain Raspberry pi architecture and its applications.	**Unit-3.0 Cloud features: -** 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	**Unit. 5 IoT App Development**: - 5.1 Framework selection for IoT app development	**CO-4 and CO-5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.5.b. Identify various stages of selected app TSO.5.c. Develop the app. TSO.5.d. Implement and deploy the app TSO.5.e Maintain and improve the app based on the feedback	5.2 Identify stages of app to be developed. 5.3 Develop, Implement, and Deploy the App 5.4 Testing and Integration 5.5 Maintain and improve	

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

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical (2000608C):

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 1.1 Python installation LSOs 1.2 Prepare and run python program on given problem LSOs 1.3 Prepare python program on Dictionary, Tuple and operators. LSOs 1.4 Prepare program on arrays LSOs 1.5 Prepare a program on 2-dimensional array LSOs 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**
LSOs 2.1 Prepare python program on Do & while loops LSOs 2.2 Prepare python program on break and continue statement. LSOs 2.3 Prepare Python program using break and continue statements LSOs 2.4 prepare python program using OOP LSOs 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	**CO-2**

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

L) Suggested Term Work and Self Learning (2000611C): Some sample suggested assignments, micro projectand other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line withthe 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 an 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 andraspberry-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 percentages 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. Python basics	5	CO1	7	2	2	3
Unit-2. Python Advance	5	Co1, CO2	7	2	2	3
Unit-3. Cloud features	14	CO3	21	8	8	5
Unit-4. Networking and Application	14	CO4, C03	21	5	7	9
Unit-5. IoT Applications	10	CO5, CO3 andCO4	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):

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA /ELA		
			Performance		Viva - Voce (%)
			PRA* (%)	PDA** (%)	
1.	Install given version of Python the computer system.	CO-1	70	20	10
2.	Prepare a python program using print() function and run it.	CO-1	60	30	10
3.	Access given value from the tuple	CO-1	60	30	10
4.	Print the given value of key from the dict.	CO-1	60	30	10
5.	Write a Python program to create an array of 5 integers and display the array items. Access individual element through indexes	CO-1	60	30	10
6.	Write a Python program which takes two digits m (row) and n (column) as input and generates a two-dimensional array.	CO-1	60	30	10
7.	Write a python program to check whether person is eligible for voting or not. (accept age from the user)	CO-1	60	30	10
8.	Write a python program to check whether the entered numberis 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

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA /ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
13.	Write a python program which can print sum of first 10 natural numbers using while/for loop.	CO-2	60	30	10
14.	Write a python program which can identify the prime number between the range given using while/for loop.	CO-2	60	30	10
15.	Consider a situation where you want to iterate over a string and want to print all the characters until a letter 'e' or 's' is encountered. It is specified that you have to do this using loop and only one loop is allowed to use.	CO-2	60	30	10
16.	Consider the situation when you need to write a program which prints the number from 1 to 10 and but not 6. It is specified that you have to do this using loop and only one loop is allowed to use.	CO-2	60	30	10
17.	Create a Class with instance attributes	CO-2	60	30	10
18.	Create a Vehicle class without any variables and methods	CO-2	60	30	10
19.	Write a Python function to find the Max of three numbers.	CO-2	60	30	10
20.	Write a Python program to reverse a string.	CO-2	60	30	10
21.	Create a free cloud account	CO-3	70	20	10
22.	Store data on cloud and retrieve it.	CO-3	60	30	10
23.	Study of different types of Network cables and practically implement the cross-wired cable and straight through cable using clamping tool.	CO-4	70	20	10
24.	Connect the computers in Local Area Network	CO-4	70	20	10
25.	Connect 2 or more devices using Bluetooth	CO-4	70	20	10
26.	Connect 2 or more devices using infrared	CO-4	70	20	10
27.	Connect 2 more machine using m2m	CO-4	70	20	10
28.	Connect 2 or more different devices using access point	CO-4	70	20	10
29.	Connect 2 devices suing LPWAN (Smart Meter)	CO-4	70	20	10
30.	Connect 2 or more devices using RFID	CO-4	70	20	10
31.	Identify a problem and develop an app	CO-5	70	20	10

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

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

P) **Suggested Instructional/ Implementation Strategies:** Different Instructional/ Implementation Strategies maybe 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, Toolsand Software	Broad Specifications	Relevant Experiment/PracticalNumber
1	Python software	Openly available as per instruction	As mentioned above list
2	Cables connecters and crimping tools	Cat 6e cable, RJ-45 connectors and Crimping Tool	
3	Bluetooth and infrared devices	Any mobile and wireless keyboard and mouse	
4	IoT free cloud	Free available	
5	Smart devices	Like meters, bulbs etc.	
6	Wireless access point	Wireless router or access point	
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 andHardware 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 andHardware 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 January2014) ISBN-10: 9332535922 ISBN-13: 978-9332535923
6.	Fundamentals of Internet of Things	Eden Scott	States Academic Press 2023 ISBN 9781649649235
7	Internet of Things	Alaina Wilson	Murphy & Moore Publishing 2023 ISBN 9781649872731
8	Principles of Internet of Things	Hallie Parker	Larsen and Keller Education 2023 ISBN 9781641728312

(b) Online Educational Resources:

1. nptel.iitm.ac.in/courses/.../IIT.../lecture%2023%20and%2024.htm
2. en.wikipedia.org/wiki/Shear_and_moment_diagram
3. www.freestudy.co.uk/mech%20prin%20h2/stress.pdf
4. www.engineerstudent.co.uk/stress_and_strain.html
5. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf
6. https://www.veritis.com/blog/aws-vs-azure-vs-gcp-the-cloud-platform-of-your-choice/
7. https://wiki.python.org/moin/TimeComplexity
8. www.engineerstudent.co.uk/stress_and_strain.html
9. https://www.iit.edu/arc/workshops/pdfs/Moment_Inertia.pdf

Amini, P. (2014). Sulley: Pure Python fully automated and unattended fuzzing frame- work. https://github.com/OpenRCE/sulley

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

Dr. M. A. Rizvi (Coordinator)

******

A) Course Code **: 2000605D/2000608D/2000611D**

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 drones.

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 performvarious 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 isoptional

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				
2000605D/ 2000608D/ 2000611D	Drone Technology (Advance)	03	-	04	02	09	05

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 feedbackof 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 LabAssessment (PLA)	End Laboratory Assessment (ELA)	
2000605D/ 2000608D/ 2000611D	Drone Technology (Advance)	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 (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of TheorySession 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 beintegrated appropriately.

J) Theory Session Outcomes (TSOs) and Units:

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 centre of gravity of different drone structure. TSO 1d. Analyse different types of force acting drone system. TSO 1e. Differentiate between static and dynamic force analysis. TSO 1f. Explain how gyroscopic motion keepsdrone balanced and hovering.	**Unit-1.0 Engineering mechanics for Dronetechnology** 1.1 Drone Mechanics • Free body diagram of drone • Method of finding resultant of force system • Equilibrium of coplanar force system 1.2 Centre of Gravity • Centroid of plane figure • Centre 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 hardwareinterfacing. TSO 2e. Write steps to interface GPS module for drone navigation. TSO 2f. Describe different RF blocks and antennas used in RF transmitter and receiver.	**Unit-2.0 Drone Frame and components** 2.1 Drone frame design • Calculation principle for drome frame sizes • Quadcopter frame design • Smart materials for UAV frame • Green material uses in drone 2.2 Advance Drones component • GPS, Interfacing of GPS hardware • Thermal and chemical sensor • Tilt and LiDAR sensor 2.3 RF transmitter and receiver • RF blocks • RF antennas 2.4 Micro-electromechanical systems (MEMS) based sensor 2.5 HD and thermal Image camera	**CO-2**
TSO 3a. Identify features and specifications of FCBuse in different application	**Unit-3.0 Advance flight controller Board (FCB)**	**CO-3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number (s)
TSO 3b. Explain ports of any given advance flightcontroller 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.	3.1 Specification and ports of FCB 3.2 Software for FCB • Software installation 3.3 Radio Communication with FCB • Installation of Radio Telemetry • Radio Calibration with FCB 3.4 Calibration of accelerometer 3.5 Calibration of ESC 3.6 Interface of motor with FCB using ESC 3.7 GPS interface with FCB 3.8 Safety features of advance FCB	
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 applicabilityin drone assembly • Parameters and profile measurements of standard propellers • Concepts of drone assembly using 3D modelling	**CO-4**
TSO 5a. Describe function of autonomous drone using AI. TSO 5b. Describe IoT enable UAV for surveillanceand 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 (2000608D):

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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 12.3 Measure unknown frequency and its level using spectrum analyser.			
LSO 13.1 Inspect drone as per the given checklist LSO 13.2 Diagnose drone problems after flying of 50 and 100hrs	13.	Perform preventive maintenance of drone components	**CO-4**
LSO 14.1 Perform dismantle process of drone. LSO 14.2 perform services need for operation LSO 14.3 Check and Install different parts of thedrone system. LSO 14.4 Assemble drone component.	14.	Dismantle and service of different parts of drone system	**CO-4**

L) Suggested Term Work and Self Learning (2000611D): Some sample suggested assignments, micro projectand other activities are mentioned here for reference.

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

b. Micro Projects:

1. Prepare maintenance report for small UAV.
2. Survey nearby electronics shop and Prepare report on types of drone frames and drone sensorsavailable 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 dronedesign, 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 percentages given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mappedwith total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions relatedto achievement of each COs.

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA /ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Determine Centre of gravity of different done structure.	CO-1	50	40	10
2.	Demonstrate gyroscopic effect on a drone model	CO-1	40	50	10
3.	Compare different types of airframe structure like quadcopter frame (plus shape, cross shape and H-shape), hexacopter frame (hexa + and hexa S).	CO-2	50	40	10
4.	Test Tilt and LiDAR sensors and their characteristics with Microcontrollerbased 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 maybe 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 andCustomize Your Own Quadcopter	Terry Kilby & BelindaKilby	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 videofootage	Ty Audronis	Packt Publishing Limited; Illustratededition,2014, ISBN-978-1782175438
5.	The Complete Guide to Drones	Adam Juniper	Ilex Press, Extended 2nd Edition,2018ISBN-9781781575383
6.	Unmanned Aircraft Systems - UAVS Design, Development and Deployment (Aerospace Series)	R Austin	John Wiley & Sons Inc, 1st edition, 2010,ISBN-978-0470058190
7	Drone Technology	Miranda Hall	NY Research Press 2023 ISBN 9781632389574
8	Introduction to UAV Systems	Rupert Baker	Willford Press 2023 ISBN 9781682860890

9	Theory, Design, and Applications of Unmanned Aerial Vehicles	Tyler Wood	Larsen and Keller Education 2023 ISBN 9781641728338

(b) Online Educational Resources:

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

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

(c) Others:

1. Development of an Autonomous IoT-Based Drone for Campus Security, Abdelrahman Mahmoud Gaber, Rozeha A. Rashid, Nazri Nasir, Ruzairi Abdul Rahim, M. Adib Sarijari, A. Shahidan Abdullah, Omar A. Aziz, Siti Zaleha A. Hamid, Samura Ali,2021
2. IoT based UAV platform for emergency services; S. K. Datta, J. L. Dugelay, & C. Bonnet, 2018
3. Development of an Autonomous Drone for Surveillance Application; M. A. Dinesh, S. SanthoshKumar, 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

S) Course Curriculum Development Team (NITTTR, Bhopal)

- Dr. K. K. Jain (Coordinator)
- Dr. Sanjeet Kumar (Co-coordinator)

******

A) Course Code : **2000605E/2000608E/2000611E**

B) Course Title : 3D Printing and Design (Advance)

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 performvarious 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 SpecificOutcomes* (PSOs)	
	PO-1 Basic and Disciplin eSpecific 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				
2000605E/ 2000608E/ 2000611E	3D Printing and Design (Advanced)	03	-	04	02	09	05

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 feedbackof 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)	
2000605E /2000608E /2000611E	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:

- 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:

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

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5a. Justify the need of post processing in the given 3D printed component. *TSO 5b.* List the various post processing techniques. *TSO 5c.* List the steps to perform post processing. *TSO 5d.* Explain the given Cleaning related post processing approach for 3D printed component. *TSO 5e.* Explain the given Surface finishing related post processing approach for 3D printed component. *TSO 5f.* Apply simple inspection and testing techniques on the given 3D printed component. *TSO 5g.* Identify the type of defect(s) in the given 3D printed component.	**Unit-5.0 Post Processing and Quality** 5.1 Need of post processing: Functional and Aesthetic reasons. 5.2 Steps of Post Processing: Cleaning/Support removal, Fixing, Curing or hardening, Surfacefinishing, Colouring. 5.3 Cleaning: Support Removal (FDM and Material Jetting); Powder Removal (SLS and Powder BedFusion); 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 (2000608E):

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

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

L) Suggested Term Work and Self Learning (2000611E): Some sample suggested assignments, micro projectand other activities are mentioned here for reference

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

b. Micro Projects:

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**.

	Course Evaluation Matrix						
	Theory Assessment (TA)**		**Term Work Assessment (TWA)**			**Lab Assessment (LA)#**	
COs	**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 relatedto 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):

SN	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 componentof 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 availabledevices/techniques.	CO5	40	50	10

Legend:
PRA*: Process Assessment
PDA**: Product Assessment

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

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

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

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
1.	High end computers	Processor Intel Core i7 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10	All
2.	Parametric Computer Aided Design software	CATIA/Solid works/NX/Creo **OR** Available with CoE	1 to 5
3.	FDM based 3D printer	Fused Deposition Modelling system with complete accessories; Build Volume-300 x 300 x 300mm or Higher; Layer Thickness-0.1 – 0.4 **OR** Available with CoE	1,4,5,6
4.	SLA based 3D printer	Printing Technology: SLA, 145 x 145 x 175mm build volume, Common layer thickness 25–100 µm, Dimensional Accuracy ± 0.5% (lower limit: ±0.10 mm), cure time of only 1-3s per layer, Material type: UV-sensitive liquid resin, Curing unit.	2,4,5,6
5.	SLS based 3D printer	Printing Technology: SLS., Build Volume: 130 x 130 x 180 mm, Recommended min. wall thickness: 0.8 mm, Powder Diameter: 60 Microns, Material Type: Nylon, TPU, Light Source: Laser Diode	3,4,5,6
6.	3D Printing Material	ABS/PLA, Resin based Photosensitive material, Polymer/metal/ceramic powder **OR** Available with CoE	1,2,3,4,5,6
7.	3D Printing software	Latest version of software like: Cura/PrusaSlicer/ideaMaker/Meshmixer/MeshLab **OR** Available with CoE	1 to 6
8.	3D Scanner and Processing software	Handheld 3D scanner, Accuracy up to 0.1 mm, Resolution up to 0.2 mm, Real time onscreen 3D model projection and processing, Wireless technology with an inbuilt touch screen and battery, Extended field of view for capturing both large and small objects, Processing Software **OR** Available with CoE	6
9.	Post processing equipments and tools	Deburring tools (tool handle & deburring blades), Electronic DigitalCaliper, Cleaning Needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removalspatula, Needle file, Cutting mat, Glue stick, Wire stripper, Chemicals, Etching agents etc.	7
10.	Inspection and Testingdevices	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: RapidPrototyping 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, DelhiISBN: 9789386173768
4.	3D Printing and Rapid Prototyping-Principlesand Applications	C.K. Chua, Kah Fai Leong	World Scientific, 2017 ISBN: 9789813146754
5.	Getting Started with 3D Printing: A Hands-onGuide 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, 2001ISBN: 9781461514695
7.	3D Printing: A Practical Guide	Clay Martin	Larsen and Keller Education 2023 ISBN 9781641728323
8.	Fundamentals of 3D Printing	Elizah Brooks	Clanrye International 2023 ISBN 9781647290943
9.	Principles of 3D Printing	Brady Hunter	NY Research Press 2023 ISBN 9781632389549

(b) Online Educational Resources:

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

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

(c) Others:

1. 3D Printing Projects DK Children; Illustrated edition, 2017
2. The 3D Printing Handbook: Technologies, design and applications Ben Redwood, FilemonSchöffer, 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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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A) Course Code **: 2000605F/2000608F/2000611F**
B) Course Title **:** Industrial Automation (Advance)
C) Pre- requisite Course(s) **:** Industrial automation (Basic)

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 inputsand 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 performvarious 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 SpecificOutcomes* (PSOs)	
	PO-1 Basic and Disciplin eSpecific Knowledge	**PO-2** Problem Analysi s	**PO-3** Design/ Developmen tof Solutions	**PO-4** Engineer ingTools	**PO-5** Engineering Practices for Society, Sustainability and Environment	**PO-6** Project Managem ent	**PO-7** Life Long Learning	**PSO-1**	**PSO-2**
CO-1	3	2	2	2	2	-	2		
CO-2	3	3	3	3	-	-	2		
CO-3	3	3	3	3	2	2	2		
CO-4	3	2	2	2	2	2	2		
CO-5	3	2	2	3	2	2	2		

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

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

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				
2000605F/ 2000608F/ 2000611F	Industrial Automation (Advance)	03	-	04	02	09	05

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	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2000605F/ 2000608F/ 2000611F	Industrial Automation (Advance)	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 andsession 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:

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 procedureto interface the PLC with other given hardware.	**Unit-1.0 Industrial automation communication andInterfacing** 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 otherhardware	**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 andrelay 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 reductionTechniques. TSO.3d Explain preventive maintenanceprocedure associated with PLC system to reduce environmentalimpact TSO.3e Identify faults in the given PLC system	**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 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	**CO-3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
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	• 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 connectiondiagram, Object Linking and Embedding for Process Control (OPC) architecture 4.5 Creating SCADA Screen HMI for simple object, Steps forlinking SCADA object (defining Tags and items, creatingtrends 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 5.3 **Defence- guided rockets and missiles,** counter measures, UAV drones, launcher, radar antenna, engagement control system	**CO-5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	5.4 **Automobile –B**reak monitoring system, Vehicle tracking system, Rear-view alarm to detect obstacles behind, Four-wheel drive, Traction control system, Dynamic steering response, Anti-lock braking system (ABS) Adaptive cruise control, Adaptive headlamps, Intelligent Parking Assist System, Driverless/Autonomous Cars 5.5 **Agriculture-** harvesters, irrigation systems, ploughing 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 (2000608F):

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 1.1 Data communication from PLC to PC and vice versa	1.	Transfer the control data from PLC to PC andvice versa	**CO1**
LSOs 1.2 Establish Communication channels between PLC s.	2.	Transfer the control data from PLC to PLC	**CO1**
LSOs 1.3 Transfer data from sensors to PLC and from PLC to PC.	3.	Transfer the sensor data from sensor to PLC to PLC and PC	**CO1**
LSOs 1.4 Interface the given PLC with a PC ora Laptop	4.	Interface the given PLC with a PC or a Laptop	**CO1**
LSOs 2.1 Identify Different parts and front panel indicators of a PLC	5.	Identify the various parts and front panel status indicators of the given PLC.	**CO2**
LSOs 2.2 Develop Ladder logic program for different arithmetic operations	6.	Develop/Execute ladder logic program for different arithmetic operations such as Addition, subtraction, multiplication, division increment, decrement, trigonometric in a given PLC	**CO2**
LSOs 2.3 Develop Ladder logic program fordifferent 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**
LSOs 2.4 Program Latch and Unlatch circuit in a PLC for motor operation	8.	Program the given PLC to start run and stop the given motor using latch circuit	**CO2**
LSOs 2.5 Create delay in operation using on delay, off delay and retentive timer function in a given PLC.	9.	Test the functionality of on delay, off delay and retentive timer for its correct operation in a given PLC.	**CO2**
LSOs 2.6 Count the number of objects/events using Up counter, Down counter and UP/Down counter in a PLC	10.	Test the functionality of Up, Down and Up-down counter for its correct operation in a given PLC.	**CO2**
LSOs 2.7 Program PLC using ladder logic to controla LED/Lamp	11.	Develop/Execute a ladder logic program to put LED/lamp in the blinking mode	**CO2**
LSOs 2.8 Program PLC using ladder logic to controla 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)
LSOs 3.1 Use hygrometer to measure the humidity inside the panel *LSOs 3.2* Use thermometer to measure ambient temperature inside the panel *LSOs 3.3* Use tester to determine the voltage fluctuation at the power supply terminals is within specifications *LSOs 3.4* Test the ground connections of the given PLC. *LSOs 3.5* A given PLC is not working as per the logic instructions investigate the PLC to identify the cause of failure to show the desired output *LSOs 3.6* Investigate the cause of Noise in the given PLC *LSOs 3.7* PLC goes on blackout out by losing itsoperating power. Troubleshoot the cause of failure. *LSOs 3.8* Troubleshoot the corrupted PLC memory. *LSOs 3.9* Replace CPU and power supply fuses in a given PLC system.	13.	Troubleshooting of PLC system	**CO3**
LSOs 4.1 Download any open-source SCADA software and install the same. *LSOs 4.2* Interpret the available components in symbol factory of SCADA software *LSOs 4.3* Create simple SCADA HMI applicationsand 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 propertiesto 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. *LSOs 4.4* Create historical and real time trends for the given automation	14.	Develop simple SCADA HMI applications usingany one open-source SCADA software and apply dynamic properties	**CO4**
LSOs 5.1 Develop a smart irrigation device to detect the change in moisture level in the soil and controls the flow of water accordingly with a DC pump. *LSOs 5.2* Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application	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)
LSOs 5.3 Develop a PLC program to control the robot in such a way that the robot can automatically pick and place components and works in syncwith the conveyor belt system. *LSOs 5.4* Develop a Automation system to Open and close the door in the shop *LSOs 5.5* Develop a line following robot with RFID sensor for supplying materialsand automating workflow. *LSOs 5.6* Develop smart street light controlling mechanism which willSwitch on/off the lights automatically depending on the intensity of the sunlight at that particular time of the day. *LSOs 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 (2000611F): Some sample suggested assignments, micro projectand other activities are mentioned here for reference.

a. Assignments:

Questions/Problems/Numerical/Exercises to be provided by the course teacher in line withthe 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 analyse 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 flowof water accordingly with a DC pump.
5. Build an electronic device that can remotely control home appliances with your Bluetooth-enabledsmartphone 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 assessmentstrategy 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 percentages given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COsmapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA** (%)	PDA** (%)	
13.	Use hygrometer to measure the humidity inside the panel	CO3	50	40	10
14.	Use thermometer to measure ambient temperature inside the panel	CO3	50	40	10
15.	Use tester to determine the voltage fluctuation at the power supply terminals is within specifications	CO3	50	40	10
16.	A given PLC is not working as per the logic instructions investigate the PLC to identify the cause of failure to show the desired output	CO3	50	40	10
17.	Investigate the cause of Noise in the given PLC	CO3	50	40	10
18.	PLC goes on blackout out by losing its operating power. Troubleshoot the cause of failure.	CO3	50	40	10
19.	Troubleshoot the corrupted PLC memory.	CO3	50	40	10
20.	Replace CPU and power supply fuses in a given PLC system	CO3	50	40	10
21.	Download any open source SCADA software and install the same.	CO4	50	40	10
22.	Interpret the available components in symbol factory in SCADAsoftware	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
25.	**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 forsupplying 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 theday. vii. Develop smart automated railway crossing system to detect train arrival and departure and send appropriatesignals to the microcontroller.	CO5	60	30	10

Legend:
PRA*: Process Assessment
PDA**: Product Assessment

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

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, 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, Siemensetc.,)	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 TrainingSystem with HMI (Of reputed make such as Allen Bradely, Siemens, etc.,) Compatible with SCADAsoftware	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 andrespirators.	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, Digital Multimeter Clamp Meter with Amp, Volt, and Ohm, Non-Contact Voltage Tester	13
7.	Spare parts	PLC Programming Cables, SD Card Reader Compact flash, Wire Nut Set, Fuses- Class J 30, 35, 60, and 100 -amp fuses, Class CC 2, 3, 5, 10, 15, 20, and 30 -amp fuses, 5mm x 20mm 0.032 (for 4 -20mA circuits), 0.5, 1, 2, 5, 10, and 15 amps, Cube Relays, Resistor Kit, batteries, LED Indicators PLC Processor (CPU), Input/ output module	13

S. No.	Name of Equipment, Toolsand Software	Broad Specifications	Relevant Experiment/Practical Number
8.	Thermo-hygrometer	Measuring range Temp.: -30 ... 60°C / -22 ... 140°F Measuring range rel. Humidity: 0 ... 100% rh, Measurement protocol as PDF, Data export possible as CSV, Readable without software, data sets of measured values can be stored.	13
9.	Digital Hygrometer	maximum humidity measurement- 100%RH, temperature measurement resolution -0.1egree centigrade, humidity measurement resolution -0.1%RH, minimum operating temperature - -10 to -20-degree centigrade, Maximum operating temperature +45 to +50 degree centigrade	13

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction to Programmable LogicControllers	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 MATLABApplications, 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), UK2003, ISBN:0750658053
11	Industrial Automation: Systems and Engineering	Geoffrey Williamson	States Academic Press , 2022 ISBN 9781649649270
12	Industrial Automation Technologies	Jane Taylor	States Academic Press 2023 ISBN 9781649649255
13	Introduction to Industrial Automation	Kian Pearson	Willford Press 2023, ISBN 9781682860864

(b) Online Educational Resources:

1. Software: - www.fossee.com
2. Software: - www.logixpro.com
3. Software: - www.plctutor.com
4. Software; - www.ellipse.com
5. PLC lecture: - https://www.youtube.com/watch?v=pPiXEfBO2qo
6. PLC tutorial: http://users.isr.ist.utl.pt/~jag/aulas/apil3/docs/API_I_C3_3_ST.pdf
7. https://www.youtube.com/watch?v=277wwYWolpw-PLC system troubleshooting and repair.Industrial control panel. PLC system repair.
8. https://www.youtube.com/watch?v=5Jmtvrch5Jg
9. https://www.youtube.com/watch?v=peyV9bwEaLY
10. https://www.youtube.com/watch?v=QdJhRmtKpxk&list=RDCMUCke36Liq-w5fboMHkq1APZw&index=3

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

- Dr. Vandana Somkuwar (Coordinator)
- Dr. C.S.Rajeshwari (Co-coordinator)

*****

A) Course Code : **2000605G/2000608G/2000611G**

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 includedas an open elective for all the diploma programmes to provide a sound knowledge of EVs to engineering diploma students and develop skills related to testing and maintenance of various electrical, electronic and mechanical systems in EVs.

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

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

CO-1 Compute various parameters affecting Vehicle movement.

CO-2 Test the operation of the different elements of the Automobile System.

CO-3 Test the battery and motor used for Power Transmission in EVs.

CO-4 Test electronic control unit system of EVs.

CO-5 Interpret the impact of Grid to Vehicle (G2V) and Vehicle to Grid (V2G) during the charging cycle.

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+ SL)	Total Credits (C)
		L	T				
2000605G/ 2000608G/ 2000611G	Electric Vehicle (Advanced)	03	-	04	02	09	05

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)						
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		Total Marks (TA+TWA+LA)
		Progressive Theory Assessment (PTA)	End Theory Assessment(ETA)	Internal	External	Progressive LabAssessment (PLA)	End Laboratory Assessment (ELA)	
2000605G/ 2000608G/ 2000611G	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:

- 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 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) andothers must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units:

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, typicalvalues 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 Testingof 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 stepBraking 2.3 Transaxle 2.4 Elements of Noise Vibration andHarshness 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 PowerTrain. TSO 3c. Explain the functions of the given EV PowerTrain 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. TSO 3j. Describe the Mechanism of Gear and Differential Assembly.	**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 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 AreaNetwork 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 BodyControl Module. 4.2 Predefined functions 4.3 Connections with EV subsystem 4.4 Controller Area Network (CAN)communication 4.5 Interaction of CAN Communication withVCU. 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) techniquefor 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 (2000608G):

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 testrig. LSO 2.2 Test the performance (Speed v/s Braking Torque) of the Disc Braking System in Half step and Full step braking modes.	1.	• Testing of Control Disc Braking systemand Control Regenerative Braking system.	**CO2**
LSO 2.3 Test the performance of different types of propulsion motors.	2.	• Testing of Motors	
LSO 2.4 Test the continuity of the automotive wiring system in the EV	3.	• Testing of the automotive wiring system.	
LSO 3.1 Test the performance of a new set of batteries and aged batteries. LSO 3.2 Compare the performance of the battery and find the Fuel Gauge after discharging the battery. a. 0% - 100% b. 30% - 100% c. 50% - 100% LSO 3.3 Evaluate the following parameters of the given EV battery. a. Specific power b. Specific energy	4.	• Testing of Batteries used in EVs	**CO2, CO3**

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
c. Life span and d. Cost parameters LSO 3.4 Evaluate the State of Health (SoH) of the given EV Battery after several charge/discharge cycles.			
LSO 3.5 Test the dynamic performance of the given motor; a) Speed and torque spectrum. b) Speed and torque oscillation c) Friction torque friction spectrum. LSO 3.6 Test the following speed-controlled performance characteristics of the given motor; a. Motor voltage over time b. Motor current over time. c. Speed and torque over time. d. Torque over speed. e. Current over speed. f. Electrical input power and the mechanical input power over speed	5.	• Speed control of Electrical Motors	
LSO 4.1 Connect the components of the EC Units with EV subsystems. LSO 4.2 Troubleshoot basic faults in the electronic control unit of EV.	6.	• Connection of Electronic Control Unitcomponents • Troubleshooting of electronic control unit	**CO4**
LSO 5.1 Evaluate the impact of the Grid on VehicleCharging and Vehicle Charging on the Grid.	7.	• Impacts of G2V and V2G	**CO 5**
LSO 5.2 Prepare a layout of a charging station	8.	• Demonstration of Charging stations	

L) Suggested Term Work and Self-Learning (2000611G): 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 withthe 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 COsmapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

S. N.	Laboratory Practical Titles	Relevant COs Number(s)	PLA /ELA		
			Performance		Viva-Voce(%)
			PRA * (%)	PDA* * (%)	
1	Testing of Control Disc Braking system and ControlRegenerative Braking system.	CO2	60	30	10
2	Testing of Motors.				
3.	Testing of automotive wiring system.				
4.	Testing of Batteries used in EVs	CO2, CO3	60	30	10
5.	Speed control of Electrical Motors		60	30	10
6.	Connection of Electronic Control Unit components	CO4	60	30	10
7.	Troubleshooting of electronic control unit				
7	Impacts of G2V and V2G	CO5	30	60	10
8	Demonstration of Charging stations		70	20	10

Legend:
PRA*: Process Assessment
PDA**: Product Assessment

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

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies maybe 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 Regenerativebraking system test rig	Test rig equipment for Demonstration of Disc Brakingand 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

S. No.	Name of Equipment, Tools andSoftware	Broad Specifications	Relevant Experiment/Practical Number
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 ElectricVehicles (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 January2019) ISBN-13: 978-0367137465
4.	Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and FuelCell Vehicles	John G. Hayes, G. AbasGoodarzi	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, NewDelhi, 1st Edition (2018) ISBN: 9789386173713, 9386173719

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
9.	Power Electronics: Circuits, Devices and Applications,	Rashid, M. H.	Pearson, 3rd edition, (2013) ASIN: B07HB3BM1W
10	Electric Vehicle Engineering	Liana Walker	Clanrye International2023, ISBN-978164729097
11	Electric Vehicles: Current Progress & Technologies	Vanessa Jones	Murphy & Moore Publishing 2023, ISBN 9781649872746
12	20 Electric and Hybrid Vehicles: Principles, Design and Technology	Mary Murphy	Larsen and Keller Education 2023 ISBN 9781641728520

(b) Online Educational Resources:

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

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

- Dr. A. S. Walkey (Coordinator)
- Dr. S. S. Kedar (Co- coordinator)

******

A) Course Code : 2000605H/2000608H/2000611H

B) Course Title : Robotics (Advance)

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 performvarious 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.

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	-	-		

B) Suggested Course Articulation Matrix (CAM):

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

C) 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**				
2000605H /2000608H /2000611H	Robotics (Advance)	03	-	04	02	09	05

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.

D) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		Total Marks (TA+TWA+LA)
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment	
2000605H/ 2000608H/ 2000611H	Robotics (Advance)	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.

E) 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 KnowledgeSystem (IKS) and others must be integrated appropriately.

F) Theory Session Outcomes (TSOs) and Units:

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 inversekinematics 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 specificapplication. 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 Pneumaticdrives 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 withjustification. TSO 3c. Analyse robot cycle time. TSO 3d. Explain industrial applications of roboticcell. TSO 3e. Follow safety procedures in robotic cell.	**Unit– 3.0 Robot Cell Design and Application** 3.1 Robot work cell design, control and safety 3.2 Robot cell layouts 3.3 Multiple Robots and machine interference 3.4 Robot cycle time analysis 3.5 Industrial application of robotic cells	**CO3**
TSO 4a. List different programming languages for the robots TSO 4b. Describe artificial intelligence TSO 4c. Write a programme in the required language to operate a robot for the given task. TSO 4d. Optimise robot programming parameters.	**Unit– 4.0 Robot Programming and Economics of Robotization** 4.1 Characteristics of task level languages through programming methods 4.2 Motion interpolation 4.3 Artificial intelligence: Goals of artificialintelligence, AI techniques, problem representation in AI	**CO1, CO4, CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
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.	4.4 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, costdata 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 & firefightingoperations • 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.

G) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical (2000608H):

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 1.1 Identify Wireless Sensor Network. LSOs 2.1 LSOs 1.2 Use wireless sensor Network for different robotic applications	1.	Identify different wireless sensor network in robotics viz. ZigBee, LoRa.	**CO1, CO3**
LSOs 2.2 Identify different Radio Frequency (RF)Controlled Wireless LSOs 2.2 Use Radio Frequency (RF) Controlled Wireless for different robotic applications.	2.	Use different Radio Frequency (RF) ControlledWireless Robots.	**CO1, CO2**
LSOs 3.1 Identify the different Voice operated robot with speaker identification technology	3.	Examine different voice operated robot with speaker identification technology.	**CO1, CO3**

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 3.2 Use different Voice operated robot with speaker identification technology for different robotic applications.			
LSOs 5.1 Identify the components required for a computer-controlled pick and place robot (wireless). LSOs 5.2 Integrate the components for the required application.	4.	Design a computer-controlled pick and place robot (wireless)	**CO1**
LSOs 6.1 Identify the components required for a Zigbee controlled Boat with wireless video and voice transmission. LSOs 6.2 Integrate the components for the required application.	5.	Design a Zigbee controlled Boat with wireless video and voice transmission.	**CO2, CO3**
LSOs 8.1 Identify the components required for a PC controlled wireless Multipurpose robot for engineering applications. LSOs 8.2 Integrate the components for the required application.	6.	Design a PC controlled wireless Multipurpose robot for simple engineering applications.	**CO2, CO4, CO5**
LSOs 9.1 Identify the components required for an unmanned arial photography LSOs 9.2 Integrate the components for the required application.	7.	Design an unmanned arial photography system.	**CO3, CO5**
LSOs 10.1 Develop a program LSOs 10.2 Simulate palletizing and depalletizing operations through robots.	8.	Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots.	**CO5**
LSOs 11.1 Develop a program LSOs 11.2 Simulate direction control and step control logic for robotization	9.	Develop TPP / Offline program for vision-basedinspection for robots.	**CO4, CO5**
LSOs 12.1 Develop a program LSOs 12.2 Simulate robotising an inspection and part assembly.	10.	Program and simulate coordinated identification, inspection and part assembly for robots.	**CO1, CO5**
LSOs 13.1 Develop a program. LSOs 13.2 Simulate obstacle avoidance of robots.	11.	Develop obstacle avoidance robot Programming	**CO1, CO5**
LSOs 14.1 PLC programming. LSOs 14.2 Simulate robotising of welding operation.	12.	Program and simulate welding operation using robot simulation software.	**CO1, CO5**
LSOs 15.1 Simulate robotising of drilling operation.	13.	TPP / Offline program for drilling operation.	**CO1, CO5**
LSOs 16.1Develop a program for an industrialapplication. LSOs 16.2Execute the robot programme.	14.	Program to execute an industrial robot application using a given configuration.	**CO1, CO5**
LSOs 17.1 Use robot simulation software for DirectKinematic analysis upto 4-axis robots LSOs 17.2 Correlate the simulated results with respective mathematical calculations.	15.	Analyse Direct Kinematics of 4-axis robot usingavailable software.	**CO2**

H) Suggested Term Work and Self Learning (2000611H): Some sample suggested assignments, micro project andother 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 mines 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:
6. Robotic component manufacturers

I) 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 percentages given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mappedwith 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.

J) **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 MaterialHandling	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 Programmingand 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.

K) 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	40	20
2.	Use different Radio Frequency (RF) Controlled Wireless Robots.	CO1, CO2	40	40	20
3.	Examine different voice operated robot with speaker identification technology.	CO1, CO3	40	40	20
4.	Design a computer-controlled pick and place robot (wireless)	CO1, CO4	40	40	20
5.	Design a Zigbee controlled Boat with wireless video and voice transmission.	CO2, CO3	40	40	20
6.	Design a PC controlled wireless Multipurpose robot for simple engineering applications.	CO3, CO4	40	40	20
7.	Design an unmanned arial photography system.	CO3, CO5	40	40	20
8.	Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots.	CO5	40	40	20
9.	Develop TPP / Offline program for vision-based inspection forrobots.	CO4, CO5	40	40	20

10.	Program and simulate coordinated identification, inspection and part assembly for robots.	CO1, CO5	40	40	20
11.	Develop Obstacle avoidance robot Programming	CO1, CO5	40	40	20
12.	Program and simulate welding operation using robot simulation software.	CO1, CO5	40	40	20
13.	TPP / Offline program for drilling operation.	CO1, CO5	40	40	20
14.	Program to execute an industrial robot application using a given configuration.	CO1, CO5	40	40	20
15.	Analyse Direct Kinematics of 4-axis robot using availablesoftware.	CO2, CO3	40	40	20

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.

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

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

S.No.	Name of Equipment,Tools and Software	Broad Specifications	Relevant Experiment /Practical Number

1.	6 Axis Articulated Robot(Material Handling)- 1 No	• Articulated Type
		• Controlled axis: 6-axes (J1, J2, J3, J4, J5, J6)
		• Reach: 717 mm
		• Installation Floor, Upside-down (Angle mount)
		• Motion range (Maximum Speed)
		  ◦ J1 Axis Rotation7.85 rad/s
		  ◦ J2 Axis Rotation 6.63 rad/s
		  ◦ J3 Axis Rotation 9.08 rad/s
		  ◦ J4 Axis Rotation 9.60 rad/s
		  ◦ J5 Axis Rotation 9.51 rad/s
		  ◦ J6 Axis Rotation 17.45ras/s
		• Max. load capacity Wrist: 4Kg
		• Allowable Load moment 16.6 N-m at wrist J4 Axis, J5Axis, J6 Axis
		• Allowable Load inertia).47 kg-m^2 at wrist J4 Axis J5Axis, J6 Axis
		• Repeatability: +/- 0.05mm
		• Mass: 21 Kg Minimum
		• Installation environment: Ambient temperature: 0 – 45°C
		• Ambient humidity: Normally 75%RH or less. No dew,nor frost allowed.
		• Vibration Acceleration: 4.9 m/s2 (0.5G or less)
			1, 2, 3, 12

S.No.	Name of Equipment,Tools and Software	Broad Specifications	Relevant Experiment /Practical Number
2.	6 Axis Articulated Robot (General Purpose-Welding, Assembly, Drilling) - 1 No	Link 1: 300 mm Link 2: 300 mm Joint actuator: DC Stepper Motor Transmission: Timing Belt Drive Position feedback: Proximity Switch Gripper actuator: Pneumatic Weight of robot: 50 Kg. Accuracy: ±0.3 Repeatability: ±0.2Tip Velocity range: 500 mm / minPay load capacity: 2 kg (including griper) J1 - Waist: ± 140°J2 - Shoulder: - 100 - 60°J3 - Elbow: - 70 + 10°J4 - Wrist rotate: ± 70°J5 - Wrist pitch: ± 35°J6 - Wrist roll: ± 180°External I/O8 Programmable digital inputs8 Programmable digital outputs	8, 9, 14
3.	A mounted vision system with software (Free open-source Robot simulation software)	Integrity Serial Bus System, CAN to Build Intelligent Device Network, Open Hardware Platform, Arduino, to control Robot sub-Systems of motor-sensor, movable Omni Wheel of Omni-Directional, Actuator operation control by DC Encoder Motor, DC-Motor control and operation by Accelerometer, Gyro, Ultrasonic and PSD sensor, Androx Studio; brushless ILM 70×10 Robo Drive DC motor; sensor-actuator units of ARMAR-4; SD-25-160-2A-GR-BB	3, 4, 5, 11
		Harmonic Drive reduction gear unit high gear ratio of 160: 1; structural parts (white) are made out of high-strength aluminium, Hollow shaft with strain gauges for torque sensing, motor's magnetic incremental encoder (AMS5306), digital buses (SPI or 12C); Motor interface PCB includes a 13-Bit temperature-to-digital converter with a temperature range from −40°C to 125°C (Analog Devices ADT7302)	
4.	6-axis Robotics Trainer	Programmable robotic arm with an interactive frontpanel. Software to demonstrates functioning of the trainer as well as allows a user to develop their own programs. NV330; 8-bit microcontroller to ARM processors**;** Record and Play capability**;** Optional interfacing with PL**C;** Touch operated ON/OFF Switch**;** Auto set to home position**;** Applications can be developed**;** Data acquisition using USB	3, 4, 5, 13
5.	E-Yantra Firebird kit	• Fire Bird V 2560 Robot • Spark V Robot • Fire Bird V P89V51RD2 adapter card • Fire Bird V LPC2148 adapter card • LSM303 3 axis digital accelerometer and 3 axes magnetometers • L3G4200 3 axis digital gyroscope • Gyroscope, accelerometer and GPS interfacing module for the robot • GPS receiver • Zigbee Modules 100m range • Zigbee Modules Adapter • Metal-gear Servo Motors • Servo Motor Based Gripper kit for the Fire Bird Vrobot • Sharp infrared range sensor (10cm to 500cm) • Arduino Uno/Nano • Hexapod	1, 3, 5, 6, 7, 10

		• 16 Programming Software (AVR studio, Keil, AVRBoot 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

N) 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 Education978-9356062191
2.	Robotics and controls	Mittal R.K., Nagrath I.J.	Tata McGraw Hill Education Pvt. Ltd.;2017; **978**-0070482937
3.	Robotics and Image Processing: AnIntroduction	Janaki Raman. P. A	Tata McGraw Hill Publishing companyLtd.,1998; 978-0074621677
4.	Industrial Robotics - Technology,Programming and Applications	Nicholas Odrey, Mitchell Weiss, Mikell Groover Roger Nagel, Ashish Dutta	McGraw Hill Education; 2nd Edition;978 -1259006210
5.	Robotic Engineering: an integrated approach	Richard D. Klafter, Thomas A. Thomas A. Chmielewski, Michael Negin	Prentice Hall of India, N. Delhi, 2009;978-8120308428
6.	Industrial Robotics Technology, Programming and Applications	Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey	McGraw-Hill Education, Second Edition, 978-1259006210
7.	Robotics	Appuu Kuttan K. K.	Dreamtech Press, First Edition, 2020,978-9389583281
8.	Introduction to Robotics: Analysis, Control, Applications	Saeed B. Niku	Wiley; Second Edition,978-8126533121
9.	Essentials of Robotics ProcessAutomation	S. Mukherjee	Khanna Publication, First Edition, 978-9386173751
10.	Robotics	R R Ghorpade, M M Bhoomkar	Nirali Prakashan 978-9388897020
11.	Mechatronics: Engineering Fundamentals	Allie Weaver	Murphy & Moore Publishing 2022 ISBN 9781649872758
12.	Elements of Robotics	Greg Scott	States Academic Press 2022 ISBN 9781649649261
13.	Robotics: Design, Construction and Applications	Allie Weaver	Willford Press 2022 ISBN 9781682860944
14.	Modern Robotics: Mechanics, Systems and Control	Julian Evans	Larsen and Keller Education 2022 ISBN 9781641728515
15.	Introduction to Mechatronics	Randy Dodd	Larsen and Keller Education 2022 ISBN 9781641728493
16.	Introduction to Robotics	Julian Evans	Larsen and Keller Education 2022 ISBN 9781641728503

(b) Online Educational Resources:

1. https://web.iitd.ac.in/~saha/ethiopia/appln.pdf
2. https://nptel.ac.in/courses/112105249
3. https://www.robotsscience.com/industrial/industrial-robots-types-applications-benefits-and- future/
4. https://www.marian.ac.in/public/images/uploads/pdf/online-class/MODULE-6%20ROBOTICS%20INDL_APPLNS-converted.pdf
5. https://forcedesign.biz/blog/5-common-industrial-robot-applications
6. https://www.hitechnectar.com/blogs/top-industrial-robotics-applications-role-of-robots-in-manufacturing/
7. https://en.wikipedia.org/wiki/Industrial_robot
8. https://www.youtube.com/watch?v=fH4VwTgfyrQ
9. https://www.youtube.com/watch?v=aW_BM_S0z4k
10. https://www.automate.org/industry-insights/smarter-robot-grasping-with-sensors-software-the-cloud
11. https://robots.ieee.org/robots/?t=all
12. https://www.youtube.com/watch?v=fc_Cynqr6jM

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

(c) Others:

1. Learning Packages:

- https://www.edx.org/learn/robotics
- https://www.coursera.org/courses?query=robotics
- https://www.udemy.com/topic/robotics/
- https://library.e.abb.com/public/9a0dacfdec8aa03dc12578ca003bfd2a/Learn%20with%20ABB.%20Robotic%20package%20for%20education.pdf

2. Users' Guide:

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

3. Lab Manuals:

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

O) Course Curriculum Development Team (NITTTR, Bhopal)

- Dr. Nishith Dubey (Coordinator)
- Prof. (Mrs.) Susan S. Mathew (Co-Coordinator)
- Dr. Sharad Pradhan

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PROCESS CONTROL LAB

Subject Code 2043606	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	02
	L	T	P/S	INTERNAL	:	15	
	--	—	04	EXTERNAL	:	35	

OBJECTIVES

- Study the basic concepts of instrumentation
- Categories the different types of sensors and transducer.
- Explain the signal conditioning.
- Explain the working of recorder
- Explain the measurement technique of strain, force, Torque and power.
- Explain the measurement technique of pressure, temperature and flow.

LIST OF EXPERIMENTS

1. Transient response of thermocouple
2. Effect of Capacity
3. On- off control of temperature process
4. On – off control of pressure process
5. On off control of level process
6. Differential output of a thermocouple
7. Measurement of temperature using RTD
8. Measurement of temperature using thermistor
9. Characteristics of control valve
10. Measurement of Pressure
11. Response of PID controller
12. Measurement of displacement using LVDT

ROBOTICS LAB

Subject Code 2043607	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	02
	L	T	P/S	ESE	:		
	--	—	04	INTERNAL	:	15	
				EXTERNAL	:	35	

OBJECTIVES:

- Identify different part of robot
- Record positions using Cartesian coordinate and joint co ordinates
- Write programmers for pick and place
- Operate and control robot through teach pendant
- Operate and control robot through programming
- Study and use vision system in robot application

LIST OF EXERCISES:

1. Robot system connection and component recognition
2. Robot operation, moving the various axis continuous and intermittent motions.
3. Writing programs off-line
    a. Homing operation
    b. Recording positions
4. Writing programs for pick and place at least three programs
5. Write a Program for stacking the object using offline
6. Write a Looping program using offline.
7. Writing programs on-line
    a. Homing operation
    b. Recording positions
8. Teaching positions via XYZ co-ordinates
9. Write a Program using XYZ Coordinates
10. Write a program using wait, speed commands
11. Measurement of Robot work envelope
12. Measurement of Robot of motion
13. Measurement of Repeatability
14. Practicals connected with Photo sensor/transducer
15. Study of Vision system in Robot

CAD LAB

Subject Code	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	
2043608A	L	T	P/S	INTERNAL	:	20	02
	--	—	04	EXTERNAL	:	30	

OBJECTIVES:

- Understand the types of sections and sectional views
- Understand limits, fits and Tolerances
- Explain the use of threaded fasteners and the types of threads
- Select different types of fits and tolerances for various mating parts
- Draw assembled drawings of various joints and couplings using CAD
- Draw assembled drawings of various types of machine elements using CAD.

CAD PRACTICAL

1. Introduction
2. Sectional views, Limits, fits and tolerances
3. Keys and surface finish
4. Screw threads and threaded fasteners
5. Draw Group commands, Osnap options, Drafting setting and Function keys
6. Commands Practice
7. Edit and Modify Group commands, Pedit, Text edit
8. Commands Practice
9. View groups, Inquiry, Block commands
10. Commands Practice
11. Hatching, Layer, color and line types
12. Commands Practice
13. Technical drawing with AutoCAD, Creating Isometric Drawing Ex. Practice
14. Detailed drawing, sectional views Practice
15. Isometric Drawing Ex. Practice
16. File commands, Plotting, External reference
17. Drawing Ex. Practice (Machine & Assembly drawings in 2D only
    i) Sleeve and cotter joint ii) Stuffing box iii) Knuckle joint iv) Protected type flange coupling v) Universal coupling vi) connecting rod vii) Machine vice
18. 3D Fundamentals
19. Predefined 3D objects, creating surfaces, 3D solid primitives, Working with UCS-3D coordinate system
20. Solid Rendering
21. 3D solid modeling practice
    i) Geneva Mechanism ii) Cast iron block iii) Bushed bearing iv) Bearing block v) Screw jack

PROJECT WORK

Subject Code 2043609	Practical						Credits
	No. of Periods Per Week			Full Marks	:	100	02
	L	T	P/S	ESE	:		
	--	—	04	INTERNAL	:	30	
				EXTERNAL	:	70	

OBJECTIVES:

- To develop the ability to solve a specific problem right from its identification and literature review till the successful solution of the same
- To train the students in preparing project reports and to face reviews and viva voce examination

Course Outcomes: On completion of the course, the student will be able to:

- Fabricate any components using appropriate manufacturing techniques.
- Use of design principles and develop conceptual and engineering design in robotics and automation field.
- Demonstrating the function of the fabricated model.
- Prepare the project as a technical report and deliver it in oral presentation.
- Show their team work and technical skills.

GUIDELINE FOR REVIEW AND EVALUATION

- The students in a group of 3 to 4 works on a topic approved by the head of the department under the guidance of a faculty member and prepares a comprehensive project report after completing the work to the satisfaction of the supervisor.
- The progress of the project is evaluated based on a minimum of three reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester.
- The project work is evaluated based on oral presentation and the project report jointly by external and internal examiners constituted by the Head of the Department.
- Each batch is required to select any new component or an integrated robotics /automation/mechatronics system that involves various sub components which are to be designed in Project Work.
- Marks are awarded to each student of the project group based on the individual performance in the viva-voce examination

Courses under NPTEL / MOOCS/others (TW)

Subject Code 2043611	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	01
	L	T	P/S	INTERNAL	:	20	
	--	—	02	EXTERNAL	:	30	