STATE BOARD OF TECHNICAL EDUCATION, BIHAR

Scheme of Teaching and Examinations for

Vth SEMESTER DIPLOMA IN CHEMICAL ENGINEERING

(Effective from Session 2020-21 Batch)

THEORY

Sr. No.	SUBJECT	SUBJECT CODE	TEACHING SCHEME	EXAMINATION-SCHEME							
			Periods per Week	Hoursof Exam.	Teacher's Assessment (TA) MarksA	Class Test (CT) MarksB	End Semester Exam.(ESE) Marks C	Total Marks (A+B+C)	Pass Marks ESE	Pass Marks in the Subject	Credits
1.	Mass Transfer - II	2014501	03	03	10	20	70	100	28	40	03
2.	Chemical Reaction Engineering	2014502	03	03	10	20	70	100	28	40	03
3.	Process Control & Instrumentation	2014503	03	03	10	20	70	100	28	40	03
4.	Petrochemical Technology	2014504	03	03	10	20	70	100	28	40	03
5.	Open Elective/COE		02	03	10	20	70	100	28	40	02
	Safety in Chemical Process Industries (2014505 A)		Energy Engineering (2014505 B)			Artificial Intelligence (Basics) (2000505B)					
	Internet of Things (Basics) (2000505C)		Drone Technology (Basics) (2000505D)			3D Printing (Basics) (2000505E)					
	Industrial Automation (Basics) (2000505F)		Electric Vehicles (Basics) (2000505G)			Robotics (Basics) (2000505H)					
		Total :-	**14**				**350**	**500**			14

PRACTICAL

Sr. No.	SUBJECT	SUBJECT CODE	TEACHING SCHEME	EXAMINATION-SCHEME					
			Periods per Week	Hours of Exam.	Practical (ESE)		Total Marks	Pass Marks in the Subject	Credits
					Internal (PA)	External (ESE)			
6.	Chemical Reaction Engineering Lab	2014506	04 50% Physical 50% Virtual	03	15	35	50	20	02
7.	Petrochemical Technology Lab.	2014507	04 50% Physical 50% Virtual	03	15	35	50	20	02
8.	Elective Lab/COE Lab		04 50% Physical 50% Virtual	03	20	30	50	20	02
	Mass Transfer Lab (2014508A)		Artificial Intelligence (Basics) **Lab** (2000508 B)				Internet of Things (Basics) **Lab** (2000508 C)		
	Drone Technology (Basics) **Lab** (2000508D)		3D Printing (Basics) **Lab** (2000508E)				Industrial Automation (Basics) Lab (2000508F)		
	Electric Vehicles (Basics) **Lab** (2000508G)		Robotics (Basics) **Lab** (2000508H)						
		Total :-	**12**				**150**		06

TERM WORK

Sr. No.	SUBJECT	SUBJECT CODE	TEACHING SCHEME	EXAMINATION-SCHEME				
			Periods per Week	Marks of Internal (PA)	Marks of External (ESE)	Total Marks	Pass Marks inthe Subject	Credits
9.	Major Project	2014509	06	15	35	50	20	03
10.	Course Under COE / Moocs /NPTEL / Others	2000511 / 2014511	02	20	30	50	20	01
		Total :-	**08**			**100**		04
Total Periods per week Each of duration One Hour		**34**			Total Marks =	**750**		**24**

MASS TRANSFER – II

Subject Code	Theory						Credits
	No. of Periods Per Week			Full Marks	:	100	
2014501	L	T	P/S	ESE	:	70	03
	03	—	—	TA	:	10	
				CT	:	20	

COURSE CONTENT:

UNIT-I	Principle, theory, Vapour Liquid Equilibria calculations, Effect of Pressure and temperature on VLE, Methods of distillations, batch, continuous, flash, steam distillation.
UNIT-II	Stage-wise and continuous contactors operations, Mc-Cabe Thiele Method, Azeotropic distillation and Extractive distillation, Introduction - Multi component Flash and differential distillation.
UNIT-III	Liquid - Liquid Equilibria, Effect of Pressure and Temperature on LLE, Solubility criteria, Batch and continuous extraction towers for miscible and immiscible systems. Industrial Applications.
UNIT-IV	Theory, Mechanism, Types of leaching, Solid - Liquid equilibria, Batch and continuous extractors. Equipments and industrial applications.
UNIT-V	Types of adsorption, nature of adsorbents, Adsorption isotherms, Operation of adsorption columns. Batch and continuous operations

REFERENCE BOOKS:

1. R. E. Treybal, “Mass Transfer Operations”, 3rd Edn., McGraw Hill Book Co., New York, 1981.

2. N. Anantharaman and K.M.Meera Sheriffa Begum, “Mass Transfer Theory and Practice”, Printice Hall of India Pvt. Ltd., New Delhi, 2013.

3. M. Coulson and J. F. Richardson, “Chemical Engineering.”, Vol - II, 5th Edn., Pergamon Press, New York, 2002.

4. W. L. Mccabe, J. C. Smith and P. Harriot, “Unit Operations in Chemical Engg.”,7th Edn., McGraw Hill Book Co., New York, 2004.

CHEMICAL REACTION ENGINEERING

Subject Code	Theory						Credits
	No. of Periods Per Week			Full Marks	:	100	
2014502	L	T	P/S	ESE	:	70	03
	03	—	—	TA	:	10	
				CT	:	20	

COURSE CONTENT:

UNIT-I	Basics of Rate process and Chemical Kinetics: Introduction – Rate of a Chemical Reaction, kinetics of homogeneous reactions: Concentration dependent, Temperature dependent term of rate equation, Searching for a mechanism. Interpretation of Batch Reactor data.
UNIT-II	Types and Mechanisms of Chemical Reactions, Single Ideal Reactors, Batch, Mixed flow reactors and plug flow reactors – Performance equations
UNIT-III	Reactors for Multiple Reactions. Size comparison of single reactors for single reactions. Multiple Reactor system for single reactions. Reactions in parallel, reactions in series and series - parallel reactions of first order. Recycle reactor, auto catalytic reactions.
UNIT-IV	Heat Effects: Temperature and pressure effects on single and multiple reactions.
UNIT-V	Non - ideal flow: Residence time distribution studies: C, E, F and I curves

REFERENCE BOOKS:

1. K. A. Gavhane Chemical Reaction Engineering -I, Nirali Prakashan Publications, Pune
2. S C Roy and C Guha, 'A Text book of Chemical Reaction Engineering' Dhanpat Rai & Co. (P) Ltd.,
3. O. Levenspiel, "Chemical Reaction Engineering", Wiley Easter Ltd., New York.

PROCESS CONTROL & INSTRUMENTATION

Subject Code	Theory						Credits
	No. of Periods Per Week			Full Marks	:	100	
2014503	L	T	P/S	ESE	:	70	03
	03	—	—	TA	:	10	
				CT	:	20	

COURSE CONTENT:

UNIT-I	Laplace transforms - properties of Laplace transform, solution of linear differential equations using Laplace transform techniques, piecewise continuous functions
UNIT-II	Dynamic behaviour of systems - derivation of transfer functions for first and second order systems, liquid level, temperature, pressure, flow and concentration control processes, linearization of nonlinear systems, interacting and non-interacting systems.
UNIT-III	Transient response of first and second order systems, natural frequency, damping factor, overshoot, decay ratio, rise time and settling time.
UNIT-IV	Transient analysis of control systems - block diagram algebra, overall transfer function of closed loop control systems, regulator and servo problems, transient response of first and second order systems with P, PI and PID controller. Definition of stability of control systems, Routh test, limitations of Routh test.
UNIT-V	Principles of measurements and classification of process instruments, measurement of temperature, pressure, fluid flow, liquid weight and weight flow rate, viscosity, pH, concentration, electrical and thermal conductivity, humidity of gases.

REFERENCE BOOKS:

1. D.R. Coughanowr and S. E. LeBlanc, 'Process Systems Analysis and Control', Mc.Graw Hill, III Edition.
2. G. Stephanopoulous, 'Chemical Process Control – Theory and Practice', Prentice Hall of India Ltd.
3. D.C. Sikdar, "Instrumentation and Process Control", Khanna Publishing House
4. S. Sundaram, "Process Dynamics and Control" CENGAGE Learning.
5. K. Padmanabhan & S. Ananthi, "A Treatise on Instrumentation Engineering" I.K International Publishing Pvt. Ltd.

PETROCHEMICAL TECHNOLOGY

(CHEMICAL ENGINEERING)

Subject Code	Theory						Credits
2014504	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

CONTENTS : THEORY

	Name of the Topic	Hrs	Marks
Unit -1	Introduction to Petroleum Refining: 1.1 Indian Refineries, Their location and capacity 1.2 Global crude oil producers, 1.3 Characteristics of crude, Composition, constituents of crude oil	08	08
Unit -2	***Refining:*** 2.1 Process of Refining of crude oil to obtain various fractions (8 Marks) 2.2 Unit operations used in separation processes- Fractionation, VacuumDistillation (4 Marks) 2.3 List of Hydrocarbons/ fractions obtained, their Boiling Ranges andtheir uses (4 Marks)	10	14
Unit - 3	Unit Processes in Refineries: Flow charts, Reactions, Description 3.1 Hydrogenation, Cracking, Alkylation, Polymerisation, (10 Marks) 3.2 Hydrocracking, Isomerisatiopn, Reforming, Esterifiaction &Hydration. (10 Marks) 3.3 Waste Treatment (8 Marks)	12	24
Unit – 4	C_1 to C_4 Hydrocarbons: (4 Marks each) 4.1 C_1 Hydrocarbons, Petrochemicals from C_1 4.2 C_2 Hydrocarbons, Petrochemicals from C_2 4.3 C_3 Hydrocarbons, Petrochemicals from C_3 4.4 C_4 Hydrocarbons, Petrochemicals from C_4 4.5 Aromatic Fractions	10	16
Unit - 5	Hazard & Safet (4 Marks each) 5.1 Hazards in Petrochemical Industry	08	08
	5.2 Safety in Petrochemical Industry		
	TOTAL	48	70

Text/ Reference Books:

Titles of the Book	Name of Authors	Name of the Publisher
Dryden's Outlines of Chemical Tech	M. Gopala Rao, M. Sittig,	East West Press
Shreve's Chemical Process	George Austin	Mc Graw Hill Publication
Petrochemicals	Peter Wiseman	John Willey & Sons
Petrochemicals	Bhaskar Rao	--

Open Elective / COE

(i) Safety in Chemical Process Industries

Subject Code	Theory						Credits
	No. of Periods Per Week			Full Marks	:	100	
2014505A	L	T	P/S	ESE	:	70	
	02	—	—	TA	:	10	
				CT	:	20	02

COURSE CONTENT:

UNIT-I	Hazard identification methodologies, risk assessment methods - PHA, HAZOP, MCA, ETA, FTA, consequence analysis,
UNIT-II	Hazards in work places - nature and type of work places, types of hazards, hazards due to improper house-keeping, hazards due to fire in multi-floor industries and buildings, guidelines and safe methods in the above situations.
UNIT-III	Workers' exposures to hazardous chemicals, TLVs of chemicals, physical and chemical properties of chemicals leading to accidents like fire explosions, ingestion and inhalation, pollution in work places due to dangerous dusts, fumes and vapours, guidelines and safe methods in chemicals handling, storage and entry into confined spaces.
UNIT-IV	Hazards peculiar to industries like fertilizer, heavy chemicals, petroleum, pulp and paper, tanneries, dyes, paints, pesticides, glass and ceramics, dairy and sugar industries, guidelines for safeguarding personnel and safeguarding against water, land and air pollution in the above industries.
UNIT-V	Safety education and training - safety management, fundamentals of safety tenets, measuring safety performance, motivating safety performance, legal aspects of industrial safety, safety audit.

REFERENCE BOOKS:

1. Dr B.K. Bhaskara Rao, Er. R.K. Jain, and Vineet Kumar, "Safety in Chemical Plants/Industry and Its Management" Khanna Publishers.
2. S.C. Sharma, "Industrial Safety and Maintenance Management", Khanna Book Publishing Co. Private Limited, New Delhi

(ii) Energy Engineering

Subject Code	Theory						Credits
	No. of Periods Per Week			Full Marks	:	100	
2014405B	L	T	P/S	ESE	:	70	
	02	—	—	TA	:	10	
				CT	:	20	02

COURSE CONTENT:

UNIT-I	Fuels - Classification, Properties, tests and analysis. Solid Fuels - Coal, origin, classification, storage and handling, carbonization, gasification and briquetting - gasification of biomass.
UNIT-II	Liquid fuels - Petroleum based fuels, synthetic fuels, alcohol and blended fuels, storage and handling.
UNIT-III	Gaseous fuels - Water gas, carbureted water gas, producer gas, coal gas and natural gas.
UNIT-IV	Combustion - Air requirement for solid, liquid and gaseous fuels, Combustion equipment
UNIT-V	Solar energy, Wind energy, Tidal energy, Hydropower, Geothermal energy, Nuclear energy.

REFERENCE BOOKS:

1. Gupta, “Energy Technology”, Khanna Publishing House, New Delhi
2. G.D.Rai, “Non-conventional energy sources”, Khanna Publishers, IV edition, New Delhi,

A) Course Code : 2000505B / 2000508B /2000511B

B) Course Title : Artificial Intelligence (Basics)

C) Pre- requisite Course(s) :

D) Rationale :

Artificial intelligence is the theory and development of computer systems able to perform tasks such as, visual perception, speech recognition, decision-making etc. normally requiring human intelligence. Data analytics gives the basis of developing any artificial intelligence system.

The Python programming language is one of the most accessible programming languages, has several modules to write programs to solve Artificial Intelligence, Machine Learning, Data Analysis problems. Moreover, it has simplified syntax and versatile data structures and functionsto speed up the code writing efficiently.

This course provides the basics for Artificial Intelligence problem solving techniques, data analytics and articulates the different dimensions of these areas. This course also provides the students the foundations for data analytics with python. The course explains data science techniques and the various Python programming packages required to prepare data for analysis, perform data analytics and create meaningful data visualization.

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 Artificial Intelligence for the problem solving as Technological driver.

CO-2 Write Python Programmes for solving problems.

CO-3 Analyze given data by using NumPy package of Python.

CO-4 Analyze given data by using Pandas package of Python.

CO-5 Visualize given data set using Matplotlib.

F) Suggested Course Articulation Matrix:

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs)(if any)		
	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**	**PSO-3**
CO-1	-	2	2	-	-	-	1			
CO-2	-	3	3	3	-	-	2			
CO-3	-	3	3	3	-	-	2			
CO-4	-	2	3	3	-	-	2			
CO-5	-	3	3	3	-	-	2			

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

G) Scheme of Studies:

CourseCode	CourseTitle	Scheme of Studies (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (CI+LI+SW+SL)	Total Credits(C)
		L	T				
2000505B / 2000508B /2000511B	Artificial Intelligence (Basics)	02	-	04	02	08	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 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.

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

SL: Self Learning, MOOCS, spoken tutorials, open educational resources (OERs)

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

Note: SW 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) Scheme of Assessment:

Course Code	Course Title	Scheme of Assessment (Marks)						Total Marks (TA+SWA+LA)
		Theory Assessment (TA)		Sessional Work Assessment (SWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Sessional Work Assessment (PSWA)	End Sessional Work Assessment (ESWA)	Progressive Lab Assessment(PLA)	End Laboratory Assessment (ELA)	
2000505B / 2000508B /2000511B	Artificial Intelligence (Basics)	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)

SWA: Sessional Work/ Term work& Self Learning Assessment (Includes assessment related to student performance in self learning, assignments, Seminars, micro projects, industrial visits, any other student activities etc.

Note: Separate passing is must for progressive and end semester assessment for both theory and practical.

Theory: 100 marks
Practical 50 marks

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), Sessional Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: [2000505B]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Elaborate the use of Artificial Intelligence TSO 1b. Explain various technological Drivers of Modern AI TSO 1c. Describe Knowledge representation TSO 1d. Classify Intelligent agents TSO 1e. List the characteristics of agents TSO 1f. Apply various search strategies for problem solving	**Unit-1.0. Artificial Intelligence** **Artificial Intelligence:** What is AI?, Types of AI, History of AI, Turing Test, Symbol Systems and the scope of Symbolic AI, Structure of AI, Goals of AI, Importance ofAI, Techniques used in AI, Perception, Understanding and Action**,** Technological drivers of modern AI **Knowledge**: Definition, Knowledge Representation, objectives and requirements, practical aspects of representation, Components **Intelligent Agents**: Agents and Environments, Properties of environments, characteristics of agents, classification of agents **Problem Solving:** Problem Formulation, Goal Formulation, State Space Search,Search Problem, Basic search algorithm,Search Tree, Search strategies – Uninformed and informed search, Breadth First Search, Depth First Search, Best First Search, Constraint Satisfaction Problem (CSP), Backtracking Search.Problem Definitions: N Queen Problem, 8Puzzle Problem, Tic-tac-Toe.	CO-1
TSO 2a. Explain Python tokens and variables TSO 2b. Use the concept of l-value and r-value TSO 2c. Write python program using various data types TSO 2d. Write Program using various operators in Python TSO 2e. Write program using conditional	**Unit-2.0 Python Programming** 2.1 Python character set, Python tokens, variables, concept of l-value and r-value,use of comments. Data types: number (integer, floating point, complex), boolean, sequence (string, list, tuple), none, mapping (dictionary),	CO-2

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
statements. TSO 2f. Use various string functions for problem solving in python program TSO 2g. write programmes using various operations on list TSO 2h. Write programmes by using various operations on Tuples and Dictionary TSO 2i. Create user defined functions TSO 2j. Write python programmes using built-in functions TSO 2k. Describe the procedure to import module in the Python TSO 2l. Describe procedure to Import Library and functions in the Python TSO 2m. Write program using Iterative statements.	mutable and immutable data types Operators: arithmetic operators, relational operators, logical operators, assignment operator, augmented assignment operators. Expressions, statement, type conversion & input/output: precedence of operators, expression, evaluation of expression. **Conditional and Iterative statements:** if, if-else, if-elif-else, for loop, range function, while loop, break and continue statements, nested loops **String, List, Tuples and Dictionary:** String: indexing, string operations (concatenation, repetition, membership & slicing), traversing a string using loops, built-in functions. Lists: introduction, indexing, list operations (concatenation, repetition, membership & slicing), traversing a list using loops, built-in functions, linear search on list of numbers and counting the frequency of elements in a list Dictionary: accessing items in a dictionary using keys, mutability of dictionary (adding a new item, modifying an existing item), traversing a dictionary, built-in functions **Python Functions:** types of function (built-in functions, functions defined in module, user defined functions), creating user defined function, arguments and parameters, default parameters, positional parameters, function returning value(s), flow of execution, scope of a variable (global scope, local scope) **Modules and Packages:** Importing module using 'import' Regular Expressions, Exception Handling, PyPI Python Package Index, Pip Python package manager, Importing Libraries and Functions	

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 3a. Explain Data Analytics and its elements TSO 3b. Differentiate Data Analysis and Data Analytics TSO 3c. Explain the use of open source data TSO 3d.Differentiate Qualitative and Quantitative data analysis TSO 3e. Explain procedure to Install NumPy Library TSO 3f. Use NumPy library to perform various operations and functions on array TSO 3g. Write Programs using NumPy for array manipulations	**Unit-3.0 Data Analytics and Computing with NumPy** Data Analytics: Data, Types of Data, Importance of Data, Data Analysis Vs Data Analytics, Types of Data Analytics, Elements of Analytics, Data Analysis Process, Qualitative and Quantitative analyses, Open Source Data. NumPy Library: Introduction, Installation, Ndarray: creating an array, intrinsic creation of an array, Data types, basic operations, aggregate functions, Indexing, slicing, Iterating, Conditions and Booleanarrays, Array manipulation: Joining, splitting, shape changing, sorting, Structured arrays, Reading and Writingarray data on a File.	CO-3
TSO 4a. Apply Pandas data structure for data analysis **TSO** 4b. Write Programs using Pandas to perform various operations and functions on series. **TSO** 4c. Perform various operation in a Data Frame columns and rows **TSO** 4d. Write Programme to read and write on CSV, XLS and Text data files **TSO** 4e. Apply various data cleaning operations and prepare data.	**Unit-4.0 Data Analysis with Pandas** Pandas data structures: Series, Declaration, selecting elements, assigning values, Filtering values, operations, mathematical functions, evaluating values, handling missing data, creating series from dictionaries, adding two series. Data Frame: Defining, selecting elements, assigning values, membership, deleting a column, filtering. Index Objects: Indexing, Re-indexing, Dropping, sorting and ranking, Descriptive Statistics Data Loading: Reading and Writing csv, xls, text data files, Data Cleaning and Preparation: Handling missing data, removing duplicates, replacing values,Vectorized String Methods, HierarchicalIndexing, Merging and Combining, Data aggregation and Grouping.	CO-4
TSO 5a. Illustrate the use of Matplotlib and PyPlot package for showing plots and images TSO 5b. Customize plots with Colors, Markers, Line Styles, Limits, Tics, Labels, Legends, Grids TSO 5c. Differentiate various charts based on their applications	**Unit-5.0 Data Visualization with Matplotlib** Data Visualization: Introduction to Matplotlib ,PyPlot package, Figures and Subplots, showing plots and images Customizing Plots: Colors, Markers, Line Styles, Limits, Tics, Labels, Legends, Grids , Annotating with text, Matplotlib configuration	CO-5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	Chart types: Line, Bar, stacked bar, Box plots, pie chart , Histogram and Density plots, Scatter plot, Saving Plots to a file, Close and clear plots.	

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

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508B]

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
Use various data types and operators to solve given problem Use conditional and iterative statements for solving given problem	1	**Conditional and Iterative statements** 1a. Write a program to generate random numbers between 5 and 10. 1b. Write a program to find the square root of a number. 1c. Write a python program to check if a number is positive, negative or 0. 1d. Write Python program to print all prime numbers between 0-50.	CO-2
2.1Use string functions for performing various string operations	2	**String Handling** 2a. Write a Programme that asks the user for a string with only single space between words, and return number of words in the string. 2b. Write a Program that inputs a line of text and print the count of Vowels in it. 2c. Write a Program that inputs a line of text and print the biggest word in it. 2d. Write a Program that inputs a line of text and print a new line of text where each word of input line is reversed.	CO-2
Use list operations for concatenation, repetition & slicing Perform various operation in the Tuples Perform various operation in the dictionary	3	**List, Tuples and Dictionary** 3a. Write a python program to convert a string to a list. 3b. Write a program to print the largest number in a list. 3c. Given a tuple pairs = ((3,9), (8,4), (3,7), (24,18)), count the number of pairs (a, b) such that both a and b are odd. 3d. Write a program to input a list of numbers and swap elements at the even location with the elements at the odd location. 3e. Write a program to merge two dictionaries.	CO-2
4.1 Use built-in functions to solve given problem	4	**Python Functions** 4a. Write a function to reverse a string. 4b.Write a function to calculate the factorial of a	CO-2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
4.2 Create user defined functions tosolve given problem		number.	
use basic data structure using NumPy Convert the list and tuple as NumPy array	5.	**Basic data structures in NumPy** 5a. Create a List, set, tuple and dictionary which stores the details of a student (roll no, name, dept, branch, percentage of mark) in Python and print the values. 5b. Convert the list and tuple as NumPy array.	CO-3
Create Arrays in Numpy using different intrinsic methods Performarithmetic operations and mathematical operations using arange and ones intrinsicmethod.	6	**Arrays in NumPy** 6a. Create arrays using different intrinsic methods (ones, zeros, arange, linspace, indice) and print their values. 6b. Check the results of arithmetic operations like add(), subtract(), multiply() and divide() with arrays created using arange and ones intrinsic method. 6c. Check the results of mathematical operations like exp(), sqrt(), sin(), cos(), log(), dot() on an array created using arange intrinsic method.	CO-3
7.1 Apply aggregate functions on data by using Built-in functions in Numpy	7	**Built-in functions in NumPy.** 7a. Load your class Mark list data from a csv (comma separated value) file into an array. Perform the following operations to inspect your array. Len(), ndim, size, dtype, shape, info() 7b. Apply the aggregate functions on this data and print the results. (Functions like min(), max(), cumsum(), mean(), median(), corrcoef(), std())	CO-3
8.1 Handle multiple arrays by applying various operations on arrays	8	**Handling Multiple Arrays** 8a. Create two python NumPy arrays (boys, girls) each with the age of nstudents in the class. 8b. Get the common items between two python NumPy arrays. 8c. Get the positions where elements of two arrays match. 8d. Remove from one array those items that exist in another. 8e. Extract all numbers between a given range from a NumPy array.	CO-3
9.1 Apply indexing on the given set of data	9	**Indexing in NumPy** 9a. Load your class Mark list data from a csv file into an array. 9b. Access the mark of a student in a particular subject using indexing techniques. 9c. Select a subset of 2D array using fancy indexing (indexing using integer arrays	CO-3

Practical/Lab Session Outcomes(LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
Create series using list and dictionary in pandas Print different values fromseries.	10	**Working with a Series using Pandas** 10a. Create a series using list and dictionary. 10b. Create a series using NumPy functions in Pandas. 10c. Print the index and values of series. 10d. Print the first and last few rows from the series.	CO-4
11.1 Perform various operation in a Data Frame rows	11	**Working with Data Frame Rows** 11a. Slicing Data Frame using loc and iloc. 11b. Filter multiple rows using isin. 11c. Select first n rows and last n rows 11d. Select rows randomly n rows and fractions of rows (use df. sample method) 11e. Count the number of rows with each unique value of variables 11f. Select nlargest and nsmallest values. 11g. Order/sort the rows	CO-4
12.1 Apply different techniques to merge and combine data	12	**Merge and combine data** 12a. Perform the append, concat and combine first operations on Data Frames. 12b. Apply different types of merge on data. 12c. Use a query method to filter Data Frame with multiple conditions.	CO-4
Create Linear Plot to identify various relation in the data using Matplotlib Create Scatter Plot to identify various relation in the data using Matplotlib	13	**Consider the Salary dataset, which contains 30 observations consisting of years of working experience and the annual wage. Download the data set from** https://www.kaggle.com/rohankayan/years-of-experience-and-salary-dataset 13a. Create a linear plot to identify the relationship between years of working experience and the annual wages with suitable title, legend and labels. 13b. Create a scatter plot to identify the relationship between years of working experience and the annual wages with title	CO-5

Practical/Lab Session Outcomes(LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
		of the Set osa iris class using a bar chart. 14b. Format the obtained bar graph by Changing the color of each bar, Change the Edge color, Line width and Line style.	

L) Sessional Work and Self Learning: [2000511B]

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

b. Micro Projects:

1. **Handing Two-dimensional array in NumPy**
   Download the data set from
   https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.datahttps://www.kaggle.com/arshid/iris-flower-dataset

   a. Import iris dataset with numbers and texts keeping the text intact into python NumPy.
   b. Convert the 1D iris to 2D array (iris2d) by omitting the species text field.
   c. Find the number and position of missing values in iris2d's sepal_length
   d. Insert np.nan values at 20 random positions in iris 2d dataset
   e. Filter the rows of iris2d that has petal_length> 1.5 and sepal_length< 5.0

   Expected Outcome(Use various operations on two dimensional arrays in NumPy)

2. **Handling missing data and duplicates in Pandas**
   a. Identify rows with missing data (isnull(), notnull()) and replace NA/Null data with a given value.
   b. Drop rows and columns with any missing data (dropna(), dropna(1))
   c. Find duplicate values and drop duplicates.
   d. Fill the missing values using forward filling and backward filling.
   e. Replace the missing value with new value and write the dataframe to a CSV file in the local directory.

   Expected Outcomes (a. Identify missing data, b. Find Duplicates values, c. Write the dataframe to a CSV file in the local directory.)

3. **Working with Data Frame Columns**
   a. Create and print a Data Frame.
   b. Find the descriptive statistics for each column.
   c. Group the data by the values in a specified column, values in the index.
   d. Set Index and columns in a Data Frame.
   e. Rename columns and drop columns
   f. Select or filter rows based on values in columns.
   g. Select single and multiple columns with specific names

Expected Outcome (Perform various operation in a Data Frame columns)

4. **Indexing & Sorting in NumPy**
   a. Load your class Mark list data from a csv file into an array.
   b. Sort the student details based on Total mark.

c. Print student details whose total marks is greater than 250 using Boolean indexing.

Expected Outcomes (a. Sort the given set of data, b. Use indexing in an array)

5. **Array Slicing in NumPy**
   a. Load your class Mark list data into an array called "marks" to store students roll num, subject marks and result.
   b. Split all rows and all columns except the last column into an array called "features".
   c. Split the marks array into 3 equal-sized sub-arrays each for 3 different subject marks.
   d. Split the last column into an array "label".
   e. Delete the roll num column from the marks array and insert a new column student name in its place.
   Expected Outcome (Use array slicing in NumPy for the given set of data)

6. Consider the Iris dataset, where observations belong to either one of three iris flower classes.
   Download the data set from
   https://www.kaggle.com/arshid/iris-flower-dataset

   a. Visualize the Histogram for each feature (Sepal Length, Sepal Width, petal Length & petal Width) separately with suitable bin size and color.
   b. Plot the histograms for all features using subplots to visualize all histograms in one single plot. Save the plot as JPEG file.
   c. Plot the box plots for all features next to each other in one single plot. Perform 3D printing of plastic casing of inhaler used by Asthma patients and estimate the cost.

   Expected Outcomes (a. Plot the Histogram for the various features using subplot, b. Plot the box plots for all features next to each other in one single plot)

c. Other Activities:

1. **Lab Activities**
   - Install Python IDE and important Python Libraries
   - Install Anaconda and find the features of Jupyter Notebook.
   - Import various module using 'import '
   - Use Pip Python package manager.
   - Import Libraries and Functions in Python

2. **Seminar Topics:**
   - Technological rivers of modern Artificial Intelligence
   - Intelligent Agents and Environments in Artificial Intelligence
   - Various Search Strategies
   - Python for Data Science
   - Python Libraries and Packages used in data Science
   - Data Visualisation
   - Various data set available over Internet

3. **Self-learning topics:**
   - Use of AI in Engineering and Technology
   - Data Science and Machine Learning
   - Problem and Goal Formulation
   - Search strategies
   - Breadth First Search and Depth First Search
   - Back tracking Search

- N Queen and 8 Puzzle Problem

M) **Course Evaluation Matrix:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional 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)**		Sessional Work Assessment (SWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Sessional Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	20%	20%	--	30%	--	--
CO-2	10%	10%	20%	--	20%	20%	20%
CO-3	20%	20%	20%	30%	20%	20%	20%
CO-4	30%	30%	20%	20%	30%	30%	30%
CO-5	20%	20%	20%	50%	--	30%	30%
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: For indirect assessment of COs, Course exit survey can be used which comprises of questions related to achievement of each COs.

N) **Specification Table for End Semester Theory Assessment:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Title and Number	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0. Artificial Intelligence	CO-1	15	7	5	3
Unit-2.0. Python Programming	CO-2	15	4	3	8
Unit-3.0. Data Analytics and Computing with NumPy	CO-3	14	3	3	8
Unit-4.0. Data Analysis with Pandas	CO-4	13	3	3	7
Unit-5.0. Data Visualization with Matplotlib	CO-5	13	3	3	7
	Total Marks	**70**	**20**	**17**	**33**

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

O) Specification Table for Laboratory (Practical) Assessment:

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA (%)	PDA (%)	
1.	Conditional and Iterative statements	CO-2	-	80	20
2.	String handling	CO-2	-	80	20
3.	List, Tuples and Dictionary	CO-2	20	70	10
4.	Python Functions	CO-2	-	80	20
5.	Basic data structures in NumPy	CO-3	-	80	20
6.	Arrays in NumPy	CO-3	-	80	20
7.	Built-in functions in NumPy.	CO-3	20	70	10
8.	Handling Multiple Arrays	CO-3	20	70	10
9.	Indexing in NumPy	CO-3	-	70	30
10.	Working with a Series using Pandas	CO-4	-	80	20
11.	Working with DataFrame Rows	CO-4	20	60	20
12.	Merge and combine data	CO-4	40	50	10
13.	Consider the Salary dataset, which contains 30 observations consisting of years of working experience and the annual wage.	CO-5	80	10	10
14.	Consider the Iris dataset, where observations belong to either one of three iris flower classes.	CO-5	80	10	10

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) Instructional/Implementation Strategies: Different Instructional/ ImplementationStrategies 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 GB HDD	S.No. 1 to 14
2.	Online Python IDE	https://www.online-python.com/	S.No. 1 to 14
3.	Jupyter Notebook	Download from https://jupyter.org/	S.No. 1 to 14
4.	Pip Python package manager	Download Pip 22.3 From https://pypi.org/project/pip/	S.No. 1 to 14
5.	Various modules, Libraries and Packages	NumPy, Pandas, Matplotlib,PyPlot package	S.No. 1 to 14

R) Suggested Learning Resources:

(a) Suggested Books :

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Artificial Intelligence Basics - A Non-Technical Introduction	TomTaulli	Apress(2019)
2.	Fundamentals of artificial Intelligence	Chowdhary K. R	Springer 2020
3.	Artificial Intelligence A Modern approach	Stuart J. Russell and Peter Norvig	PrenticeHall 2010, 3rdEdition
4.	Introduction to Computing and Problem Solving using Python	E. Balagurusamy	McGraw Hill Education(India)Pvt. Ltd. 1st Edition /2016
5.	Learning Python Programming	Jeffrey Elkner, Allan B.Downey, Chris Meyers	Samurai Media Limited. 2016
6.	Python Programming	Ashok Namdev Kamthane and Amit Ashok Kamthane	McGraw Hill Education(India) Pvt.Ltd.2020, 2nd Edition
7.	Programming in Python	Dr. Pooja Sharma	BPB Publications 2017
8.	Taming Python By Programming	Jeeva ose	Khanna Book Publishing Co(P)Ltd , 2017, Reprinted2019
9.	Python Data Analytics	Fabio Nelli	Apress,2015
10.	Python for Data Analysis: Data Wrangling with Pandas, Numpy, and IPython	Wes McKinney	O'REILLY 2018,SecondEdition

(b) Suggested Open Educational Resources (OER):

1. NPTEL Web Content- Artificial Intelligence, Prof. P. Mitra, Prof. S. Sarkar, IIT Kharagpur URL: https://nptel.ac.in/courses/106/105/106105078/
2. https://www.learnpython.org
3. www.python.org
4. https://www.tutorialspoint.com/python

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

(c) Others: (If any)

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)

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

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A) Course Code : **2000505C / 2000508C / 2000511C**

B) Course Title : **Internet of Things (Basic)**

C) Pre- requisite Course(s) : **Digital Electronics, Electronics Circuits, Fundaments of Computers and Computer networks**

D) Rationale:

The Internet of Things (IoT) is the upcoming field that has the capability to connect everything on the earth. This course focuses on the development of IoT concepts such as sensing, actuation with implementation of communication protocols.

The course also focuses on real life aspects of IoT and how to integrate it in real life projects. The course will simplify the concept of IoT by using the Node MCU board for IoT application development. In this course students will learn about the use of Node MCU and its applications as a beginner/intermediate in the field of IoT. Apart from this, students will learn about the APIs, by using which integration of features like send Email, WhatsApp messages and notification based on certain events in projects is possible. Overall, this course covers both hardware and software aspects of IoT with practical exposure.

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 Describe the functions of each block of the basic IoT system

CO-2 Explain communication protocol used in IoT and its applications

CO-3 Use appropriate sensors for the specific measurement through the IoT platform

CO-4 Explain APIs, client-server connections and its integration in real life applications.

CO-5 Build and test a complete, working IoT system involving prototyping, programming, and data analysis

F) Suggested Course Articulation Matrix:

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs) (if any)		
	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**	**PSO-3**
CO-1	3	-	-	-	-	-	-			
CO-2	1	2	2	2	2	-	-			
CO-3	1	3	2	2	2	2	2			
CO-4	1	1	2	3	-	2	2			
CO-5	1	1	3	2	2	3	3			

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

G) Scheme of Studies:

CourseCode	CourseTitle	Scheme of Studies (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (CI+LI+SW+SL)	Total Credits(C) (CI+LI+SW+SL)
		L	T				
2000505 C / 2000508 C / 2000511C	**Internet of Things (Basic)**	02	-	04	02	08	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 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.

SW: Sessional Work/Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCS, spoken tutorials, open educational resources (OERs)

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

Note: SW 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) Scheme of Assessment:

Course Code	Course Title	Scheme of Assessment (Marks)						Total Marks (TA+SWA +LA)
		Theory Assessment (TA)		Sessional Work Assessment (SWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment(ETA)	Progressive Sessional Work Assessment (PSWA)	End Sessional Work Assessment (ESWA)	Progressive Lab Assessment(PLA)	End Laboratory Assessment (ELA)	
2000505 C / 2000508 C / 2000511C	Internet of Things (Basic)	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)

SWA: Sessional Work/Term work& Self Learning Assessment (Includes assessment related to student performance in self learning, assignments, Seminars, micro projects, industrial visits, any other student activities etc.

Note: Separate passing is must for progressive and end semester assessment for both theory and practical.

Theory: 100 marks

Practical 50 marks

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), Sessional Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: [2000505C]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.1.a. Describe the concept of IoT. TSO.1.b. Explain the functions of each block of the Basic IoT system. TSO.1.c. Compare features of various IoT platforms TSO.1.d. List IoT Real time Applications. TSO.1.e. Describe the functioning of given real-time applications	**Unit-1.0 Introduction to IoT** Basics of IoT, concepts of IoT, History of IoT Basic IoT System and its building blocks Various platforms for IoT (e.g. AWS, AZURE, GCP) Introduction to Python programming andIoT software Applications of IoT	CO-1 and CO-5
TSO.2.a.Explain various communication protocols. TSO.2.b.Explain working and application of blue tooth TSO.2.c.Explain working and application of ZigBee TSO.2.d.Explain working and application of LoRa TSO.2.e.Explain working and application of Wi-fi	**Unit 2. IoT Communication protocols** Basics of given communication protocol along with its applications Explain Communication Protocols MQTT Bluetooth Low Energy ZigBee LoRa Wi-fi	CO-1 and C02
TSO.3.a. Differentiate between sensor and Actuator. TSO.3.b. Classify IoT sensors on the basis of their application. TSO.3.c. Describe the function of each block of Node MCU. TSO.3.d. Explain the procedure to connect sensors with Node MCU.	**Unit-3.0 Sensors and Hardware for IoT** Sensors and Actuators, Transducers, Classifications of sensors, IoT Sensors Development Boards, classifications, and basics of wireless networks, WiFi libraries Introduction to node MCU, block diagram, functions, interfacing with sensors and publishing data on webserver Device integration with node MCU Interfacing of sensors with boards	**CO-1, CO-3 and CO-5**
TSO.4.a. Define APIs and its uses TSO.4.b.Explain working and application of REST. TSO.4.c.Explain working and application of SOAP TSO.4.d.Explain working and application of json TSO.4.e.Explain the integration of API in IoT application development.	**Unit.4 IoT APIsand its Integration** Explain APIs and its use Explanation of given IoT APIs along with its applications MQTT, Broker, subscriber, publisher **REST** **SOAP** **4.5 JSON** **4.6 Programming API using Python**	**CO-1 and CO-4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.5.a. Differentiate between industrial IoT and IoT. TSO.5.b. Describe the applications of IoT in the medical field. TSO.5.c. Describe the medical applications of IoT in the agriculture field. TSO.5.d. Describe the innovative IoT applications.	**Unit. 5 IoT Applications**: - Industrial IoT and Internet of everything IoT for consumer electronics products IoT for Medical applications IoT for Agriculture IoT for security and Law enforcement	**CO-1 and CO-5**

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

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508 C]

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 1.1 List various IoT platforms. List Down broad features of given platforms. List IoT based features in python language.	1.	Prepare a list of platforms used for IoT. Prepare a list of features of above IoT platforms. Prepare a list of features provided by python language for IoT applications.	**CO-1**
LSOs 2.1 Arduino connection with Arduino IDE. Connect Bluetooth with Arduino. verification of data communication with Bluetooth.	2.	Establish connectivity between various components of IoT. Establish connection between Arduinoand Bluetooth module. Establish connection using WiFi	**CO-2**
LSO 3.1 Measure the temperature of the given sensor. LSO 3.2 Measure the humidity of the given sensor. LSO 3.3 Measure the pressure of the given sensor.	3.	Publish data on the IoT platform. Measure the temperature of a remotely located temperature sensor Using IOT based temperature data-monitoring system. Measure the humidity of a remotely located humidity sensor Using IOT based humidity data-monitoring system. Measure the pressure of a remotely located pressure sensor Using IOT based pressure data-monitoring system.	**CO-3**
LSO 4.1 Working with APIs. LSO 4.2 Implementation of APIs using POSTMAN Application.	4	Download and Configure POSTMAN Application Verify REST APIs through POSTMAN. Verify JSON APIs through POSTMAN. Verify SOAP APIs through POSTMAN.	**CO-4**
LSO 5.1 Identification of components for various applications. LSO 5.2 Estimate the cost for components.	5.	Identify components for given project Estimate the cost to make Project working.	**CO-5**

L) Sessional Work and Self Learning: [2000511C]

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

b. Micro Projects:

1. Prepare a report on IoT Systems using Internet data.
2. Market survey to identify various types of IoT sensors and its pricing.
3. Interface IR sensor with Arduino and send the data to Arduino cloud.
4. Send IoT data using Node MCU to things Speak cloud.
5. Interface Bluetooth module with Arduino and send data using the Bluetooth module.

c. Other Activities:

1. Seminar Topics: - "Future of IoT"
   "Technologies for IoT ", "Smart City and IoT"
2. Visit to industry for latest IoT setup in industrial process.
3. Surveys of market for availability of various types of sensors and its pricing.
4. Product Development: Development of projects for real life problem solution using IoT.
5. Software Development: various open source platform operations.

6. Self-learning topics:

1. IoT hardware and their use for various applications
2. IoT sensors technical specifications
3. IoT enabled services

M) Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional 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)**		**Sessional Work Assessment (SWA)**			**Lab Assessment (LA)#**	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	**End Theory Assessment (ETA)**	**Sessional 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: For indirect assessment of COs, Course exit survey can be used which comprises of questions related to achievement of each COs.

N) Specification Table for End Semester Theory Assessment: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Title and Number	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0. Introduction to IoT	CO-1	5	3	2	-
Unit-2.0. IoT Communicationprotocols	CO-2	9	4	3	2
Unit-3.0. Sensors and Hardware for IoT	CO-3	19	5	6	8
Unit-4.0 IoT APIs and its Integration	CO-4	19	5	5	9
Unit-5.0. IoT Applications	CO-5	18	3	6	9
	Total Marks	**70**	**20**	**22**	**28**

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

O) Specification Table for Laboratory (Practical) Assessment:

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA (%)	PDA (%)	
1.	Prepare a list of platforms used for IoT.	CO-1	60	30	10
2.	Prepare a list of features of above IoT platforms.	CO-1	60	30	10
3.	Prepare a list of features provided by python language for IoT applications.	CO-1	60	30	10
4.	Establish connectivity between various components of IoT.	CO-2	60	30	10
5.	Establish connection between Arduino and Bluetooth module.	CO-2	60	30	10
6.	Establish connection using WiFi	CO-2	70	20	10
7.	Publish data on the IoT platform.	CO-3	70	20	10
8.	Measure the temperature of a remotely located temperature sensor Using IOT based temperature data-monitoring system.	CO-3	60	40	10
9.	Measure the humidity of a remotely located temperature sensor Using IOT based temperature data-monitoring system.	CO-3	60	40	10
10.	Measure the pressure of a remotely located temperature sensor Using IOT based temperature data-monitoring system.	CO-3	60	40	10
11.	Publish the data using Mqtt	CO-4	60	30	10
12.	Download and Configure POSTMAN Applications	CO-4	60	30	10
13.	Verify REST APIs through POSTMAN.	CO-4	60	30	10
14.	Verify JSON APIs through POSTMAN.	CO-4	60	30	10
15.	Verify SOAP APIs through POSTMAN.	CO-4	60	30	10
16.	Identify components for given project	CO-5	50	40	10
17.	Estimate the cost to make Project working.	CO-5	50	40	10

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) **Instructional/Implementation Strategies:** Different Instructional/ Implementation Strategies may be appropriatelyselected, 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	Bluetooth Modem-BlueSMiRF Silver	Sparkfun Bluetooth modem	As mentioned above list
2	Postman Software	Open-source downloadable	
3	Node MCU board	Generic	
4	IoT free cloud	Arduino cloud/Thing Speak/Blynk	
5	ATAL Lab Package-1 Package-2 Package-4	As per the list as address below ATAL Equipment list' (http://aim.gov.in/guidelines-for-school.php).	

R) **Suggested Learning Resources:**

(a) **Suggested Books** :

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1	Internet of Things Architecture and Design Principles	Raj Kamal	Mc Graw Hills, New Delhi ISBN 13: 978-93-90722-38-4

2	Internet of things (IoT) : technologies, applications, challenges and solutions	Edited By BK Tripathy , J Anuradha	CRC Press ,ISBN 9780367572921, June 30, 2020	
3	Internet-of-Things (IoT) Systems: Architectures, Algorithms, Methodologies	by Dimitrios Serpanos & Marilyn Wolf	Springer; 1st ed. 2018 edition (17 January 2018)	
4	Custom Raspberry Pi Interfaces: Design and build hardware interfaces for the Raspberry	Pi by Warren Gay	Apress; 1st ed. edition (23 February 2017), ISBN-10 : 9781484224052, ISBN-13 : 978-1484224052	
5	'Learning Internet of Things',	Peter Waher	Packt Publishing, 2015, ISBN 9781783553532, https://lib.hpu.edu.vn/handle/123456789/31693	
6	Sensors, Actuators and Their Interfaces,	N. Ida	Scitech Publishers, 2014.	

(b) Suggested Open Educational Resources (OER):

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

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

(c) Others: (If any)

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

S) Course Curriculum Development Team(NITTTR)

- Dr. M. A. Rizvi(Coordinator)
- Dr. Anjali Potnis(Co-coordinator)

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A) Course Code : 2000505D / 2000508D / 2000511D

B) Course Title : Drone Technology (Basics)

C) Pre- requisite Course(s) :

D) Rationale :

Rapid technological innovation has provided users cutting-edge products at affordable prices. Traditionally, drones had been limited to military use due to high costs and technical sophistication. In recent years, the drone has number of commercial uses and are also proving to be extremely beneficial in places where a man cannot reach or is unable to perform in a timely and efficient manner. Today, drones are used in construction, photography, agriculture, defense, environmental studies and monitoring and other industries to protect the skies, repopulate forests and accomplish much more on a huge scale. This course will acquaint the student with the basic drone technology and applicable drone rules and regulations in India. Considering that the main operational areas of diploma holders, it is essential that he should be exposed to basic drone designing, programming, operating, maintaining and using them safely.

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 Operate a drone safely by applying appropriate drone rules and regulations.

CO-2 Design the structure of drone with drone components and equipment.

CO-3 Interface flight controller board with sensors, ESC and radio communication unit in drone technology.

CO-4 Use drone simulator and identify different types of ports and connectors of drone.

CO-5 Use python programming while drone designing.

F) Course Articulation Matrix:

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs)(if any)		
	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**	**PSO-3**
CO-1	2	-	-	-	3	-	2			
CO-2	3	2	3	3	-	-	-			
CO-3	3	2	3	3	-	-	-			
CO-4	2	-	-	2	-	3	2			
CO-5	-	2	2	3	-	-	-			

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

G) Scheme of Studies:

CourseCode	CourseTitle	Scheme of Studies (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (CI+LI+SW+SL)	Total Credits(C) (CI+LI+SW+SL)
		L	T				
2000505D / 2000508D / 2000511D	Drone Technology (Basics)	02	-	04	02	08	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 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.

SW: Sessional Work/Term work(includesassignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCS,spoken tutorials, open educational resources (OERs)

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

Note: SW 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) Scheme of Assessment:

Course Code	Course Title	Scheme of Assessment (Marks)						Total Marks (TA+SWA+LA)
		Theory Assessment (TA)		Sessional Work Assessment (SWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment(ETA)	Progressive Sessional Work Assessment (PSWA)	End Sessional Work Assessment (ESWA)	Progressive Lab Assessment(PLA)	End Laboratory Assessment (ELA)	
200505D / 200508D / 200511D	3D Printing and Design (Basics)	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)

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

Note: Separate passing is must for progressive and end semester assessment for both theory and practical.

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), Sessional Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: [2000505D]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Describe the various historical evolutionary steps of drone technology TSO 1b. Explain Drone motion based on principle of aerodynamics. TSO 1c. Classify different types of drones and make chart of its application, advantages and disadvantages. TSO 1d. Develop attitude to follow proper rules and regulations of drones flying in India. TSO 1e. Explore future prospects of drones in India.	**Unit-1.0Introduction to Drone Technology** Introduction to Drones and UAV • Definition • History • Drone in Indian aspect Introduction to Flight Dynamics Various types of Drones and their respective Applications • Multirotor drones • Fixed wing structure Drone flights using an understanding of FAA • DGCA • Digital sky platform • RPTO 1.5 Drone regulations-No drone zones	CO-1
TSO 2a. Explain the use and function of different types of Drone components. TSO 2b. Select suitable drone frame and propellers for given application. TSO 2c. Explain working principle and function of different sensors used indrone technology. TSO 2d. Write use of Gyro sensor and Accelerometer in drone. TSO 2e. Describe different types and capacity of Battery used in various drone applications. TSO 2f. State the selection criteria of motor for given drone application. TSO 2g. Write advantage of BLDC motors in making of Drones.	**Unit-2.0Droneand its components** Drones components • Drone frame • Propellers Sensors • Gyro sensor and Accelerometer • Speed and Distance Sensor • Temp sensor • Barometer • TOF Sensor Battery • Types and Capacity Motors • Motor types • Motor capabilities • Application of BLDC motors in drones	CO-2
TSO 3a. Explain four types of motion used in drone's operation. TSO 3b. Describe the working and applications of Electronic speed controller. TSO 3c. Explain the working principle of Flight controller unit used in drone.	**Unit-3.0 Drone controller and motion** Propulsion and Vertical Motion Controller and Flying Instructions • Electronic speed Controller (ESC) • Flight Controller Board(FCB)	**CO-3**

Major Theory Session Outcomes (TSOs)		Units	Relevant COs Number(s)
TSO 3d. TSO 3e.	Explain Radio communication unit used in drone. Explain the communication of Flight controller board with motor, ESC and sensors with suitable diagram	Radio Communication • Transmitter and Receiver for radio signal	
TSO 4a. TSO 4b. TSO 4c.	Describe utility of different communication port used in drone. Identifydifferent types of connectors and write their specifications. Explain the use of drone simulator software and hardware.	**Unit-4.0 Connections and Interfaces of Devices in Drone and Drone Simulator** Communication Port • PWM • RS232, RS422, RS485 • UART • CAN • I2C Different types of connectors and its specification Drone Simulator software Drone simulator Hardware	**CO-4**
TSO 5a. TSO 5b. TSO 5c. TSO 5d.	Write basic code in Python. Explain structure and components of a Python program. write syntax of loops and decision statements in Python. Explain steps to create functions and pass arguments in Python.	**Unit-5.0 Introduction to Python for Drone** Python programing refreshers for IoT, AI and Drone Integration of devices with cloud services Microsoft Azure, AWS	**CO-5**

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508D]

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1 Choose suitable materials for making drone frame.	1.	Determine the strength of materials used in drones frame.	CO-2
LSO 2 Select suitable materials for making drone propellers.	2.	Determine the strength of materials used in drones Propellers.	CO-2
LSO 3 Use appropriate battery as per need of flight time for specific drone application.	3.	Test different parameters of batteries used in drones	CO-2
LSO 4 Identify suitable motors as per payload of specific drone application.	4.	Test motors suitable for specific Drone application.	CO-2
LSO 5 Operate Gyro sensor and Accelerometer.	5.	Test and measure Gyro sensor and Accelerometer and their characteristics.	CO-2
LSO 6.1 Identify different sensors based on their characteristics. LSO 6.2 Interface different types of sensor in drone.	6.	Test different sensors and their characteristics with Microcontroller based Flight controller board.	CO-2, CO-3
LSO 7 Demonstrate four type of drone motion.	7.	Determine thrust/torque of motor by changing different drone motion	CO-2, CO-3
LSO 8.1 Configure Flight control board (FCB) LSO 8.2 Demonstrate use of Flight control board (FCB)	8.	Test and troubleshoot Flight control board (FCB).	CO-3
LSO 9.1 Measure various parameters of sensor LSO 9.2 Interface sensor with flight controller board.	9.	Test and perform communication of Flight control board (FCB) with sensor	CO-3, CO-2
LSO 10 Use motor with flight controller board.	10.	Test and perform communication of Flight control board (FCB) with motor.	CO-3, CO-2
LSO 11 Interface ESC with flight controller board.	11.	Test and perform communication of Flight control board with ESC.	CO-3
LSO 12 Configure radio communication device to control drones	12.	Test and perform communication of Flight control board with RF transceiver.	CO-3
LSO 13.1 Identify different types of ports and connectors of drone. LSO 13.2 Assemble drone component.	13.	Test Hardware assembly for drone.	CO-4 CO-3
LSO 14.1 Identify different motions in drone simulator. LSO 14.2 Operate drone in simulator for specific task	14.	Perform different motion in drone simulator.	CO-4
LSO 15.1 Write code of loop and decision statement in python. LSO 15.2 Interpret loop and decision statement LSO 15.3 Debug code of loop and decision statement	15.	Build and run loops and decision statements for specific application in Python.	CO-5
LSO 16.1 Make function in python. LSO 16.2 Interpret given function statement	16.	Build and Run functions for specific application and pass arguments in Python.	CO-5

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 16.3 Debug code of function in python			
LSO 17.1 Identify python programming steps to interface drone components.	17.	Write basic programming in python to interface different component of Drones.	CO-5, CO-3
LSO 17.2 Identify error in python program			
LSO 17.3 Debug the given python program			

L) Sessional Work and Self Learning: [2000511D]

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

b. Micro Projects:

1. Design drone for simple application.
2. Test different sensors, their characteristics and make chart which are used in different drones' applications.
3. Download 5 videos on drone design with different components. Watch them and write report on it.
4. Write report on Drone application for precision agriculture.
5. Survey nearby electronics shop and Prepare report of list of drone component and its specification.
6. Visit nearby tool room, small industry, Drone training institute facilities. Prepare report of visit with special comments of drone technology used, material used, cost of printed component.

c. Other Activities:

1. Seminar Topics-History of Drone, Drone regulations, Proximity sensor, Bernoulli's principle apply in drone, Radio communication used in drones, Drone Simulator, Python Programming.
2. Visits: Visit nearby tool room, small industry, Drone training institute facilities. Prepare report of visit with special comments of drone technology used, material used, cost of printed component.
3. Surveys: Survey nearby electronics shop and Prepare report of list of drone component and its specification and explore Drone simulator.
4. Product Development
5. Software Development

d. Self learning topics:

1. History of Drones
2. Drone in Indian aspect
3. Drone regulations
4. Principle of aerodynamics for Drones
5. Drone simulator

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

	Course Evaluation Matrix				
	Theory Assessment (TA)**		Sessional Work Assessment (SWA)	Lab Assessment (LA)#	
	Progressive Theory Assessment	End Theory Assessment (ETA)	Sessional Work & Self Learning Assessment	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)

COs	(PTA) Class/Mid Sem Test		Assignments	Micro Projects	Other Activities*		
CO-1	10%	10%	10%	--	10%	-	-
CO-2	30%	30%	30%	33%	30%	30%	30%
CO-3	30%	30%	30%	34%-	30%	30%	30%
CO-4	15%	10%	15%	-	15%	20%	20%
CO-5	15%	20%	15%	33%	15%	20%	20%
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

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

******: Mentioned under point- (N)

: Mentioned under point-(O)

Note: To calculate CO attainment 80% weightage of direct assessment tools and 20% of indirect assessment tools may be taken.

N) Specification Table for End Semester Theory Assessment: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Title and Number	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0. Introduction to Drone Technology	**CO-1**	08	03	02	03
Unit-2.0. Drone and its component	**CO-2**	20	05	07	08
Unit-3.0. Drone controller and motion	**CO-3**	20	05	07	08
Unit-4.0. Connections and Interfaces ofDevices in Drone and Drone Simulator	**CO-4**	08	03	02	03
Unit-5.0. Introduction to Python for Drone	**CO-5**	14	04	04	06
	Total Marks	**70**	**20**	**22**	**28**

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

O) Specification Table for Laboratory (Practical) Assessment:

S.No	Laboratory Practical Titles	Relevant COs Number(s)	PLA # /ELA # (Marks)		
			Performance		Viva-Voce (…%)
			PRA (…%)	PDA (…%)	
1.	Determine the strength of materials used in drones frame.	CO-2	60	30	10
2.	Determine the strength of materials used in drones Propellers.	CO-2	60	30	10
3.	Test different parameters of batteries used in drones	CO-2	50	40	10
4.	Test motors suitable for specific Drone application.	CO-2	50	40	10
5.	Test and measure Gyro sensor and Accelerometer and their characteristics.	CO-2	50	40	10
6.	Test different sensors and their characteristics with Microcontroller based Flight controller board.	CO-2, CO-3	50	40	10
7.	Determine thrust/torque of motor by changing different drone motion	CO-2, CO-3	60	30	10

S.No	Laboratory Practical Titles	Relevant COs Number(s)	PLA #/ELA # (Marks)		
			Performance		Viva-Voce (…%)
			PRA (…%)	PDA (…%)	
8.	Test and troubleshoot Flight control board (FCB).	CO-3	60	30	10
9.	Test and perform communication of Flight control board (FCB) with sensor	CO-3, CO-2	60	30	10
10.	Test and perform communication of Flight control board (FCB) with motor.	CO-3, CO-2	60	30	10
11.	Test and perform communication of Flight control board with ESC.	CO-3	60	30	10
12.	Test and perform communication of Flight control board with RF transceiver.	CO-3	60	30	10
13.	Test Hardware assembly for drone.	CO-4 CO-3	50	40	10
14.	Perform different motion in drone simulator.	CO-4	50	40	10
15.	Build and run loops and decision statements for specific application in Python.	CO-5	50	40	10
16.	Build and Run functions for specific application and pass arguments in Python.	CO-5	50	40	10
17.	Write basic programming in python to interface different component of Drones.	CO-5, CO-3	50	40	10

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) Instructional/Implementation Strategies: Different Instructional/ImplementationStrategies 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 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	1-13
2.	Propellers	10X4.5 CW/Others	1-13
3.	Speed Sensor	3.3 or 5.0Vdc	1-13
4.	Distance Sensor	5Volt operating voltage	1-13
5.	Gyro sensor and Accelerometer	5Volt operating voltage	1-13
6.	Barometer	Altitude tracking, temp range from 25°C to 40°C	1-13

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
7.	TOF Sensor	Accurate ranging up to 4 m, Fast ranging frequency up to 50	1-13
8.	Battery	Lithium Polymer Battery,2200mAH/others	1-13
9.	Motor	BLDC,1000kv or 1000RPM/volt	1-13
10.	Electronic speed Controller (ESC)	30 Amp,2-4s or cell	1-13
11.	Flight Controller Unit	KK 2.1.5/ ArdupilotAPM 2.8/ Pixhawk/others	1-13
12.	Transmitter and Receiver for radio signal	4 channels/6 Channels, 2.4 GHz & 5.8 GHz	1-13
13.	Drone Simulator Software	RC flight simulator	14
14.	Python Software	Hardware required-More than 4 GB RAM, 64 bit CPU preferable	15,16,17

R) Suggested Learning Resources:

(a) Suggested Books :

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Make: Getting Started with Drones: Build and Customize Your Own Quadcopter	Terry Kilby&Belinda Kilby	Shroff/Maker Media, First edition 2016, ISBN-978-9352133147
2.	Agricultural Drones: A Peaceful Pursuit	K R Krishna	Apple Academic Press,1st edition 2018, ISBN-978-1771885959
3.	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
4.	Building Multicopter Video Drones: Build and fly multicopter drones to gather breathtaking video footage	Ty Audronis	Packt Publishing Limited; Illustrated edition,2014,ISBN-978-1782175438
5.	The Complete Guide to Drones	Adam Juniper	Ilex Press, Extended 2nd Edition,2018 ISBN-9781781575383

(b) Suggested Open Educational Resources (OER):

1. https://nptel.ac.in/courses/101104073
2. https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle
3. https://www.scienceabc.com/innovation/what-is-drone-technology.html
4. https://www.dronezon.com/learn-about-drones-quadcopters/what-is-drone-technology-or-how-does-drone-technology-work/
5. https://www.youtube.com/watch?v=OWaXIK9sHeE
6. https://books.google.co.in/books?id=2M0hEAAAQBAJ&printsec=copyright&redir_esc=y#v=onepage&q&f=false

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

(c) Others: (If any)

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

S) Course Curriculum Development Team(NITTTR)

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

******

A) Course Code : 2000505E / 2000508E / 2000511E

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

C) Pre- requisite Course(s) : Computer aided Modeling

D) Rationale :

Additive manufacturing (AM) or Additive layer manufacturing (ALM) is the industrial production name for 3D Printing. 3D Printing is a process that makes solid objects from a digital model. It involves depositing material either metal, powdered plastic, or liquid in thin layers (2D) to get a 3D object. This basic course on 3D Printing tries to develop understanding of the process of making real object from digital model in the students. It also covers the software/hardware required, various materials used for 3D Printing and details about printing process parameters. The knowledge gained through this course will help the students to take up advanced course on 3D Printing in next semester.

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

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

CO-1 Develop CAD models for 3D Printing.

CO-2 Import and Export CAD data in .STL file format to generate GCODE file.

CO-3 Select suitable 3D Printing material for given applications.

CO-4 Select suitable 3D Printing process for given situations.

CO-5 Produce products using most popular FDM/SLA/SLS 3D Printing processes.

F) Course Articulation Matrix:

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs) (if any)		
	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**	**PSO-3**
CO-1	3	-	3	2	-	-	2			
CO-2	3	2	-	2	-	-	-			
CO-3	3	3	-	2	3	-	-			
CO-4	3	3	-	2	-	-	-			
CO-5	3	-	3	3	-	3	2			

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

G) Scheme of Studies:

CourseCode	Course Title	Scheme of Studies (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (CI+LI+SW+SL)	Total Credits(C)
		L	T				
2000505E / 2000508E / 2000511E	3D Printing and Design (Basics)	02	-	04	02	08	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)

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

Note: SW 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.

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2000505E / 2000508E / 2000511E	3D Printing and Design (Basics)	30	70	**20**	**30**	20	30	200

Legend:

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

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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), Sessional Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: [2000505E]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain CAD-CAM and related terminologies. *TSO 1b.* Convert the given CAD file format into others. *TSO 1c.* Transfer the given CAD data to CAM facilities. *TSO 1d.* Classify 3D Printing processes. *TSO 1e.* List the advantages of additive manufacturing processes over	**Unit-1.0 Additive Manufacturing Introduction and CAD** CAD-CAM and its integration CAD- Part and Surface modeling CAD file formats Additive v/s Conventional Manufacturing processes Process chain for 3D Printing Classification of 3D Printing Processes Product design and prototyping	CO1

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
conventional manufacturing processes. *TSO 1f.* List typical steps involved in 3D printing of an object from digital model. *TSO 1g.* Explain reverse engineering steps for 3D Printing.	1.8 Reverse Engineering for 3D Printing	
TSO 2a. Explain the given STL interface terminology. *TSO 2b.* Use the given alternative 3D printing interface. *TSO 2c.* Generate STL file for the given CAD file. *TSO 2d.* Repair the given STL file. *TSO 2e.* Apply part orientation and support techniques for the given situation. *TSO 2f.* Perform slicing of the given CAD model using the given slicing software. *TSO 2g.* Generate tool path using simulation software for the given situation.	**Unit-2.0 Data Preparation for 3D Printing** STL interface Specification, STL data generation, STL data Manipulation, Advantages and limitations of STL file format, Open files, Repair of STL files, Alternative 3D Printing interfaces Part orientation and support generation, Factors affecting part orientation, Various models for part orientation determination, The function of part supports, Support structure design, Automatic support structure generation Model Slicing and Contour Data organization, Direct and adaptive slicing:Identification of peak features, Adaptivelayer thickness determination Tool path generation	CO1, CO2
TSO 3a. Explain the given 3D Printing processe. *TSO 3b.* List process parameters of the given 3D Printing processes. *TSO 3c.* Select 3D Printing materials for the given application. *TSO 3d.* Select 3D Printing processes among FDM, SLS, SLA for given application with justification.	**Unit-3.0 Additive Manufacturing Techniques** Stereo- Lithography, LOM, FDM, SLS, SLM, Binder Jet technology, Direct Energy Deposition Process parameter, Process Selection for various applications 3D Printing materials and selection Comparison between FDM, SLS, SLA	CO3, CO4
TSO 4a. Identify various Aerospace, Electronics, Health care, Automotive, Construction, Food processing, Machine tool components that can be 3D Printed. *TSO 4b.* Estimate the cost and time of 3D printing of the given component.	**Unit-4.0 Application of 3D Printing** 4.1 Additive Manufacturing Application Domains: Aerospace, Electronics, Health Care, Defense, Automotive, Construction, Food Processing, Machine Tools	CO3, CO4
TSO 5a. Select suitable 3D Printer and software for the given application with justification. *TSO 5b.* Analyze the effect of given 3D printing process parameters using 3D printer software simulation. *TSO 5c.* List steps to perform 3D scanning of the given object.	**Unit-5.0 3D Printers and Software and Scanners** Construction details and working of established 3D printers for plastics parts only: Stereolithography (SLA), Selective Laser Sintering (SLS), and Fused DepositionModeling (FDM). Accuracy, Precision and Tolerance in 3D printing. 3D Printer software- Fusion 360,	CO4, CO5

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5d. Repair 3D scanned digital model. *TSO 5e.* Set different 3D printing process parameters to get a sound plastic component.	Solidworks, Onshape, Tinkercad, Ultimaker Cura, MeshLab, Simplyfy 3D, Repetier host, Slic3r, etc. – use and operation of anyone. 3D Scanners and working. Producing a part using FDM, SLA and SLS 3D Printer	

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

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508E]

Practical/Lab Session Outcomes(LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Use CAD software. *LSO 1.2.* Prepare digital models of simple 3D entities.	1.	Develop digital models of following simple components using any CAD software: • Nut • Bolt • Network cable Jack • Coat button • Spoon	CO1
LSO 2.1. Prepare digital models of complex 3D entities and assemblies.	2.	Develop digital models of following assemblies using any CAD software: • Connecting Rod • Piston • Electric switch • Bathroom Tap • Mouse	CO1
LSO 3.1. Surf web for downloading readymade free CAD models. *LSO 3.2.* Convert one CAD file format into another.	3.	Download three digital CAD models freely available on web in different formats and then convert them into .stl/obj format.	CO1
LSO 4.1. Use the given Slicing software for 3D Printing. *LSO 4.2.* Perform slicing operation on the given digital model.	4.	Perform slicing operation on one digital model available under each Pr. No.1, 2 and 3.	CO2
LSO 5.1. Use the available 3D printing software. *LSO 5.2.* Selection of 3D printing process and performance parameters.	5.	Analyse the effect of different process parameters, materials on printing time, material required, surface finish, etc. through simulation using 3D printing software on sliced models available from Pr. No. 4	CO3, CO4, CO5
LSO 6.1. Produce single plastic components using available 3D printer. *LSO 6.2.* Perform post processing operations on printed component.	6.	Print one single component on available 3D printer with PLA/ABS material	CO3, CO4, CO5
LSO 7.1. Select appropriate layer thickness, tolerance, fit. *LSO 7.2.* Produce an assembly of plastic	7.	Print one assembly on available 3D printer with PLA/ABS material	CO3, CO4, CO5

Practical/Lab Session Outcomes(LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
components using available 3D printer.			
LSO 8.1. Choose suitable material for printing flexible structure (assembly of same small pieces to give flexible fabric effect). *LSO 8.2.* Choose suitable design/shape to create a flexible type structure. *LSO 8.3.* Produce flexible plastic structure using available 3D printer.	8.	Model and print a flexible fabric structure with PLA/ABS material (assembly of same small pieces to give flexible fabric effect)	CO3, CO4, CO5
LSO 9.1. Selection of 3D printing process parameters.	9.	Change printing process parameters and repeat experiment number 6.	CO4, CO5
LSO 10.1. Use of available 3D scanner. *LSO 10.2.* Develop 3D digital model using scanning approach. *LSO 10.3.* Modeling of complex 3D objects using 3D scanning.	10.	Scan the given complex component using available 3D Scanner.	CO5
LSO 11.1. Produce a complex plastic structure using available 3D printer and scanner. *LSO 11.2.* Apply Reverse Engineering approach to exactly 3D print an existing real object.	11.	Print the 3D scanned digital model of Pr. No. 10 on available 3D printer with PLA/ABS material	CO5

L) Sessional Work/Term Work and Self Learning: [2000511E]

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

b. Micro Projects:

1. Perform 3D printing of plastic casing of inhaler used by Asthma patients and estimate the cost.
2. Download 5 videos on 3D printing of different components, 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. Print two pieces of same components using ABS and PLA and compare their strength, surface roughness, weight, cost.
4. Download two 3D printing free software and try to check their compatibility with your lab printer.

c. Other Activities:

1. Seminar Topics:
   - Commercially available 3D printers and software.
   - Strength of 3D printed Plastic components as compared to Die cast Plastic components.
   - Properties of PLA and ABS 3D printing materials.
   - Reverse engineering application of 3D Printing.
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 flexible plastic components.
    - 3D printing of micro/mini components.
    - Conversion of CAD file formats into IGES.
    - 3D scanning process.

M) Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional 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)**		Sessional Work Assessment (SWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Sessional Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	15%	10%	15%	-	-	20%	20%
CO-2	10%	20%	10%	25%	-	10%	20%
CO-3	15%	20%	15%	25%	33%	15%	20%
CO-4	30%	20%	30%	25%	33%	15%	20%
CO-5	30%	30%	30%	25%	34%	40%	20%
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

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

****** : Mentioned under point- (N)

: Mentioned under point-(O)

Note: 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) Specification Table for End Semester Theory Assessment: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Title and Number	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Additive Manufacturing Introduction and CAD	CO1	12	4	3	5
Unit-2.0 Data Preparation for 3D Printing	CO1, CO2	10	4	2	4
Unit-3.0 Additive Manufacturing Techniques	CO3, CO4	19	5	5	9
Unit-4.0 Application of 3D Printing	CO3, CO4	10	2	3	5
Unit-5.0 3D Printers and Software and Scanners	CO4, CO5	19	5	5	9
Total Marks		**70**	**20**	**18**	**32**

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

O) Specification Table for Laboratory (Practical) Assessment:

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA (%)	PDA (%)	
1.	Develop digital models of following simple components using any CAD software: • Nut • Bolt • Network cable Jack • Coat button • Spoon	CO1	30	60	10
2.	Develop digital models of following assemblies using any CAD software: • Connecting Rod • Piston • Electric switch • Bathroom Tap • Mouse	CO1	40	50	10
3.	Download three digital CAD models freely available on web in different formats and then convert them into .stl/obj format.	CO1	30	60	10
4.	Perform slicing operation on one digital model available under each Pr. No.1, 2 and 3.	CO2	30	60	10
5.	Analyse the effect of different process parameters, materials on printing time, material required, surface finish, etc. through simulation using 3D printing software on sliced models available from Pr. No. 4	CO3, CO4, CO5	30	60	10
6.	Print one single component on available 3D printer with PLA/ABS material	CO3, CO4, CO5	30	60	10
7.	Print one assembly on available 3D printer with PLA/ABS material	CO3, CO4, CO5	30	60	10
8.	Model and print a flexible fabric structure with PLA/ABS material (assembly of same small pieces to give flexible fabric effect)	CO3, CO4, CO5	40	50	10
9.	Change printing process parameters and repeat experiment number 6.	CO4, CO5	40	50	10
10.	Scan the given complex component using available 3D Sanner.	CO5	40	50	10
11.	Print the 3D scanned digital model of Pr. No. 10 on available 3D printer with PLA/ABS material	CO5	30	60	10

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) Instructional/Implementation Strategies: Different Instructional/ ImplementationStrategies 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.	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	1,2
3.	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	6, 7, 8, 10
4.	3D Printing Material	ABS/PLA **OR** Available with CoE	6, 7, 8, 10
5.	3D Printing software	Latest version of software like: Cura/PrusaSlicer/ideaMaker/Meshmixer/MeshLab **OR** Available with CoE	3,4
6.	Post processing equipments and tools	Deburring tools (tool handle & deburring blades), Electronic Digital Caliper, Cleaning Needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removal spatula, Needle file, Cutting mat, Glue stick, Wire stripper etc.	6, 7, 8, 10
7.	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	10

R) Suggested Learning Resources:

(a) Suggested Books :

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing	Lan Gibson, David W. Rosen, Brent Stucker	Springer, 2010 ISBN: 9781493921133
2.	Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing	Andreas Gebhardt,	Hanser Publisher, 2011 ISBN: 156990507X, 9781569905074

3.	3D Printing and Design	Sabrie Soloman	Khanna Publishing House, Delhi ISBN: 9789386173768
4.	3D Printing and Rapid Prototyping-Principles and Applications	C.K. Chua, Kah Fai Leong	World Scientific, 2017 ISBN: 9789813146754
5.	Getting Started with 3D Printing: A Hands-on Guide to the Hardware, Software, and Services Behind the New Manufacturing Revolution	Liza Wallach Kloski, Nick Kloski	Make Community, LLC; 2nd edition, 2021 ISBN: 9781680450200
6.	Laser-Induced Materials and Processes for Rapid Prototyping	L. Lu, J. Fuh, Y.S. Wong	Kulwer Academic Press, 2001 ISBN: 9781461514695

(b) Suggested Open Educational Resources (OER):

1. https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. https://archive.nptel.ac.in/courses/112/104/112104265/
3. https://www.youtube.com/watch?v=b2Od4YHcLAQ
4. https://www.youtube.com/watch?v=EF8CNR-gcXo
5. https://www.academia.edu/41439870/Education_Resources_for_3D_Printing
6. https://www.think3d.in/landing-pages/beginners-guide-to-3d-printing.pdf
7. https://all3dp.com/1/types-of-3d-printers-3d-printing-technology/

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

(c) Others: (If any)

1. 3D Printing Projects DK Children; Illustrated edition, 2017
2. The 3D Printing Handbook: Technologies, design and applications Ben Redwood, Filemon Schöffer, Brian Garret, 3D Hubs; 1st edition, 2017
3. 3D Printer Users' Guide
4. 3D Printer Material Handbook
5. Lab Manuals

S) Course Curriculum Development Team(NITTTR)

- Dr. Sharad Pradhan(Coordinator)
- Dr. A. K. Sarathe(Co-coordinator)

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A) Course Code : 2000505 F / 2000508 F /2000511F

B) Course Title : Industrial Automation (Basic)

C) Pre- requisite Course(s) : Basic Mechanical Engineering, Basic Electrical Engineering, Digital Electronics and Basic programming skills

D) Rationale :

The technological education and research scenario, all over the world, is turning towards a multidisciplinary one. The present scenario is different as compared to the recent past in the sense that the engineering disciplines are now dilating instead of diverging. The primary reason being that the current technological designs are of highly complex and inter-interdisciplinary nature involving synergistic integration of many aspects of engineering knowledge base**.** Industrial automation has become an essential part of every modern industry. Automation helps industry to increase the productivity, quality, accuracy and precision of industrial processes. Stiff competition, higher quality standards and growing concerns of safety & environmental damage have pushed the Industrial sector to adapt state-of-the-art Automation Techniques for effective utilization of resources and optimized performance of the plants. Today engineer is needed to meet the requirements of designing appropriate automation systems. They should have the knowledge of different fields like PLC and PID based Controller, Instrumentation, Networking, Industrial Drives, SCADA/HMI, High speed data acquisition, etc., to become a successful automation engineer. The discipline Automation is enormous in magnitude. The students passing this course will gain basic understanding about industrial automation and will be prepared to take up the advance course in Industrial automation in next semester**.**

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

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

CO-1 Apply principles and strategies for automation for a given situation.

CO-2 Use sensors and input devices as per given situation.

CO-3 Test the given PLC for its functionality.

CO-4 Use actuators and output devices as per given situation.

CO-5 Test the working of various types of control system and controllers

F) Suggested Course Articulation Matrix:

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs) (if any)		
	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**	**PSO-3**
CO-1 Apply principles and strategies for automation for a given situation	3	2	-	2	2	-	2			
CO-2 Use sensors and input devices as per	3	2		2			2			

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs) (if any)		
	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**	**PSO-3**
the requirement.			2		-	-				
CO-3 Test the given PLC for its functionality.	3	2	2	2	2	-	2			
CO-4 Use actuators and output devices a per given situation**.**	3	2	2	2	2	-	2			
CO-5 Test the functionality of various types of control system and controllers	3	2	2	2	-	-	2			

Legend: High (3), Medium (2), Low (1) andNo mapping (-)

G) Scheme of Studies:

CourseCode	Course Title	Scheme of Studies (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (CI+LI+SW+SL)	Total Credits(C) (CI+LI+SW+SL)
		L	**T**				
2000505 F / 2000508 F/ 2000511F	Industrial Automation (Basic)	02	-	04	02	08	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 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.

SW: Sessional Work (includesassignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCS,spoken tutorials, open educational resources (OERs)

C: Credits.

Note: SW 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) Scheme of Assessment:

Course Code	Course Title	Scheme of Assessment (Marks)						Total Marks (TA+SWA+LA)
		Theory Assessment (TA)		Sessional Work Assessment (SWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Sessional Work Assessment (PSWA)	End Sessional Work Assessment (ESWA)	Progressive Lab Assessment(PL	End Laboratory Assessment (ELA)	
2000505F / 2000508F /2000511F	Industrial Automation (Basics)	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)

SWA: Sessional Work/ Term work& Self Learning Assessment (Includes assessment related to student performance in selflearning, assignments, Seminars, micro projects, industrial visits, any other student activities etc.

Note: Separate passing is must for progressive and end semester assessment for both theory and practical.

Theory: 100 marks

Practical 50 marks

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), Sessional 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 attainmentof Course Outcomes (COs) upon thecompletion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Indian Knowledge System (IKS) and others need to be integrated.

J) Theory Session Outcomes (TSOs) and Units: [2000505 F]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.1.a Describe Industry 4.0 and its component TSO.1.b Explain different types of automation systems TSO.1.c Identify the type of automation used in a given industry TSO.1.d Analyze the working of industrial processes and products for automation. TSO.1.e Select principles and strategies for automation for a given situation using 4R's and 1U TSO.1.f Select criteria for factory automation and processes automation for a given industry. TSO.1.g Describe briefly different systems used for industrial automation. TSO.1.h Describe IOT, IIOT and role of robots with respect to automation.	**Unit-1.0OverviewofIndustrial Automation** Introduction to Industry 4.0 and its components, Issues and challenges in automation Need of automation in industries, Principlesand strategies of automation, factory automation, process automation Basic elements of an automated system, Structure of Industrial Automation Advanced automation functions, Levels of automations Industrial control Systems- Process andDiscrete system Types of automation system: Fixed, Programmable, Flexible IntegratedAutomation and its application Different systems used for Industrial automation: PLC, HMI, SCADA, DCS, Drives. Introduction to Internet of Things (IoT) and Industrial Internet of Things (IIOT) and its application in Automation. Role of robots in automation and its components.	CO1 Apply principles and strategies for automation for a given situation.
TSO.2.a Explain PLC and list its advantages over relay systems. TSO.2.b Distinguish between PLC and a PC, PLC and dedicated controllers. TSO.2.c List the types of PLCs and brands available in the market. TSO.2.d Describe the function of each block of a PLC with the help of a block diagram. TSO.2.e Describe the basic sequence of operation of a PLC with a simple example. TSO.2.f Explain different PLC programming languages with simple examples. TSO.2.g Describe a simple PLC programming using ladder logic specifying I/O addressing TSO.2.h List the applications of PLC	**Unit-2.0Fundamentals of PLC** Introduction to PLC, evolution of PLC • Comparison of PLC and Personal Computer (PC) • Comparison of PLC and dedicated controllers like PAC and CNC • Types of PLC – Fixed, Modular and their types • Different brands of PLCs available in the market Building blocks of PLC -CPU, Memory organization, Input-Output modules (Discreteand Analog) Specialty I/O Modules, Power supply PLC programming languages with simple examples: • Functional Block Diagram (FBD), • Instruction List. • Structured text, • Sequential Function Chart (SFC), • Ladder Programming PLC I/O addressing in ladder logic Simple programming example using ladder logic Applications of PLC: Traffic light control, Elevator control, Motor sequencing control, Tank level control, temperature control, Conveyor system	CO2 Use sensors and input devices as per given situation.

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	control	
TSO.3.a Identify the commonly used input field devices in PLC installations along with their symbols. TSO.3.b Draw symbol of various switches used in PLC installations describing the function of each switch. TSO.3.c Identify the various digital input devices used in a PLC installation. TSO.3.d Identify the commonly usedsensors as input field devices found in PLC installations. TSO.3.e Describe the working of different types of discrete sensors giving their applications. TSO.3.f Describe the working of different types of advanced sensors giving their applications. TSO.3.g Select Sensors as per the given requirement for ecofriendly automation	**Unit 3 – Sensors and Input field devices** Analog input devices-Electromagnetic relays, Contactors, Motor starters, Manually operated Switches Toggle switch, pushbutton switch, knife switch and selector switches Mechanically operated switches, Limit switch, Temperature switch (Thermostat), Pressure switch, Level switch and their symbols Discrete/Digital Input device, Constructionand working of Sensors • Proximity sensors- Inductive, Capacitive, Optical and ultrasonic Advanced sensors- Construction and workingof • Temperature sensors- Thermistor, Thermocouple and Resistance temperature Detector (RTD) • Liquid level sensor -Capacitive andUltrasonic • Force -Strain/Weight sensors • Flow sensors – turbine flow sensor • Pressure sensors- Linear Variable Differential Transformer (LVDT) • Inclination sensor -Inclinometer • Acceleration sensor- Accelerometer • Angular and linear position sensor	**CO3** Test the given PLC for its functionality
TSO.4.a Classify the actuators. TSO.4.b Describe the construction and working of a given actuator. TSO.4.c Explain the basic principle of operation of a given actuator. TSO.4.d Differentiate between hydraulic and pneumatic actuators TSO.4.e Explain the basic principle of operation of a given control valve. TSO.4.f Select actuators and valves as per the given requirement for ecofriendly automation. TSO.4.g Develop different hydraulic and pneumatic circuits for simple application. TSO.4.h Identify the commonly usedoutput field devices in PLC installations	**Unit 4- Actuators and output devices** Introduction to actuators, Classification ofactuators Mechanical actuators -Translational and rotational motion, kinematic chains, cams, gears, belt and chain drives, bearings Hydraulic and Pneumatic actuators- linear and rotary actuators, single and double acting cylinder, directional, process and pressure control valves Electrical actuators • Electromechanical actuators Construction, working and application of Stepper motors, AC/DC Servo motors,BLDC Motor (Very brief) • Electrohydraulic actuators-Construction, working and application of Electro-hydrostatic actuator (EHA), ON/OFF Electro-hydraulic Rotary Actuator (E2H90, Control Valve Rotary Actuator (E2HR), Solenoid valve Thermal actuators -Construction, working and application ofHot-And-Cold-Arm Actuators, Chevron-	**CO4** Use actuators and output devices as per given situation.

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	4.6 Magnetic actuators- Construction, working principle and application of Moving coil actuators, moving magnet actuator, Moving iron actuator Selection criteria of actuators Other Output devices- Indicators, Alarms Pilot Lights, Buzzers, Valves, Motor starters, Horns and alarms, Stack lights Control relays,Pumps and Fans.	
TSO.5.a Describe the basic process control system with the help of a block diagram TSO.5.b Explain the types of control available in a process control TSO.5.c Describe the different types of controllers in a closed loop system with the help of a block diagram TSO.5.d Describe the construction, working and application of a given control system components.	**Unit 5– Control system** Block diagram of a basic control system Open and closed loop system, their transfer function First order and second order system and their output response and parameters Different types of inputs-step and ramp Types of control – On-off, Feed forward, Open loop and closed loop control and Transfer function Controllers in closed loop control • Proportional Controller(P Controller) • Integral Controller (I Controller) • Derivative controller (D- Controller) • P-I Controller • P-D Controller • PID Controller	**CO5** Test the working of various types of control system and controllers

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508 F]

Practical/Lab Session Outcomes (LSOs)	S.No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 1.1 Identify various building blocks and major automation components in a given robotic system LSOs 1.2 Identify various building blocks and major automation components in a given electrical drives	1.	Identify major automation components in a given system	**CO1**
LSOs 1.3 Analyze and plan the steps to automate the given system.	2.	Analyze given traditional machine in the laboratory for and identify the steps and components required to automate it.	
LSO 1.4. Identify the building blocks of a given typical SCADA system LSO 1.5. Identify the symbol library of SCADA software	3.	Use Scada software for simple application	
LSOs 2.1 Identify the various parts and front panel status indicators of the given PLC.	4.	Observe various parts and front panel indicators of a PLC	**CO2**

LSOs 2.2 Identify different input and output devices that can be connected to a given PLC.	5.	Observe different types of switches and their symbols sensors, lamp, alarm, motor, fan used in a PLC	
LSOs 2.3 Test the analog input and output lines of the given PLC.	6.	Identify Analog input and output lines of a PLC	
LSOs 2.4 Test the digital input and outlines of the given PLC.	7.	Identify digital input and output lines of a PLC	
LSOs 2.5 Use PLC to control the devices like Lamp, Alarm, motor using push button switches	8.	Practice using PLC to control various digital and analog output devices	
LSO 3.1. Test the response of digital inductive proximity sensorused to detectdifferent types of materials	9.	Identify different types of digital inductive proximity sensor and its use	**CO3**
LSO 3.2. Test the response of digital capacitive proximity sensors used to detect o different materials	10.	Identify different types of digital capacitive proximity sensor and its use	
LSO 3.3. Test the response of digital optical proximity sensor used to detect different materials	11.	Identify different types of digital optical proximity sensor and its use	
LSO 3.4. Test the response of digital ultrasonic proximity sensors used to detect different materials	12.	Identify different types of digital ultrasonic proximity sensor and its use	
LSO 3.5. Use thermistor to measure temperature of a given material	13.	Identify different types of thermistor and its use	
LSO 3.6. Use Thermocouple to measure the temperature of a given liquid and plot the output voltage versus temperature	14.	Observe the conversion of temperature to electric parameter conversion of a Thermocouple	
LSO 3.7. Use RTD to control the temperature of an oven	15.	Observe different types of RTDs used in industries for temperature measurement	
LSO 3.8. Use flow sensors to measure the flow of a given liquid or gas	16.	Observe different types of flow sensors used in industries for flow measurement	
LSO 3.9. Use pressure sensors to measure the pressure of a liquid or gas	17.	Observe different types of pressure sensors used in industries for pressure measurement	
LSO 3.10. Use load cell for measurement of mechanical force/weight.	18.	Observe the different types of load cell used in industries for force/weight measurement	

LSOs 4.1 Design and actuate pneumatic circuit for lift control LSOs 4.2 Design a pneumatic system that rivets the pockets on jeans LSOs 4.3 Design pneumatic circuit to open and close the security gate and control the speed. LSOs 4.4 Design a circuit for speed control of hydraulic motor meter out circuit by using 4/3 DC valve. LSOs 4.5 Design a circuit for speed control of double acting cylinder meter in by using 4/2 dc solenoid valve. LSOs 4.6 Designing a circuit for speed control of double acting cylinder meter out by using 4/3 solenoid valve	19.	Design and actuate pneumatic/ hydraulic circuit for the given situation	
LSOs 4.7 Direct acting of hydraulic motor	20.	Operate hydraulic motor	
LSOs 4.8 Operate stepper motor and control the motor by changing number of steps, the direction of rotation and speed.	21.	Operate stepper motor	
LSOs 4.9 Identify the components of thermal and magnetic actuators available in the laboratory. LSOs 4.10 Use thermal and magnetic actuators	22.	Thermal and magnetic actuators	
LSOs 5.1 Test the output response of a open loop closed loop and feed forward path	23.	Analyze the given system to study open loop, closed loop and feed forward path.	**CO5**
LSOs 5.2 Build and test the output response of a first order system for a step input using a CRO	24.	Analyze the given first order system and its transfer function and output response	
LSOs 5.3 Build and test the response of a second order system for a step input usingCRO.Also mark various parameters	25.	Analyze the given second order system and its transfer function and output response	
LSOs 5.4 Test the Output response of an on-off and Proportional control-based level control system.	26.	Analyze the given water level control system with on-off, Proportional control.	
LSOs 5.5 Test the Output response pf a P+I+D based level control system.	27.	Analyze the given water level control system with P+I+D control.	

L) Sessional Work and Self Learning: [2000511 F]

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

i. State three advantages of using programmed PLC timer over mechanical timing relay.

ii. Prepare a list of open source PLC software

iii. Prepare a list of open source SCADA software.
iv. List the practical applications of PLC systems
v. List the practical applications of SCADA systems.
vi. Compare the PLC and PC with regard to:
    - Physical hardware differences
    - Operating environment
    - Method of programming
    - Execution of program
vii. Prepare classification chart of different types of actuators.
viii. Differentiate between Nano and micro actuators.

b. Micro Projects:

1. Develop a relay-based motor control automation such that the motor reverses its direction when the limit switches are activated.
2. Develop a simulation to connect analog and digital input to the PLC.
3. Develop a simulation to connect analog and digital output to the PLC.
4. Develop a simple automatic water level controller using magnetic float switch.
5. Develop a simple automatic door system using optical sensor and linear actuator.
6. Troubleshoot the faulty equipment/kit available in automation laboratory
7. Select one industry and analyze the process and propose the automation strategies' that can be used for automation.
8. Develop a working model of a given application using given actuators and valves.

c. Other Activities:

1. Seminar Topics- PLC architecture, Different types of sensors, Industrial Applications of PLC and SCADA
2. Visits – Visit any industry with full or semi automation and prepare a report on type of automation used.
3. Surveys-Carry out a market/internet survey of PLC and prepare the comparative technicalspecifications of any one type of PLC (Micro or Mini) of different manufacturer.
4. Product Development- Develop a prototype automatic railway crossing system

Software Development- Download any open source software for PLC and install on your laptop/PC and carry out basic PLC programming

5. Surveys – carry out market survey for different types of electrical actuators available and prepare the comparative technical specifications of electrical actuators used in industries.
6. Visit industry and prepare a report on different types of hydraulic and pneumatic circuits used by the industry in the given section, components used, power requirement, output achieved and maintenance activities required.

d. Self-learning topics:

1. Use of PLC for different industrial applications
2. Use of sensors in commercial field
3. Use of sensors in home automation
4. Compare Specifications of PLCs of different manufacturers of any one type PLC

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

COs	Scheme of Assessment (Marks)								
	Theory Assessment (TA)					Lab Assessment (LA)			
	Progressive Theory Assessment (PTA)# Class/Mid Sem Test	End Theory Assessment (ETA)**	Sessional Work & Self Learning Assessment (SWA)			Progressive Lab Assessment (PLA)			End Laboratory Assessment (ELA)#
			Assignments(s)	Micro Projects	Other Activities*	Process Assessment (PRA)	Product Assessment (PDA)	Viva-Voce	
CO-1	15 %	20%	20 %	100	10 %	45%	35 %	100%	20 %
CO-2	20 %	20%	20 %		15 %	45%	35 %		20 %
CO-3	25 %	20%	20 %		15 %	45%	35 %		20 %
CO-4	25 %	20%	20 %		30 %	45%	35 %		20 %
CO-5	15 %	20%	20 %		30 %	45%	35 %		20 %
Total Marks	**20**	**70**	**4**	**4**	**2**	**8**	**8**	**4**	**30**

Legend:
*** :** Other Activities include seminar, visits, surveys, product development, software development etc.
******: Mentioned under point- (N)
: Mentioned under point-(O)
Note: To calculate CO attainment 80% weightage of direct assessment tools and 20% of indirect assessment tools may be taken.

N) Specification Table for End Semester Theory Assessment: The course teacher has to decide and use appropriate assessment strategy and its weight age in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Title and Number	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Overview of Industrial Automation	**CO1**	12	4	6	4
Unit-2.0 Fundamentals of PLC	**CO2**	17	5	6	6
Unit-3.0 Sensors and Input field devices	**CO3**	16	4	6	6
Unit-4.0 Actuators and output devices	**CO4**	15	4	5	6
Unit- 5.0 Control system	**CO5**	10	3	4	4
Total Marks		**70**	**20**	**27**	**26**

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

O) Specification Table for Laboratory (Practical) Assessment:

S.NO	Laboratory Practical Titles	Relevant COs Number(s)	PLA # /ELA # (Marks)		
			Performance		Viva-Voce (10 %)
			PRA (45%)	PDA (45%)	
1.	Identify major automation components in a given system	CO1	45 %	35 %	20%
2.	Analyze given traditional machine in the laboratory for and identify the steps and components required to automate it.	CO1	45 %	35 %	20%
3.	Use Scada software for simple application	CO1	45 %	35 %	20%
4.	Observe various parts and front panel indicators of a PLC	CO2	45 %	35 %	20%
5.	Observe different types of switches and their symbols sensors, lamp, alarm, motor, fan used in a PLC	CO2	45 %	35 %	20%
6.	Identify Analog input and output lines of a PLC	CO2	45 %	35 %	20%
7.	Identify digital input and output lines of a PLC	CO2	45 %	35 %	20%
8.	Practice using PLC to control various digital and analog output devices	CO2	45 %	35 %	20%
9.	Identify different types of digital inductive proximity sensor and its use	CO3	45 %	35 %	20%
10.	Identify different types of digital capacitive proximity sensor and its use	CO3	45 %	35 %	20%
11.	Identify different types of digital optical proximity sensor and its use	CO3	45 %	35 %	20%
12.	Identify different types of digital ultrasonic proximity sensor and its use	CO3	45 %	35 %	20%
13.	Identify different types of thermistor and its use	CO3	45 %	35 %	20%
14.	19. Observe the conversion of temperature to electric parameter conversion of a Thermocouple.	CO3	45 %	35 %	20%
15.	Observe different types of RTDs used in industries for temperature measurement	CO3	45 %	35 %	20%
16.	Observe different types of flow sensors used in industries for flow measurement	CO3	45 %	35 %	20%
17.	Observe different types of pressure sensors used in industries for pressure measurement	CO3	45 %	35 %	20%
18.	Observe the different types of load cell used in industries for force/weight measurement	CO3	45 %	35 %	20%
19.	Design and actuate pneumatic/ hydraulic circuit for the given situation	CO4	45 %	35 %	20%
20.	Operate hydraulic motor	CO4	45 %	35 %	20%
21.	Operate stepper motor	CO4	45 %	35 %	20%
22.	Thermal and magnetic actuators	CO4	45 %	35 %	20%
23.	Analyze the given system to study open loop, closed loop and feed forward path.	CO5	45 %	35 %	20%
24.	Analyze the given first order system and its	CO5	45 %	35 %	20%

S.NO	Laboratory Practical Titles	Relevant COs Number(s)	PLA # /ELA # (Marks)		
			Performance		Viva-Voce (10 %)
			PRA (45%)	PDA (45%)	
	transfer function and output response				
25.	Analyze the given second order system and its transfer function and output response	CO5	45 %	35 %	20%
26.	Analyze the given water level control system with on-off, Proportional control.	CO5	45 %	35 %	20%
27.	Analyze the given water level control system with P+I+D control.	CO5	45 %	35 %	20%

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

P) 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 CommunicationsTechnology(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.	SCADA software (reputed make like Allen Bradley, Siemens etc.,)	Ready-to-use symbol library, React and respond in real-time,Real time monitoring, Friendly, manageable, secure, extensible, Easy-to-use, easy to implement, Easy configuration, simplified maintenance, Communication with PLC, easy and flexible alarm definition, data collection and analysis for new and existing systems, easy-to-use for report generation, open access to historical data, different packages available with input/output structure. Open source software SCADA software: like Ellipse/FTVSE/Wonderware/ open SCADA can also be used	3
2.	Universal PLC Training System with HMI (Of reputed make such as Allen bradely, Siemens, etc.,) Compatible with SCADA software	Human Machine Interface (HMI) display, PLC with 16 digital inputs, 16 digital outputs with RS232 communication facility. Open platform to explore wide PLC and HMI applications. Industrial look & feel. Toggle switches, push to ON switch, proximity sensor, visual indicator, audio indicator, and DC motor. Experiments configurable through patch board. Powerful instruction sets. Several sample ladder and HMI programs. PC based ladder and HMI programming. Extremely easy and student friendly software to develop different programs. Easy downloading of programs. Practice troubleshooting skills. Compact tabletop ergonomic design. Robust construction. PLC gateway for cloud connectivity. Open source software like Ladder logic simulator, Pico soft Simulator, Logixpro simulator, Simple EDA tools can also be used	4,5,6,7,8

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
3.	Proximity sensors kit	The kit should comprise of the following proximity sensor - Inductive Proximity Sensor, Capacitive Proximity Sensor,Magnetic Sensor, Optical Sensor, Audio and LED indicator for the object detection. Along with learning material	9,10,11,12
4.	Temperature transducer kit	Temperature Transducers Test Bench includes different types of temperature sensors including bimetallic strip, RTD, thermocouple, thermistor, RTD/thermocouple temperature display and thermistor, temperature display, heater, fan, switches and its indicator.Separate heater and fan chamber with stand. On panel digital voltmeter, digital ammeter, RTD/thermocouple temperature display, NTC temperature display, toggle switch for heater and fan with indicator, experiments configurable through patch board, heavy duty Test bench, castor wheel (with locking mechanism) is provided at legs of Test bench so that it can be easily moved, enhanced electrical safety consideration.	12,13,14
5.	Pressure transducer kit	Pressure transducer kit should include different types of pressure sensors including capacitive pressure transducer, load cell, bourdon tube pressure gauge, and pressure vessel.Pressure vessel with pressure gauge, safety valve, non returning valve bourdon gauge and capacitive transducer and air compressor, on panel digital voltmeter, digital ammeter, 4-20ma display, 0- 10V DC display, toggle switch for compressor, load cell withsuitable weight, experiments configurable through patch board, self - contained, bench-mounting arrangement, castor wheel (with locking mechanism) is provided at legs of Test bench so that it can be easily moved, enhanced electrical safety consideration. Detailed experiment manual should be supplied with the kit.	16
6.	Flow sensor kit	Turbine flow sensor kit	15
7.	Strain Gauge kit	The kit should provide study of Strain Gauge and their application for measurement of Strain. It should help to study bridge configuration of Strain Gauge and the signal conditioning circuits required to measure strain. It should use cantilever beam arrangement to produce strain on Strain Gauge.The Strain Gauges are firmly cemented to the cantilever at the point wherethe strain is to be measured. Weights are placed on free end of cantilever. Strain developed changes the resistance of Strain Gauge which is detected by full bridge configuration. It should comprise of Seven-segment LED display showing strain in micro strain units. Different weights should be provided to perform linearity and sensitivity experiments. Detailed experiment manual should be supplied with the kit. Test-points to observe input output of each block, onboard gain and offset null adjustment, built in DC Power Supplies, 3½ digits LED display, onboard Cantilever arrangement, high repeatability and reliability The kit should be capable of performing following experiments: • Measuring strain using strain gauges and cantilever assembly. • Determination of linear range of operation of strain measurement. • Determination sensitivity of the kit	17
8.	Cut sections of pumps, actuators, valves and	Suitably cut and mounted on a sturdy base to show the internal details.	18

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
	accessories used in hydraulic systems		
9.	Working models of pumps, actuators, valves and accessories used in hydraulic systems	Working models mounted on sturdy base to demonstrate the operation.	18
10.	Working models of pumps, actuators, valves and accessories used in pneumatic systems	Working models mounted on sturdy base to demonstrate the operation.	18
11. 8	Oil Hydraulic trainer	Mounted on sturdy base fitted with all standard units and accessories to create various hydraulic circuits. Hydraulic trainer with simulation software Pneumatic trainer with simulation software • Filter Regulator Combination with Lubricator (FRL Unit) with pressure gauge , Junction Box with slide valve, Push Button Valve , 3/2 NC Roller lever valve ,3/2 NC Roller lever valve ,5/2 Double external pilot operated valve, 5/2 External pilot operated valve with spring return , 5/2 Hand lever with spring return, 5/2 Hand lever valve with detent – for maintained pilot operation of a SAC , 5/2 Valve with Lever head, 5/2 Value with Mushroom head , Flow control valve – Metering IN & OUT , Shuttle Valve (OR valve) , Quick Exhaust Valve with Quick coupler plug • Double Acting Cylinder (DAC) with Quick coupler socket (with accessories: Screw driver – for cushioning adjustment), Single Acting Cylinder (SAC), Swivel fitting assembly with Quick coupler plug, Multi distributor fittings (for cascading circuit designing) • Single Solenoid Valve with Spring Return (with LED), Double Solenoid Valve (with LED), Magnetic Reed Switch, Magnetic Reed Switch, Relay Logic Unit – 2C/0-3 relays, Electrical Push Button Unit, Electrical Selector Switch Unit, Timer	18
12.	Pneumatic Trainer	Mounted on sturdy base fitted with all standard units and accessories to create various Pneumatic circuits. Pneumatic trainer with simulation software • Filter Regulator Combination with Lubricator (FRL Unit) with pressure gauge, Junction Box with slide valve • Push Button Valve, 3/2 NC Roller lever valve, 3/2 NC Roller lever valve, 5/2 Double external pilot operated valve (Memory valve) • 5/2 External pilot operated valve with spring return, 5/2 Hand lever with spring return, 5/2 Hand lever valve with detent, 5/2 Valve with Lever head ,5/2 Value with Mushroom head, Flow control valve, Shuttle Valve (OR valve), AND valve • Quick Exhaust Valve with Quick coupler plug, Double Acting Cylinder (DAC) with Quick coupler socket, Single Acting Cylinder (SAC), Swivel fitting assembly with Quick coupler plug • Aluminum Profile Table Top, Profile Table Top, Miniature Double Acting Cylinder (DAC), Single Solenoid Valve with Spring Return, Double Solenoid Valve (with LED) • Magnetic Reed Switch, Relay Logic Unit – 2C/0-3 relays, Electrical Push Button Unit, Electrical Selector Switch Unit (Black Selector – 1 no, Green Push Button – 1 no), Timer, Simulation software	18

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
13.	Advanced Electro - Hydraulic and Electro - Pneumatic Hardware systems with work stations and simulation software	• Electro - Hydraulic and Electro - Pneumatic Hardware systems with PLC and simulation software • Profile plate, Frame with Castor Wheels, Filter, Lubricator, Regulator with pressure gauge, Hand Slide Valve, Connection component set, Plastic Tubing, Power Supply & cables, Pressure Gauge, 3/2 Way double solenoid valve	18
14.	Output devices	Servomotor, DC motor, AC motor, stepper motor, Conveyer Belt control by PLC, water level control etc.	18,19,20
15.	Thermal actuators	Hot-And-Cold-Arm Actuators, Chevron-Type Actuators	21
16.	Magnetic actuators	Moving Coil Controllable Actuators, Moving Iron Controllable Actuator	21
17.	Open and closed loop control system kit	Open and closed loop system kit should be able to measure the output response using CRO	22
18.	First and second order control system	First and second order system with input and output terminals provision	23,24
19.	Process control system with feed forward path kit	Process control system with feed forward path kit with input and output terminals provision	22
20.	PID Controller Test Bench	PID Controller Test Bench is a complete setup to control process through two-point (on/off) and three-point (PID) controllers. Industrial PID controller with RS485 communication facility, Thermocouple temperature sensor, Float switch for detection of water level, Temperature measurement and control, Userfriendly software, USB Interface, Heavy duty Test bench, Electrical control panel, Leak proof sturdy piping and tanks, SS Sump tank for inlet and outlet of water, Enhanced electrical safety considerations, Caster wheel (with locking mechanism) at the legs of Testbench for easy movement.	25,26

R) Suggested Learning Resources:

(a) Suggested Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction to Programmable Logic Controllers	Dunning, G.	Thomson /Delmar learning, New Delhi, 2005, ISBN13: 9781401884260
2.	Programmable Logic Controllers	Petruzella, F.D.	McGraw Hill India, New Delhi, 2010, ISBN: 9780071067386
3.	Programmable Logic Controllers	Hackworth, John; Hackworth, Federic	PHI Learning, New Delhi, 2003, ISBN: 9780130607188
4.	Industrial automation and Process control	Stenerson Jon	PHI Learning, New Delhi, 2003, ISBN: 9780130618900
5.	Programmable Logic Controller	Jadhav, V. R.	Khanna publishers, New Delhi, 2017, ISBN: 9788174092281
6.	Programmable Logic Controllers and Industrial Automation - An introduction,	Mitra, Madhuchandra; Sengupta, Samarjit,	Penram International Publication, 2015, ISBN: 9788187972174
7.	Control System	Nagrath & Gopal	New Age International Pvt Ltd, ISBN: 9789386070111, 9789386070111
8.	Linear Control Systems with MATLAB Applications, Publisher:	Manke, B. S.	Khanna Publishers, ISBN: 9788174093103, 9788174093103
9.	Supervisory Control and Data Acquisition	Boyar, S. A.	ISA Publication, USA, ISBN: 978-1936007097
10.	Practical SCADA for industry,	Bailey David ; Wright Edwin	Newnes (an imprint of Elsevier), UK 2003, ISBN:0750658053

(b) Suggested Open Educational Resources (OER):

1. Process Automation Control- online Tutorial: www.pacontrol.com
2. PLC product: www.seimens.com
3. www.ab.rockwellautomation.com
4. PLC product: www.abb.co.in
5. Different product of PLC and Peripherals, Smart Tile CPU Board, All in one lighting energycontroller, Classic PLC www.triplc.com
6. Simulation software:http://plc-training-rslogix-simulator.soft32.com/free-download/
7. Simulator :www.plcsimulator.net/
8. https://www.youtube.com/watch?v=y2eWdLk0-Ho&list=PLln3BHg93SQ_X5rPjqP8gLLxQnNSMHuj-
9. https://www.youtube.com/watch?v=86CrhxgAKTw

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

(c) Others: (If any)

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

S) Course Curriculum Development Team(NITTTR)

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

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A) Course Code : 2000505G / 2000508G / 2000511G

B) Course Title : Electric Vehicle (Basic)

C) Prerequisite Course(s) :

D) Rationale :

Fossil fuel consumption and its adverse impact on the environment have led most nations in the world to adopt electric vehicles for mobility. Most automobile companies are switching from internal combustion engines to electric, a cleaner, and more sustainable alternative. But, in the present scenario, the automobile industries are facing a shortage of skilled technicians needed for the transition to electric drives as the primary source of motive power. There is a huge skill gap between industry and academia when it comes to the task of taking the entire automobile industry towards electric mobility. Therefore, this basic course on an electric vehicles is included in the curriculum of the diploma programme as an open elective course to fill this gap and gain a basic understanding of the importance and necessity of electric vehicles. This course tends to enable participants with multidisciplinary exposure and give them a brief idea about electric vehicles, and their importance. This course gives some basic technical foundations regarding electric vehicles to help them move on to advanced electric vehicle courses.

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

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

CO-1 Classify the EVs based on configurations.

CO-2 Identify relevant Motors for the given EV application.

CO-3 Test the performance of batteries used for EV applications.

CO-4 Distinguish between the EV Charging stations based on their Configurations.

CO-5 Follow regulatory requirements and policies for EV Industry.

F) Course Articulation Matrix:

Course Outcomes (COs)	**Programme Outcomes (POs)**							**Programme Specific Outcomes (PSOs)**(if any)		
	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**	**PSO-3**
CO-1 Classify the EVs based on configurations	3	2	-	2	2	-	3			
CO-2 Identify relevant Motors for the given EV application.	3	2	2	2	2	1	3			
CO-3 Test the performance of batteries used	2	2	3	3	2	2	3			

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs)(if any)		
	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**	**PSO-3**
for EV applications										
CO-4 Distinguish between the EV Charging stations based on their configurations	2	2	1	2	2	1	2			
CO-5 Follow regulatory requirements and policies for EV Industry.	1	1	-	-	3	1	2			

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

G) Scheme of Studies:

CourseCode	Course Title	Scheme of Studies (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (CI+LI+SW+SL)	Total Credits(C)
		L	T				
2000505G / 2000508G / 2000511H	Electric Vehicles (Basic)	02	-	04	02	08	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 in the 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.

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

SL: Self-Learning, MOOCs, Spoken Tutorials, Open Educational Resources (OERs)

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

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

H) Scheme of Assessment:

Course Code	Course Title	Scheme of Assessment (Marks)						Total Marks (TA+SWA+LA)
		Theory Assessment (TA)		Sessional Work Assessment (SWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Sessional Work Assessment (PSWA)	End Sessional Work Assessment (ESWA)	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2000505G / 2000508G / 2000511G	Electric Vehicles (Basic)	30	70	20	30	20	30	200

Legend:

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

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

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

Note: Separate passing is a must for progressive and end-semester assessment for both theory and practical.

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), Sessional 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, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: [2000505G]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Identify the types of the vehicle based on the physical features, specification data and information. TSO 1b. State the advantages of EVs over Conventional IC Engine Vehicles. TSO 1c. Identify different components of Electric Vehicle systems TSO 1d. Explain the functions of different components of the EV	**Unit-1.0Introduction to Electric Vehicle** Review of Conventional Vehicle Engine System Electric Vehicle (EV) • The necessity of Electric Vehicle • Types of Electric Vehicles - Plug-in hybrid - Battery electric vehicle - Hybrid electric vehicle - Fuel Cell Electric Vehicle • Advantages of Electric Vehicles Electric Vehicle Components: Motor, Motor Controller, Battery, Battery Management System, and Charging System.	CO1
TSO 2a. Explain the general characteristics of motors used in EV TSO 2b. List different types of motors used in EV TSO 2c. Explain the working principles of motors used in	**Unit-2.0 Electric Motors used in EVs** Electric Motors for EV applications • General Characteristics of motors • Types of Motors: DC, Brushless DC,	CO2

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
EV applications TSO 2d. Interpret the nameplate ratings of the motors for EV applications. TSO 2e. Explain the motor selection criteria for particular EV applications. TSO 2f. Describe the Mechanical and Electrical Connections of Motors.	Induction, Permanent Magnet Synchronous Motors, Switched Reluctance Motors Rating of Motors Selection Criteria Physical Location Connection of Motors: Mechanical Connections and Electrical Connections	
TSO 3a. List the batteries used in EVs for energy storage TSO 3b. State various parameters related to batteries used in EV applications. TSO 3c. Explain the charging and discharging process of the given batteries. TSO 3d. Explain the salient features of Lithium Ion batteries TSO 3e. Explain the Fuel Cell Storage System. TSO 3f. Identify various sensors installed for monitoring Battery condition. TSO 3g. Explain Battery Management System in EV using Block Diagram. TSO 3h. Describe the procedure of battery Disposal and Recycling	**Unit- 3.0 EV Batteries and Energy Storages** Types of Batteries: Lead Acid, Nickel Based, Lithium Based Battery Parameters Charging (AC) and Discharging(DC) Process Lithium Ion Batteries Fuel Cells, Fuel Cell Storage System Battery Condition Monitoring Battery Management System (BMS) • Need of BMS • Block Diagram of BMS Battery Disposal and Recycling	**CO3**
TSO 4a. Identify different types of diodes and transistors. TSO 4b. Describe the testing procedure for the given Diode and Transistor. TSO 4c. Explain the working principles of the given power electronic converter circuit. TSO 4d. Describe the types of Charging Systems TSO 4e. Describe different Components of the Charging System TSO 4f. Explain the working of the Charging System using a single-line diagram.	**Unit- 4.0 EV Charging Systems** Power electronics in EV • Power electronics components • Rectifiers • DC to DC Converter • DC to AC Converter Charging System • Types of charging Systems • Components of Charging Systems • Single line Diagram of Charging System	**CO4**
TSO 5a. Understand the Rules and Regulations set by the Government for selecting and manufacturing various components of an electric vehicle. TSO 5b. Understand the Policies for E-Vehicles. TSO 5c. Appreciate the importance of the reduction of greenhouse gases in the environment.	**Unit- 5.0 Regulatory Requirements and Policies for EV Industry** Rules and Regulations set by the Indian government for the designer/manufacturer of EVs. Policies in India Global Policies for E- Vehicles. Carbon Footprint Issues	**CO5**

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

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508G]

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 2.1 Use the relevant digital meter for the given application. LSO 2.2 Use a measuring instrument for the given application. LSO 2.3 Use safety kits while working in the	1.	• Practice using digital meters such as AC, DC Clamp Meters, Digital Multimeters, Lux Meters, etc. • Practice using Screw Driver Kit, Vernier	CO1

Practical/Lab Session Outcomes (LSOs)		S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
laboratory.			Caliper, Micrometer, Ampere Meter, Voltage Meter, and Techno-meter. • Practice using safety kits.	
LSO 2.1	Identify the motors used in EV applications	2.	• Identification of motors used in EVs	CO2
LSO 2.2	Identify the given motor terminals			
LSO 3.1	Identify the batteries available in the	3.	• Testing of Batteries used in EVs	CO3
	laboratory.			
LSO 3.2	Measure an open circuit voltage of the			
	given battery.			
LSO 3.3	Determine the Ampere -Hour Capacity of			
	the given battery with a given load.			
LSO 3.4	Test the performance of the given battery			
	with different charging rates and at			
	different ambient temperatures			
LSO 3.5	Demonstrate the effect on the state of			
	health of the battery after several charge/			
	discharge cycles.			
LSO 3.6	Evaluate the temperature cut-off point for		• Battery Management System	
	the given BMS.			
LSO 4.1	Identify the Electrical & Electronics	4.	• Power electronic circuits	CO4
	components available in the laboratory			
	using Digital Multimeters.			
LSO 4.2	Test the given power electronic			
	components using digital meters			
LSO 4.3	Identify the given Power Electronic Circuits			
	used in EVs			
LSO 4.4	Identify the components of the Charging		• Identification of Charging systems	
	System			
LSO 4.5	Recognize the types of Charging Systems			
	available in the Laboratory			

L) Sessional Work and Self-Learning: [2000511G]

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

b. Micro Projects:

1. Collect the information related to the performance of different types of electric vehicles and prepare a comparative report on economic and environmental analysis.
2. Collect specifications of different EVs available in the market.
3. Build and test a prototype circuit of converters used in an electric vehicle.
4. Visit a nearby Electric vehicle showroom or service centre & collect information on different types of motors used in electric vehicles and prepare a comparative report on their performance,
5. Visit a nearby charging station and prepare a report describing the layout and components of the charging station.

c. Other Activities:

1. Seminar Topics:

- Communication Systems, Sensors and batteries used in Evs.
- Technological advances in Evs
- Comparison of EVs manufactured by different companies.

2. **Surveys** – Survey the market and gather information on the electric vehicle manufacturers and submit the report.
3. **Product Development**- Develop an electric vehicle prototype using locally procured hardware components.

d. Self-learning topics:

- Global Manufacturers of EV
- Indian Manufacturers of EV

- Motors used in EV
- Batteries used in EV
- Cost comparison of EVs in market

M) **Course Evaluation Matrix:** The course teacher has to decide and use the appropriate assessment strategy and its weightage, in theory, laboratory and sessional 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)**		Sessional Work Assessment (SWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Sessional 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	15%	30%	20%	--	34%	15%	20%
CO-4	30%	30%	20%	50%	--	30%	20%
CO-5	30%	20%	20%	50%	--	30%	20%
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

***:** Other Activities include seminars, visits, surveys, product development, software development etc.

******: Mentioned under point#: Mentioned under point

Note: 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) **Specification Table for End Semester Theory Assessment:** The course teacher has to decide and use the appropriate assessment strategy and its weightage, in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Title and Number	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Electric Vehicle	**CO1**	12	3	5	4
Unit-2.0 Electric Motors used in EVs.	**CO2**	15	4	6	5
Unit- 3.0 EV Batteries and Energy Storages.	**CO3**	20	5	9	5
Unit- 4.0 EV Charging Systems	**CO4**	15	5	6	4
Unit- 5.0 Regulatory Requirements and Policies for EV Industry	**CO5**	8	3	3	3
Total Marks		**70**	**20**	**29**	**21**

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

O) Specification Table for Laboratory (Practical) Assessment:

S. N.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA (%)	PDA (%)	
1	Practice using digital meters such as AC, DC Clamp Meters, Digital Multimeters, Lux Meters, etc.	CO1	30	-	20
2	Practice using Screw Driver Kit, Vernier Caliper, Micrometer, Ampere Meter, Voltage Meter, and Techno-meter.				
3	Practice using safety kits.				
4	Identification of motors used in EV	CO2	15	40	30
5	Testing of Batteries used in EVs	CO3	15	40	30
6	Battery Management System	CO3			
7	Power electronic circuits	CO4	40	20	20
8	Identification of Charging systems	CO4			

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) 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, Labs, and 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.	AC, DC Clamp Meters	Application: Non-contact AC/DC Voltage and Current measurement **AC Application:** Current: 0-200Amp, Voltage: 0-600Volt **DC Application:** Current: 4-20mA, Voltage: 0-30Volt.	1
2.	Digital Multimeters	Display: 4 ½ digit Indications: overload protection, polarity indication, over range indication. Auto range change and auto polarity change facility, auto display of polarity and decimal point. **DC**: Volt: 200mV-600V, Current: 200mA-2A **AC**: Volt: 200mV-1000V, Current: 200mA-2A Resistance: 200W-20mW, Power supply: 230V, 50Hz Battery operation: 9 Volt battery Electronic components testing facility should be provided in the Multimeter. A provision for an A.C. adaptor(eliminator) must be available along with the multimeter.	1, 3
3.	Lux Meters	Functions: MAX / MIN, Backlight, Auto Power Off Range: 0 ~ 200,000 lux 0 ~ 20,000 fc Accuracy: ± 5% rdg + 10 dgt (< 10.000 lux / fc) ± 10% rdg +	1

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
		10 dgt (>10.000 lux / fc) Resolution: 0.1 lux or 0.1 fc Accessories: Carrying Case, Installation Manual, 9V Battery (installed).	
4.	Screw Driver toolbox	All types of screw drive sets.	1
5.	Vernier Caliper	**Range:** Lower scale: 0-200mm, Upper Scale: 0-12inch **Vernier Resolution:** Lower Scale: 0.02mm, Upper Scale: 0.001inch	1
6.	Micrometer	0-25mm (inside/outside)	1
7.	Ampere Meter	Moving iron and Moving Coil	1
8.	Voltmeter	AC(0-250V)/DC(0-24V)	1
9.	Tachometer	For speed measurement (0-3000rpm)	1
10.	Resistors	Low-value Resistors of different types	1,4
11.	Capacitors	Low-value electrolyte Capacitors.	1,4
12.	Inductors	Low-value inductors.	1,4
13.	Safety Kit	First Aid Kit, Helmet, Face Mask, Gloves etc.	1
14.	Motors for Electric Vehicle application	Brushless DC, Induction, Permanent Magnet Synchronous Motors, Switched Reluctance Motors	2
15.	EV Machine Cut-out section	for demonstration & training	2
16.	EV mock layout	for demonstration & training	2
17.	Lithium Ion Battery	12V, 7Ah	3
18.	Lead-acid battery	12V, 7Ah	3
19.	Nickel-based batteries (metal hydride and cadmium battery).	12V, 7Ah	3
20.	Battery internal resistance meter	For O.C. voltage & internal battery resistance of each cell	3
21.	Cell Capacity tester	Up to 15V batteries and 3A load current, 10mV voltage and 1mA current resolution, Automatic detection of termination voltage, LED display with a 3-button interface.	3
22.	BMS setup	For Demonstration & training	3
23.	DC power supply	0-32V	3
24.	Power diodes	Power diodes of different current values.	1, 4
25.	Transistors	Power Transistors (NPN, PNP) for Low-frequency high-power applications.	1,4
26.	Voltage Sensors	0-12 Volts.	1,3,4

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
27.	Current Sensors	Volts: + 15v, 0-5v, Current: 4-20mA.	1,3,4
28.	Converter Models	DC to DC and DA to AC converter model	4
29.	Charging Station Simulator	For Demonstration & training purposes.	4
30.	EV Technology layout 3D poster with frame	Fuel cell, EV- Charging Systems, HEV, FCEV, Motors & Controllers etc.	3,4

R) Suggested Learning Resources:

(a) Suggested Books :

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Handbook on Electric Vehicles Manufacturing (E-Car, Electric Bicycle, E- Scooter, E-Motorcycle, Electric Rickshaw, E- Bus, Electric Truck with Assembly Process, Machinery Equipments & Layout)	P.K. Tripathi	Niir Project Consultancy Services; 1st edition (1 January 2022) ISBN-13 : 978-8195676927
2.	Electric Vehicles: And the End of the ICE age	Anupam Singh	Kindle Edition ASIN : B07R3WFR28
3.	Wireless Power Transfer Technologies for Electric Vehicles (Key Technologies on New Energy Vehicles)	Xi Zhang, Chong Zhu, Haitao Song	Springer Verlag, Singapore; 1st ed. 2022 edition (23 January 2022) ISBN-13 : 978-9811683473
4.	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles	EHSANI	CRC Press; Third edition (1 January 2019)ISBN-13 : 978-0367137465
5.	Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles	John G. Hayes, G. Abas Goodarzi	Wiley; 1st edition (26 January 2018) ISBN-13 : 978-1119063643
6.	New Perspectives on Electric Vehicles	Marian Găiceanu (Editor)	IntechOpen (30 March 2022) ISBN-13 : 978-1839696145

(b) Suggested Open Educational Resources (OER):

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

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

(c) Others: (If any)

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

S) Course Curriculum Development Team(NITTTR)

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

A) Course Code : 2000505 H / 2000508 H / 2000511H

B) Course Title : Robotics (Basics)

C) Pre- requisite Course(s) :

D) Rationale :

Currently, industries demand non-stop and fine quality work in different processes used. It is difficult for the human beings to give same quantity and quality of work with respect to time, environment and complexity of the work in any process industry. To get quality and quantity of work in toughest environment or the environment which is not suitable for the humans to work, industries demand for robots and its operator. Operators who will operate these robots need some basic knowledge of robotics. To fulfill the need of industries and looking to the advancement in technology, this course aims for the diploma engineers to have knowledge and skills in robotics.

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-

Select robots for given applications employing basic concepts of design and functions of robots.

Interpret co-ordinate systems and degree of freedom for robots.

Use sensors and drives in context of various robotic applications.

Select appropriate robot control techniques,

Use programs to operate robots.

F) Course Articulation Matrix:

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes (PSOs) (if any)		
	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**	**PSO-3**
CO-1	3	-	3	-	2	2	2			
	3	2	1	2	-	-	-			
CO-2	3	2	1	2	2	-	2			
CO-3	3	1	1	2	-	-	-			
CO-4	3	2	3	3	2	3	2			

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

G) Scheme of Studies:

Course Code	Course Title	Scheme of Studies (Hours/Week)					
		Classroom Instruction (Cl)		Lab Instruction (LI)	Notional Hours (SW+ SL)	Total Hours (Cl+LI+SW+SL)	Total Credits(C)
		L	T				
2000505H/ 2000508H/ 2000511H	Robotics (Basics)	02	-	04	02	08	05

Legend:

Cl: 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 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.

SW: Sessional Work/Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, open educational resources (OERs)

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

Note: SW 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) Scheme of Assessment:

Course Code	Course Title	Scheme of Assessment (Marks)						Total Marks (TA+SWA+LA)
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		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Progressive Sessional Work Assessment (PSWA)	End Sessional Work Assessment (ESWA)	Progressive Lab Assessment(PLA)	End Laboratory Assessment (ELA)	
2000505H / 2000508H / 2000511H	Robotics (Basics)	30	70	**20**	**30**	20	30	200

Legend:

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

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Note: Separate passing is must for progressive and end semester assessment for both theory and practical.

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), Sessional Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: [2000505H]

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain the basic terms used in robotics TSO 1b. Identify components used in robots. TSO 1c. Explain various types of movements. TSO 1d. Distinguish various robots' configurations and their workspace. TSO 1e. Evaluate the degrees of freedom of the given robot. TSO 1f. Specify the methods of conversion of the given linear motion into rotary motion and vice-versa. TSO 1g. List the criteria for selecting robot for the given simple application with justification.	**Unit-1.0 Basics of Robotics Systems** 1.1 Definition, need, brief history of robotics 1.2 Basic Robot terminology, configuration and its working 1.3 Robot components overview - Manipulator, End effecters, Drive system, Controller, Sensors 1.4 Basic structure of a Robot and Classification – Cartesian, Cylindrical, Spherical, Horizontal articulated (SCARA),Parallel; Mechanic alarm, Degree of freedom, Links and joints, Wrist rotation,Mechanical transmission-pulleys, belts, gears, harmonic drive (gear box) 1.5 Linear and Rotary motion and its devices 1.6 Selection criteria for robots	CO1,CO2
TSO 2a. Explain the working of various types of End effecters used in robots with diagram. TSO 2b. Explain with sketches the function of the given sensing device used in a robot. TSO 2c. Describe working of the given sensor used in robot. TSO 2d. Explain the given robot configuration. TSO 2e. Select relevant robot sensors for a given application with justification. TSO 2f. Describe robot machine vision concepts along with block diagram of robot vision system. TSO 2g. Select vision equipment for a given robotic application.	**Unit– 2.0 Robot Components** 2.1 End effecters: types, sketches, working and applications 2.2 Sensing and Feedback devices: Optical sensors, Proximity sensors, LVDT, Thermocouple, RTD, Thermistor, Force sensing – strain gauge, Piezoelectric, Acoustic sensing Feedback devices; Potentiometers; Optical encoders; DC tachometers; 2.3 Robot machine vision: Block diagram of robot vision system, Vision equipment-camera, Imaging Components: Point, Line, Planar and Volume Sensors, Image processing, Part recognition and range detection	CO3
TSO 3a. Explain with sketches the function of the specified actuator used in a robot. TSO 3b. Differentiate between open loop and closed loop systems. TSO 3c. Explain various robotic controls. TSO 3d. Describe block diagrams of the given control system. TSO 3e. Specify drive system used for robotic control as per requirement. TSO 3f. Differentiate the various robot path controls. TSO 3g. Justify the selection of actuators, drives, control system, AC servo motor and path control for making of a robot.	**Unit– 3.0 Robotic Drive System and Controller** 3.1 Actuators; Hydraulic, Pneumatic and Electrical drives; linear actuator; Rotary drives 3.2 Control systems : Open loop and close loop with applications and its elements, Servo and non-servo control systems – Types, basic principles and block diagram Robot controller; Level of Controller 3.3 AC servo motor; DC servo motors and Stepper motors; 3.4 Robot path control: Point to point, Continuous path control and Sensor based path control	CO4

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4a. Explain various robot programming languages. TSO 4b. Programme robot for a given simple job. TSO 4c. Describe the procedure to simulate the given robot movements using the relevant software.	**Unit– 4.0 Introduction to Robot Programming** 4.1 Need and functions of programming 4.2 Methods of robot programming: Manual Teaching, Teach Pendant, Lead through, Programming languages. Programming with graphics. 4.3 Programming languages: Types, features and applications 4.4 Controller programming 4.5 Simulation for robot movements	CO5
TSO 5a. Select a robot for the given application. TSO 5b. Describe various applications of Robotics. TSO 5c. Explain safety norms in robot handling. TSO 5d. Describe maintenance procedure for the given robot. TSO 5e. Describe common problems in robot operations and suggest remedial action.	**Unit– 5.0 Robotics Applications and Maintenance aspects** 5.1 Application robots including special types 5.2 Robot maintenance: Need and types 5.3 Common troubles and remedies in robot operation. 5.4 General safety norms, aspects and precautions in robot handling	CO1,CO2, CO3,CO4

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

K) Laboratory (Practical) Session Outcomes (LSOs) and List of Practical [2000508H]

Practical/Lab Session Outcomes(LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 1.1 Identify parts of Robot on the basis of function. 1.2 Identify joint type & link parameters (link length, link twist, and Link offset), rotational vs. linear motion, used in robot.	1.	Identify components and different configurations of robots.	CO1
LSOs 2.1 Identify different types of robot end effecters. 2.2 Use Mechanical grippers to hold objects. 2.3 Use Vacuum grippers to hold objects.	2.	Pick/hold different objects (shape/weight/stiffness) using robot end effecters.	CO1, CO2
LSOs 3.1 Assemble the complete robot using the components as per the procedure 3.2 Apply the functionalities available in rotor trainer kit. 3.3 Test for various configurations. 3.4 Test for various degrees of freedom.	3.	Assemble robot to test various configurations and degrees of freedom using robot trainer kit.	CO1, CO2
LSOs 4.1 Identify various types of sensors used in robotic application.	4.	Use different types of robotic sensors for a specific situation.	CO3

Practical/Lab Session Outcomes(LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
4.2 Measure angular motion using Synchros. 4.3 Detect objects using optical sensors.			
LSOs 5.1 Interface stepper motor. 5.2 Control robot with stepper motor interfacing.	5.	Perform robot control with stepper motor interfacing	CO3
LSOs 6.1 Draw the labelled sketch of individual parts and robot arm. 6.2 Assemble the arm using the parts as per the procedure. 6.3 Interface the motor drive and operate.	6.	Assemble robot arms using mechanical transmission components and interface motor drive.	CO2, CO3
LSOs 7.1 Use open source or available relevant software to develop pick and place programme. 7.2 Perform simulation.	7.	Perform pick and place operation using Simulation Control Software.	CO5
LSOs 8.1 Develop programme for using a robot arm with three degrees of freedom. 8.2 Execute the programme.	8.	Perform 2D simulation of a 3 DOF robot arm.	CO2, CO4, CO5
LSOs 9.1 Apply stepper motor control with direction control and step control logic simulation. 9.2 Perform basic PLC programming 9.3 Develop ladder logic programs 9.4 Use programming timers	9.	Programme 5-axis Robotic arm to control various motions.	CO3, CO4, CO5
LSOs 10.1Develop a program for a simple application. 10.2 Execute the robot programme.	10.	Program to execute a simple robot application (like painting, straight welding) using a given configuration.	CO4, CO5

L) Sessional Work and Self Learning: [2000511H]

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 stair climb robot using robotic components.
2. Develop RF controller robot using robotic components.
3. Develop robot for metal detection application using robotic components.
4. Develop line follower robot using robotic components.
5. Develop solar floor cleaner robot using robotic components.
6. Develop solar tracker system using robotic components.
7. Develop a greenhouse managing robot for a horticulture application.

c. Other Activities:

1. Seminar Topics: Recent developments in the field of robotics

2. Visits: Visit an automation industry and prepare report for various types of robots employed there and details of any one type of special purpose robot used
3. Case Study: Identify a robotic application in automobiles and present a case study
4. Self learning topics:
   - History of industrial robot
   - Sociological consequences of Robots

M) Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional 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)**		Sessional Work Assessment (SWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Sessional Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	20%	20%	10%	25%	10%	20%
CO-2	20 %	25%	20%	10%	25%	**20%**	20%
CO-3	25%	25%	20%	25%	25%	**20%**	20%
CO-4	20%	20%	20%	15%	25%	**20%**	20%
CO-5	15%	10%	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: 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) Specification Table for End Semester Theory Assessment: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and sessional work for ensuring CO attainment. The response/performance of the student in each of these designed activities is to be assessed to calculate CO attainment.

Unit Number and Title	Relevant COs Number(s)	Total Marks	ETA (Marks)		
			Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Basics of Robotics Systems	CO1,CO2	20	7	7	5
Unit– 2.0 Robot Components	CO2,CO3	16	3	8	5
Unit– 3.0 Robotic Drive System and Controller	CO3,CO4	12	4	4	5
Unit– 4.0 Introduction to Robot Programming	CO5	10	2	4	4
Unit– 5.0 Robotics Applications and Maintenance aspects	CO1,CO2, CO3,CO4	12	4	4	4
Total Marks		**70**	**20**	**27**	**23**

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

O) Specification Table for Laboratory (Practical) Assessment:

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA (%)	PDA (%)	
1.	Identify components and different configurations of robots.	CO1	30	50	20
2.	Pick/hold different objects (shape/weight/stiffness) using robot end effecters.	CO1, CO2	60	30	10
3.	Assemble robot to test various configurations and degrees of freedom using robot trainer kit.	CO1, CO2	70	20	10
4.	Use different types of robotic sensors for a specific situation.	CO3	60	30	10
5.	Perform robot control with stepper motor interfacing	CO3	70	20	10
6.	Assemble robot arms using mechanical transmission components and interface motor drive.	CO2, CO3	60	30	10
7.	Perform pick and place operation using Simulation Control Software.	CO5	70	20	10
8.	Perform 2D simulation of a 3 DOF robot arm.	CO2, CO4, CO5	60	30	10
9.	Programme 5-axis Robotic arm to control various motions.	CO3, CO4, CO5	60	30	10
10.	Program to execute a simple robot application (like painting, straight welding) using a given configuration.	CO4, CO5	60	30	10

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) 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 Sessions, Video Clippings, Use of Open Educational Resources(OER), MOOCs etc.

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

S.No. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
1.	Programmable Robot trainer kit	Trainer kit with - Minimum 3 linkages, Minimum 4 degree of freedom, Mechanical end effecter with servo control, interfacing card (RC servo output, sensors input)	1,2,3
2.	Robotic Arm Control Trainer Kit	botic Arm with five axis control application through PLC.; PLC; Digital Inputs: 8 Nos with 4mm banana sockets for getting the external inputs; Digital Outputs: 6 Nos with 4mm banana sockets for applying the inputs; Digital Input Controls: On board Toggle switches, Push Buttons & input potentiometers; Digital Outputs Controls: 6 nos. on board LED indicators; PC interfacing facility through RS-232.	8,9
3.	Proximity trainer kit	Indicator Type:LED; PCB Type Glass Epoxy SMOBC PCB; Interconnections**:** 2mm banana Patch cords; On board DC motor to see the application of Proximity sensor. Test points to analyse the signal On board variable supply to vary the speed of DC motor. ON/OFF switch and LED for power indication. All interconnections to be made using 2mm banana Patch cords. User manual and patch cords. Built-in power supply. Robust enclosure wooden/plastic box.	4
4.	Robot - Line Tracking Mous Kit	Product Dimensions (20.3 x 11.4 x 8.9 cm); programmed IC, 2 unassembled gear motors, printed circuit boards, mouse-shaped plastic body, necessary components and wires, step-down power converter	3, 4,5
5.	Intelligent Robot Actuator Module	Integrity Serial Bus System, CAN to Build Intelligent Device Network, Open Hardware Platform, Arduino, to control Robot sub-Systems of motor-sensor, movable Omni Wheel of Omni-Directional, Actuator operation control by DC Encoder Motor, DC-Motor control and operation by Accelerometer, Gyro, Ultrasonic and PSD sensor, Androx Studio; brushless ILM 70×10 Robo Drive DC motor; sensor-actuator units of ARMAR-4; SD-25-160-2A-GR-BB Harmonic Drive reduction gear unit high gear ratio of 160: 1; structural parts (white) are made out of high-strength 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)	3, 4, 5

S.No. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ Practical Number
6.	6-axis Robotics Trainer	Programmable robotic arm with an interactive front panel. Software to demonstrates functioning of the trainer as well as allows a user to develop their own programs. NV330; 8 bit microcontroller to ARM processors**;** Record and Play capability**;** Optional interfacing with PL**C;** Touch operated ON/OFF switch**;** Auto set to home position**;** Applications can be developed**;** Data acquisition using USB	3, 4, 5
7.	Robotic Drive System	AC servo motor; DC servo motors, Stepper motors; DC tachometers, etc.	1,3,5,6,7,10
8.	Robot simulator for Robotics	Educational networking licensed Robotic system with simulation software	8, 10
9.	Assorted sensors	Optical encoders, Acoustic sensors ,IR, Potentiometer, RTD, Thermistor, strain gauge, piezoelectric, etc	4
10.	Vision equipment	Camera, Imaging Components: Point, Line, Planar and Volume Sensors	1, 4,10

R) Suggested Learning Resources:

(a) Suggested Books :

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction to Robotics Mechanics and Control	John Craig	Pearson Education ; 978-9356062191
2.	Industrial Robotics -Technology, Programming and Applications	Nicholas Odrey Mitchell Weiss, Mikell Groover Roger Nagel, Ashish Dutta	McGraw Hill Education; 2nd Edition; 978 -1259006210
3.	Robotic engineering : an integrated approach	Richard D. Klafter, Thomas A. Thomas A. Chmielewski, Michael Negin	Prentice Hall of India, N.Delhi , 978-8120308428
4.	Industrial Robotics Technology, Programming and Applications	Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey	McGraw-Hill Education , Second Edition, 978-1259006210
5.	Robotics	Appuu Kuttan K. K.	Dreamtech Press, First Edition, 2020, 978-9389583281
6.	Introduction to Robotics: Analysis, Control, Applications	Saeed B.Niku	Wiley; Second Edition, 978-8126533121
7.	Essentials of Robotics Process Automation	S. Muhkerjee	Khanna Publication, First edition, 978-9386173751
8.	Robotics	R R Ghorpade , M M Bhoomkar	Nirali Prakashan 978-9388897020

(b) Suggested Open Educational Resources (OER):

1. https://archive.nptel.ac.in/courses/112/105/112105249/
2. https://openlearning.mit.edu/mit-faculty/residential-digital-innovations/task-centered-learning-intro-eecs-robotics

3. http://www.mtabindia.com/
4. http://www.robotics.org/
5. https://en.wikipedia.org/wiki/Industrial_robot
6. http://www.servodatabase.com
7. https://www.youtube.com/watch?v=fH4VwTgfyrQ
8. https://www.youtube.com/watch?v=aW_BM_S0z4k
9. https://uk.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/robotic-parts-guide
10. https://www.automate.org/industry-insights/smarter-robot-grasping-with-sensors-software-the-cloud
11. https://www.iqsdirectory.com/articles/machine-vision-system.html

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

(c) Others: (If any)

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

CHEMICAL REACTION ENGINEERING LAB

Subject Code	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	
2014506	L	T	P/S	Internal (PA)	:	15	02
	—	—	04	External (ESE)	:	35	

COURSE CONTENT

1. Batch reactor
2. Plug flow reactor
3. Mixed flow reactor
4. Adiabatic reactor
5. Combined reactor: Mixed flow -plug flow
6. Combined reactor: Plug flow -mixed flow
7. RTD studies 8. Photochemical reactor

REFERENCE BOOKS

1. Lab manual

Petrochemical Technology Lab

Subject Code	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	
2014507	L	T	P/S	ESE	:	50	02
	—	—	04	Internal	:	15	
	—	—	—	External	:	35	

Skills to be developed:

Intellectual Skills:

1) Interpret test results
2) Follow systemic procedure for handling chemicals

Motor Skills:

1) To handle equipments/instruments
2) To observe physical phenomenon

List of Practical's:-

1. Determination of Aniline Point.
2. Determination of Fire Point, Flash Point.
3. Determination of calorific value.
4. Determination of viscosity index.
5. Preparation of Ethyl Acetate by Esterification.
6. Preparation of PF Resin.
7. Preparation of Biodiesel by Trans esterification.
8. ASTM, TVP Distillation.
9. Determination of Drop Point.
10. Determination of Pour Point.

MASS TRANSFER LAB

Subject Code	Practical						Credits
	No. of Periods Per Week			Full Marks	:	50	
2014508 A	L	T	P/S	Internal (PA)	:	20	02
	—	—	04	External (ESE)	:	30	

COURSE CONTENT:

1.	Diffusion
2.	Wetted wall column
3.	Simple Distillation
4.	Steam Distillation
5.	Surface evaporation
6.	Liquid-Liquid Extraction
7.	Leaching
8.	Adsorption
9.	Air drying
10.	Packed Column Distillation

REFERENCE BOOKS:

1. Lab manual

2. G Chandrasekhar, Laboratory Experiments in Chemical and Allied Engineering: Emphasis on Low Cost Experiments, Penram International Publishing (India) Pvt. Ltd..

Major Project

Subject Code	Term Work						Credits
	No. of Periods Per Week			Full Marks	:	50	
2014510	L	T	P/S	Internal (PA)	:	15	03
	—	—	06	External (ESE)	:	35	

Notes: 1) Project group size: Maximum 4 students
2) Project report will be of minimum 40 pages unless otherwise specified.
3) Project diary should be maintained by each student

Project

1.	Fabrication of small machine / devices/ test rigs/ material handling devices/ jig & fixtures/ demonstration models, etc. Report involving aspects of drawing, process sheets, costing, Installation, commissioning & testing should be prepared and submitted.
2.	Design & fabrication of mechanisms, machines, Devices, etc. Report involving aspects of designing & fabricating should be prepared & submitted.
3.	Development of computer program for designing and /or drawing of machine components, Simulation of movement & operation, 3D modeling, pick & place robots etc.
4.	Industry sponsored projects- project related with solving the problems identified by industry should be selected. One person / engineer from industry is expected to work as co- guide along with guide from institution.
5.	. Literature survey based projects: Project related with collection tabulation, classification, analysis & presentation of the information. Topic selected must be related with latest technological developments in mechanical or mechatronix field, and should not be a part of diploma curriculum. Report should be of min 60 pages.
6.	Investigative projects- Project related with investigations of causes for change in performance or structure of machine or component under different constraints through experimentation and data analysis.
7.	Maintenance based projects: The institute may have some machine/ equipment/ system which are lying idle due to lack of maintenance. Students may select the

	specific machines/equipment/system. Overhaul it, repair it and bring it to working condition. The systematic procedure for maintenance to be followed and the report of the activity be submitted
8.	Industrial engineering based project: Project based on work study , method study, methods improvement, leading to productivity improvement, data collection, data analysis and data interpretation be undertaken .
9.	Low cost automation projects: Project based on hydraulic/pneumatic circuits resulting into low cost automated equipment useful in the identified areas.
10.	. Innovative/ Creative projects – Projects related with design, develop & implementation of new concept for some identified useful activity using PLC, robotics, non-conventional energy sources, CIM , mechatronics, etc.
11.	Environmental management systems projects: Projects related with pollution control, Solid waste management, liquid waste management, Industrial hygiene, etc, Working model or case study should be undertaken
12.	Market research/ survey based projects: Projected related with identification of extent of demand, sales forecasting, Comparative study of marketing strategies, Comparative study of channels of distribution, Impact of variables on sales volume, etc. The project involves extensive survey & market research activities information to be collected through various mechanisms/tools & report be prepared.
13.	Project based on use of appropriate technology particularly benefiting rural society or economically weaker section.
14.	Project can be selected other than the area specified above. Project should provide viable and feasible solution to the problem identified. Report should be of min 50 pages.

Text/ Reference Books:		
Titles of the Book	**Name of Authors**	**Name of the Publisher**
Project management & team work	Karl Smith	Tata- Mc Graw Hill
Project management	Cliffored gray & Erik Lasson	Tata- Mc Graw Hill
Engineering Project management	Nigel J Smith	
Plant Engineers	Dennis Snow	

Magazines:

1. Invention intelligence magazine
2. Popular mechanics Journals/ Magazines

TERM WORK

COURSE UNDER COE / MOOCS / NPTEL / OTHERS

Subject Code	Term Work						Credits
	No. of Periods Per Week			Full Marks	:	50	
2000511 / 2014511	L	T	P/S	Internal (PA)	:	20	01
	—	—	02	External (ESE)	:	30	