STATE BOARD OF TECHNICAL EDUCATION BIHAR

Scheme of Teaching and Examinations for

VIth SEMESTER DIPLOMA IN MECHANICAL ENGINEERING

(Effective from Session 2020-21 Batch)

THEORY

Sr. No.	SUBJECT	SUBJECT C ODE	TEACHING SCHEME	EXAMINATION- SCHEME						
			Periods per Week	Hours of Exam.	Teacher's Assessment (TA) Marks A	Class Test (CT) Marks B	End Semester Exam (ESE) Marks C	Total Marks (A+B+C)	Pass Marks ESE	Pass Marks in the Subject	Credits
1.	Entrepreneurship and Start-ups	2000601	03	03	10	20	70	100	28	40	03
2.	Design of Machine Elements	2025602	04	03	10	20	70	100	28	40	04
3.	Advanced Manufacturing Processes	2025603	04	03	10	20	70	100	28	40	04
4.	Open Elective-I		03	03	10	20	70	100	28	40	03
Energy Conservation & Audit (2025604A)			Disaster Management (2015604B)								
5.	Open Elective-II / COE		03	03	10	20	70	100	28	40	02
Indian Constitution (2000605A)			Operations Research (2025605B)				Project Management (2015605B)				
Artificial Intelligence **(Advance)** (2000605B)		Internet of Things **(Advance)** (2000605C)		Drone Technology **(Advance)** (2000605D)			3D Printing & Design **(Advance)** (2000605E)				
Industrial Automation **(Advance)** (2000605F)		Electric Vehicles **(Advance)** (2000605G)					Robotics **(Advance)** (2000605H)				
Total :-		**17**					**350**	**500**			**16**

PRACTICAL

Sr. No.	SUBJECT	SUB.JECT CODE	TEACHING SCHEME	EXAMINATION-SCHEME					
			Periods per Week	Hours of Exam.	Practical (ESE) Internal (PA)	Practical (ESE) External (ESE)	Total Marks	Pass Marks In the Subject	Credits
6.	Elective Lab / COE Lab		04 50% Physical 50% Virtual	03	20	30	50	20	02
	Advanced Manufacturing Processes Lab (2025608A)		Artificial Intelligence **(Advance)** Lab (2000608B)			Internet of Things **(Advance)** Lab (2000608C)			
	Drone Technology **(Advance)** Lab (2000608D)		3D Printing & Design **(Advance)** Lab (2000608E)			Industrial Automation **(Advance)** Lab (2000608F)			
	Electric Vehicles **(Advance)** Lab (2000608G)					Robotics **(Advance)** Lab (2000608H)			
	Total :-	**04**					**50**		**02**

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 in the Subject	Credits
7.	Seminar	2025609	4	15	35	50	20	2
8.	Major Project	2025610	6	30	70	100	40	3
9.	Term Work		2	20	30	50	20	1
	Course Under Moocs /NPTEL/ Others TW (2025611)	Artificial Intelligence (Advance) TW (2000611B)		Internet of Things TW (Advance) (2000611C)		Drone Technology TW (Advance) (2000611D)		
	3D Printing & Design (Advance) TW (2000611E)	Industrial Automation (Advance) TW (2000611F)		Electric Vehicles (Advance) TW (2000611G)		Robotics (Advance) TW (2000611H)		
	Total :-	**12**				200		**06**
Total Periods per week Each of duration One Hour = 33					Total Marks = **750**			**24**

ENTREPRENEURSHIP AND START –UPS

Subject Code 2000601	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

Course Objectives:

The main aims of the course are to familiarize students with various concepts used in understanding processes involved in entrepreneurship and business formation and development.

- To acquire Entrepreneurial spirit and resourcefulness.
- To familiarize with various uses of human resource for earning dignified means of living.
- To understand the concept and process of entrepreneurship - its contribution and role in the growth and development of individual and the nation.
- To acquire entrepreneurial quality, competency, and motivation.
- To learn the process and skills of creation and management of entrepreneurial venture.

CONTENTS: THEORY

Unit	Name of Topics	Hrs.
Unit-I	Introduction to Entrepreneurship and Start – Ups • Definitions, Traits of an entrepreneur, Entrepreneurship, Motivation • Types of Business Structures, Similarities and differences between entrepreneurs and managers.	**06**
Unit-II	Business Ideas and their implementation • Discovering ideas and visualizing the business • Activity map • Business Plan	**06**
Unit-III	Idea to Start-up • Market Analysis – Identifying the target market, • Competition evaluation and Strategy Development, • Marketing and accounting, • Risk analysis	**10**
Unit-IV	Management • Company's Organization Structure, • Recruitment and management of talent. • Financial organization and management	**08**
Unit-V	Financing and Protection of Ideas • Financing methods available for start-ups in India • Communication of Ideas to potential investors – Investor Pitch • Patenting and Licenses	**08**
Unit-VI	Exit strategies for entrepreneurs, bankruptcy, and succession and harvesting strategy.	**04**
	Total	**42 hrs.**

References:

1. The Startup Owner's Manual: The Step-by-Step Guide for Building a Great Company, Steve Blank and Bob Dorf, K & S Ranch ISBN – 978- 0984999392
2. The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses, Eric Ries, Penguin UK ISBN – 978-0670921607
3. Demand: Creating What People Love Before They Know They Want It Adrian J. Slywotsky with Karl Weber, Headline Book Publishing ISBN – 978- 0755388974
4. The Innovator's Dilemma: The Revolutionary Book That Will Change the Way You Do Business, Clayton M. Christensen, Harvard business ISBN: 978-142219602
5. Entrepreneurship and Start-ups, Ekta Sharma, FPH

SUGGESTED SOFTWARE/LEARNING WEBSITES:

a. https://www.fundable.com/learn/resources/guides/startup
b. https://corporatefinanceinstitute.com/resources/knowledge/finance/corporatestructure/
c. https://www.finder.com/small-business-finance-tips
d. https://www.profitbooks.net/funding-options-to-raise-startup-capital-for-your-business/

Course outcomes:

Upon completion of the course, the student will be able to :

CO : 1 Understand the dynamic role of entrepreneurship and small businesses

CO :2 Organize and Manage a Small Business

CO : 3 Plan the Financial strategy and Control

CO : 4 Operate forms of Ownership for Small Business

CO : 5 Make Strategic Marketing Planning

CO : 6 Launch new Product or Service Development

CO : 7 Conceive business Plan

*****

DESIGN OF MACHINE ELEMENTS

Subject Code 2025602	Theory			No of Period in one session: 56			Credits
	No. of Periods Per Week			Full Marks	:	100	04
	L	T	P/S	ESE	:	70	
	04	—	—	TA	:	10	
				CT	:	20	

Course objectives:

- To enable the student to design and draw simple machine components used in small and medium scale industries.
- To understand the basic philosophy and fundamentals of Machine Design.
- To understand the modes of failures of m/c components and decide the design criteria and equations.
- To analyze and evaluate the loads, forces, stresses involved in components and subassemblies and decide the dimensions.
- To develop analytical abilities to give solutions to engineering design problems.

CONTENTS: THEORY

Unit	Name of Topics	Hrs
Unit-I	1.1 Introduction to Design: Machine Design philosophy and Procedures; General Considerations in Machine Design; 1.2 Fundamentals: Types of loads, concepts of stress, Strain, Stress – Strain Diagram for Ductile and Brittle Materials 1.3 Types of Stresses; Bearing pressure Intensity; Crushing; Bending and Torsion; Principal Stresses; Simple Numerical; Creep strain and Creep Curve; Fatigue; S-N curve; Endurance Limit; Factor of Safety and Factors governing selection of factor of Safety; Stress Concentration: Causes & Remedies; Converting actual load or torque into design load or torque using design factors Like velocity factor, factor of safety & service factor; 1.4 Properties of Engineering materials; Designation of materials as per IS and Introduction to International standards & Advantages of standardization; Use of design data book; Use of standards in design and preferred numbers series; 1.5 Theories of Elastic Failures; Principal normal stress theory; Maximum shear stress theory & Maximum distortion energy theory.	**10**
Unit-II	2.1 Design of simple machine parts: Cotter Joint; Knuckle Joint; Turnbuckle; Design of Levers: Hand/Foot Lever & Bell Crank Lever; Design of C- Clamp; Off-set links; Overhang Crank; Arm of Pulley. 2.2 Antifriction Bearings: Classification of Bearings; Sliding contact & Rolling contact; Terminology of Ball bearings: Life Load relationship, Basic static load rating and Basic dynamic load rating, limiting speed; Selection of ball bearings using manufacturer's catalogue.	**10**
Unit-III	3.1 Design of Shafts, Keys, Couplings and Spur Gears: Types of Shafts; Shaft materials; Standard Sizes; Design of Shafts (Hollow and Solid) using strength and rigidity criteria; ASME code of design for line shafts supported between bearings with one or two pulleys in between or one over- hung pulley; Design of Sunk Keys; Effect of Keyways on strength of shaft;	**12**

	3.2 Design of Couplings – Muff Coupling, Protected type Flange Coupling, Bush-pin type flexible coupling; 3.3 Spur gear design considerations; Lewis equation for static beam strength of spur gear teeth; Power transmission capacity of spur gears in bending.	
Unit-IV	4.1 Design of Power Screws: Thread Profiles used for power Screws - Relative merits and de- merits of each; Torque required to overcome thread friction; Self- Locking and overhauling property; Efficiency of power screws; Types of stresses induced; Design of Screw Jack; Toggle Jack. 4.2 Design of springs: Classification and Applications of Springs; Spring terminology; Materials and Specifications; Stresses in springs; Wahl's correction factor; Deflection of springs; Energy stored in springs; Design of Helical, Tension and Compression springs subjected to uniform applied loads like I.C. engine valves, Weighing balance, Railway buffers and Governor Springs: 4.3 Leaf springs: Construction and Application.	**12**
Unit-V	5.1 Design of Fasteners: Stresses in Screwed fasteners; Bolts of Uniform Strength; Design of Bolted Joints subjected to eccentric loading; Design of Parallel and Transverse fillet welds; Axially loaded symmetrical section; Merits and demerits of screwed and welded joints. 5.2 Ergonomics & Aesthetic consideration in design: Ergonomics of Design: Man– Machine relation-ship; Design of Equipment for control, environment & safety; Aesthetic considerations regarding shape, size, color & surface finish.	**12**

References:

1. Machine Design – Sadhu Singh, Khanna Book Publishing Co., Delhi (ISBN:978-9382609-575)
2. Machine Design Data Book – Sadhu Singh, Revised Edition, Khanna Book Publishing Co., Delhi (ISBN: 978-9382609-513)
3. Introduction to Machine Design – V.B.Bhandari, Tata Mc- Graw Hill, New Delhi.
4. Mechanical Engineering Design – Joseph Edward Shigley, Tata Mc- Graw Hill, New Delhi.
5. Machine design – Pandya & Shah, Dhanpat Rai & Son, New Delhi.
6. Machine design – R.K.Jain, Khanna Publication, New Delhi.
7. Design Data Book – PSG Coimbtore, PSG Coimbtore.
8. Hand Book of Properties of Engineering Materials & Design Data for Machine Elements – Abdulla Shariff, Dhanpat Rai & Sons, New Delhi.

Course outcomes:

At the end of the course, the student will be able to:

CO1 Analyze the various modes of failure of machine components under different load patterns. CO2 Design and prepare part and assembly drawings.
CO3 Use design data books and different codes of design.
CO4 Select standard components with their specifications from manufacturer's catalogue.
CO5 Develop drawings on CAD software.

ADVANCED MANUFACTURING PROCESSES

Subject Code 2025603	Theory			No of Period in one session: 56			Credits
	No. of Periods Per Week			Full Marks	:	100	04
	L	T	P/S	ESE	:	70	
	04	—	—	TA	:	10	
				CT	:	20	

Course objectives:

- To know the functions of Jigs and Fixtures.
- To know the applications of jig-boring machines.
- To identify different fabrication methods of plastic processing viz., sheet forming, blow moulding, laminating and reinforcing of plastics.
- To distinguish between non-conventional machining and traditional machining processes.
- To know about the advancements in the area of manufacturing and production processes.
- To impart knowledge & skills necessary for working in modern manufacturing environment.
- To get familiarized with working principles and operations performed on non-traditional machines, machining center, SPM, automated machines and maintenance of machine tools.

CONTENTS: THEORY

Unit	Name of Topics	Hrs.
Unit-I	Jigs & Fixtures: 1.1 Definition of jig; Types of jigs: Leaf jig, Box and Handle jig, Template jig, Plate jig, Indexing jig, Universal jig, Vice jigs - constructional details of the above jigs; General consideration in the design of drill jigs; Drill bush; 1.2 Types of fixtures: Vice fixtures, Milling fixtures, Boring fixtures, Grinding fixtures Constructional details of the above fixtures; Basic principles of location; Locating methods and devices; 1.3 Basic principles of the clamping; Types of clamps: Strap clamps, Cam clamps, Screw clamps, Toggle clamps, Hydraulic and Pneumatic clamps.	**10**
Unit-II	Jig Boring: Introduction; 2.1 Jig boring on vertical milling machine; Types jig boring machines: Open front machine, Cross rail type machine - constructional details & their working; System of lo- cation of holes. Plastic Processing: 2.2 Moulding processes: Injection moulding, Compression moulding, Transfer moulding; Extruding; Casting; Calendering; Fabrication methods-Sheet forming, Blow moulding, Laminating plastics (sheets, rods & tubes), Reinforcing; Applications of Plastics.	**12**
Unit-III	Modern Machining Processes: 3.1 Introduction – comparison with traditional machining; Ul- transonic Machining: principle, Description of equipment, applications; Electric Discharge Machining: Principle, Description of equipment, Dielectric fluid, tools (electrodes), Process parameters, Output characteristics, applications; Wire cut EDM: Principle, Description of equipment, Controlling parameters; applications; Abrasive Jet Machining: principle, description of equipment, application; Laser Beam Machining: principle, description of equipment, application; Electro Chemical Machining: de- scription of equipment, application..	**12**

Unit-IV	CNC Milling Machines: 4.1 Vertical and horizontal machining center: Constructional features, Axis identification, Electronic control system. Automatic tool changer and tool magazine. 4.2 CNC programming: Preparatory functions (G code), miscellaneous functions (M code), Part programming including subroutines and canned cycles. Principles of computer aided part programming. 4.3 Machine Tool Automation: Introduction and Need; (A) Single spindle automates, transfer lines. (B) Elements of control system, Limit switches, Proximity switches, Block diagram for feedback and servo control system, Introduction to PLC, Block diagram of PLC.	**14**
Unit- V	Special Purpose Machines (SPM): 5.1 Concept, General elements of SPM, Productivity improvement by SPM, Principles of SPM design. 5.2 Maintenance of Machine Tools: Types of maintenance, Repair cycle analysis, Repair complexity, Maintenance manual, Maintenance records, Housekeeping. Introduction to Total Productive Maintenance (TPM).	**08**

References:

1. Production Technology – HMT, Bangalore, Tata Mc-Graw Hill
2. CNC machines – Pabla B. S. & M. Adithan, New Age international limited.
3. Non-conventional Machining – P. K. Mistra, Narvasa Publishing House
4. Manufacturing Processes – Begman & Amsted, John Willey and Sons.
5. Advanced manufacturing technology – David L. Goetsch
6. Exploring Advanced Manufacturing Technologies – Stephen F. Krar& Arthur Gil, Industrial Press

Course outcomes:

At the end of the course, the student will be able to:

CO1 Know the Operation and control of different advanced machine tools and equipment's. CO2 Produce jobs as per specified requirements by selecting the specific machining process. CO3 Develop the mind set for modern trends in manufacturing and automation.

CO4 Identify the different fabrication methods viz., sheet forming, blow moulding, laminating and reinforcing of plastics.

CO5 Know different non-traditional machining processes, CNC milling machines, special purpose machines.

CO6 Work as maintenance engineer

Open Elective I

ENERGY CONSERVATION & AUDIT

Subject Code 2025604A	Theory			No of Period in one session: 56			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

Course Learning Objectives:

- To Identify demand supply gaps in present scenario.
- To understand conservations approaches to an industry.
- To draw the energy flow diagram of an industry.
- To identify energy wastage and suggest alternative methods.
- To understand the concepts energy audit.

CONTENTS: THEORY

Unit	Name of Topics	Hrs
Unit-I	**1.1 Introduction:** General problem, Sector wise consumption, demand sap, Scope for conservation and its benefit **1.2 Energy Efficiency Principle** – Maximum energy efficiency, Maximum cost effectiveness; Mandatory provisions of EC act; Features of EC act-Standards And labeling, designated consumers, Energy Conservation Building Codes (ECBC);	**10**
Unit-II	**2.1 Energy Conservation Approaches In Industries**: Methods and techniques of energy conservation in ventilation and airconditioners. **2.2** Compressors pumps, fans and blowers - Area Sealing, Insulating the Heating/ cooling fluid pipes, automatic door closing- Air curtain, Thermostat /Control; Energy conservation in electric furnaces, ovens and boilers.	**08**
Unit-III	**3.1 Energy Conservation Option:** New equipment, technology, staffing, training; **3.2** Calculation and costing of energy conservation project; Depreciation cost, sinking fund method. Cost evaluation by Return On Investment(ROI) and pay back method etc.	**08**
Unit-IV	**4.1 Performance improvement of existing power plant:** cogeneration, small hydro, DGSet; Demand side management; Load response programmes; **4.2** Types of tariff and restructuring of electric tariff Technical measures to optimize T and D losses.	**08**
Unit-V	**5.1 Energy Audit:** Energy audit and its benefits; Energy flow diagram; Preliminary, Detailed energy audit; Methodology of preliminary energy audit and Detailed energy audit– Phase I, Pre-audit, Phase II- Audit and Phase III- Post audit; Energy audit report; Electrical Measuring Instruments Power Analyzer.	**08**

Reference Books:

1. Electric Energy Generation, Utilisation and Conservation Sivaganaraju, S Pearson, New Delhi, 2012
2. Project Management, Prasanna Chandra, Tata Mcgraw Hill, New Delhi
3. O.P. Jakhar, Energy Conservations in Buildings, Khanna Publishing House, New Delhi
4. Financial Management, Prasanna Chandra Tata Mcgraw Hill, New Delhi.
5. Energy management Handbook, Prasanna Chandra, Tata Mcgraw Hill, New Delhi.
6. O.P. Gupta, Energy Technology, Khanna Publishing House, New Delhi (ed. 2018)

Course outcomes:

At the end of the course, the student will be able to:
CO1 Identify demand supply gaps in the present scenario.
CO2 Understand the conservation approaches for an industry.
CO3 Draw the energy flow diagram of and industry and identify waste stream.
CO4 Identify energy wastage and suggest alternative methods.
CO5 Evaluate the concepts of energy audit.

****

Disaster Management

Subject Code 2015604B	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
				CT	:	20	

Course Objectives:

Following are the objectives of this course:

- To learn about various types of natural and man-made disasters.
- To know pre and post disaster management for some of the disasters.
- To know about various information and organizations in disaster management in India.
- To get exposed to technological tools and their role in disaster management.

CONTENTS: THEORY

Unit	Name of Topics	Hrs
Unit-I	**Understanding Disaster:** • Understanding the Concepts and definitions of Disaster, Hazard, Vulnerability, Risk, Capacity– Disaster and Development, and disaster management.	**06**
Unit-II	**Types, Trends, Causes, Consequences and Control of Disasters:** • Geological Disasters (earthquakes, landslides, tsunami); Hydro- Meteorological Disasters (floods, cyclones, lightning, thunder-storms, hail storms, avalanches, droughts, cold and heat waves) Biological Disasters (epidemics, pest attacks, forest fire); • Technological Disasters (chemical, industrial, radiological, nuclear) and Manmade Disasters (building collapse, rural and urban fire, road and rail accidents, nuclear, radiological, chemicals and biological disasters) Global Disaster Trends – Emerging Risks of Disasters– Climate Change and Urban Disasters.	**10**
Unit-III	**Disaster Management Cycle and Framework:** • Disaster Management Cycle – Paradigm Shift in Disaster Management. Pre-Disaster – Risk Assessment and Analysis, Risk Mapping, zonation and awareness. • During Disaster – Evacuation – Disaster Communication – Search and Rescue – Emergency Operation Centre – Incident Command System – Relief and Rehabilitation • Post-disaster – Damage and Needs Assessment, Restoration of Critical Infrastructure– Early Recovery – Reconstruction and Redevelopment.	**10**
Unit-IV	**Disaster Management in India:** • Disaster Profile of India – Mega Disasters of India and Lessons Learnt. Disaster Management Act 2005. • National Policy on Disaster Management, National Guidelines and Plans on Disaster Management. • Role of Government (local, state and national), Non-Government and Inter Governmental Agencies	**10**
Unit-V	**Applications of Science and Technology for Disaster Management:** • Geo-informatics in Disaster Management (GIS, GPS and RS). Disaster Communication System (Early Warning and Its Dissemination). • S&T Institutions for Disaster Management in India.	**06**
	Total	**42 hrs.**

References:

1. Publications of National Disaster Management Authority (NDMA) on Various Templates and Guidelines for Disaster Management
2. Bhandani, R.K., An overview on natural & manmade disasters and their reduction, CSIR, NewDelhi
3. Srivastava, H.N.,and Gupta G.D., Management of Natural Disasters in developing countries, Daya Publishers, Delhi
4. Alexander ,David ,Natural Disasters ,Kluwer Academic London
5. Ghosh ,G.K., Disaster Management ,APH Publishing Corporation
6. Murthy,D.B.N.,Disaster Management :Text & Case Studies , Deep & Deep Pvt. Ltd.

Course outcomes:

After completing this course, student will be able to:

CO : 1 Acquaint with basic information on various types of disasters

CO : 2 Know the precautions and awareness regarding various disasters

CO : 3 Decide first action to be taken under various disasters

CO : 4 Familiarize with organization in India which are dealing with disasters

CO : 5 Select IT tools to help in disaster management

******

Open Elective-II / COE

INDIAN CONSTITUTION

Subject Code	Theory			No of Period in one session: 42			Credits
2000605A	No. of Periods Per Week			Full Marks	:	100	02
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
	—	—	—	CT	:	20	

Course Learning Objectives:

Following are the objectives of this course:

- To Enable the student to understand the importance of constitution
- To understand the structure of executive, legislature and judiciary
- To understand philosophy of fundamental rights and duties
- To understand the autonomous nature of constitutional bodies like Supreme Court and high court, controller and auditor general of India and election commission of India.
- To understand the central and state relation, financial and administrative

CONTENTS: THEORY

Unit	Name of Topics	Hrs
Unit-I	**The Constitution - Introduction** • The History of the Making of the Indian Constitution • Preamble and the Basic Structure, and its interpretation • Fundamental Rights and Duties and their interpretation • State Policy Principles	**08**
Unit-II	**Union Government** • Structure of the Indian Union • President – Role and Power • Prime Minister and Council of Ministers • Lok Sabha and Rajya Sabha	**10**
Unit-III	**State Government** • Governor – Role and Power • Chief Minister and Council of Ministers • State Secretariat	**08**
Unit-IV	**Local Administration** • District Administration • Municipal Corporation • Zila Panchayat	**08**
Unit-V	**Election Commission** • Role and Functioning • Chief Election Commissioner • State Election Commission	**08**
	Total	**42 hrs**

References:

1. Ethics and Politics of the Indian Constitution Rajeev Bhargava Oxford University Press, New Delhi, 2008
2. The Constitution of India B.L. Fadia Sahitya Bhawan; New edition (2017)
3. Introduction to the Constitution of India DD Basu Lexis Nexis; Twenty-Third 2018 edition

Suggested Software/Learning Websites:

a. https://www.constitution.org/cons/india/const.html
b. http://www.legislative.gov.in/constitution-of-india
c. https://www.sci.gov.in/constitution
d. https://www.toppr.com/guides/civics/the-indian-constitution/the-constitution-of-india/

Course Outcomes:

After completing this course, student will be able to:

CO 1 : To Enable the student to understand the importance of constitution

CO 2 : To understand the structure of executive, legislature and judiciary

CO 3 : To understand philosophy of fundamental rights and duties

CO 4 : To understand the autonomous nature of constitutional bodies like Supreme Court and high court, controller and auditor general of India and election commission of India.

CO 5 : To understand the central and state relation, financial and administrative

****

OPERATIONS RESEARCH

Subject Code 2025605B	Theory			No of Period in one session: 42			Credits
	No. of Periods Per Week			Full Marks	:	100	02
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
	—	—	—	CT	:	20	

Course objectives:

- To understand and analyze managerial problems in industry so that they are able to use resources (capitals, materials, staffing, and machines) more effectively.
- To acquire knowledge of formulating mathematical models for quantitative analysis of managerial problems in industry.

CONTENTS: THEORY

Unit	Name of Topics
Unit-I	**1.1 Development:** Definition, Characteristics and phase of Scientific Method, Types of models; **1.2** General methods for solving operations research models.
Unit-II	**2.1 Allocation:** Introduction to linear programming formulation, graphical solution. **2.2** Simplex Method, artificial variable technique, Duality principle. Sensitivity analysis.
Unit-III	**3.1 Transportation Problem:** Formulation; Optimal solution; Unbalanced Transportation problems; Degeneracy; **3.2** Assignment problem: Formulation; Optimal solution.
Unit-IV	**4.1 Sequencing:** Introduction; Terminology; Notations and Assumptions; Problems with n- jobs and two machines; Optimal sequence algorithm; Problems with n- jobs and three machines.
Unit-V	**5.1 Theory of games:** Introduction; Two- person zero-sum games; The Maximum– Minimax principle; Games without saddle points; Mixed Strategies; 2 x n and m x 2 Games; **5.2** Graphical solutions; Dominance property; Use of L.P. to games

Reference Books:

1. Operations Research: Principles and Applications - G.Srinivasan, PHI Learning Private Limited.
2. Operations Research: An Introduction - HamdyA. Taha, Pearson.
3. Operations Research: Principles and Practice - Ravindran, Phillips and Solberg, Wiley India
4. Operations Research: Concepts and Cases - Hillier and Liberman, McGraw-Hill

Course outcomes: At the end of the course, the student will be able to:

CO1 Recognize the importance and value of Operations Research and mathematical modeling in solving practical problems in industry.

CO2 Formulate a managerial decision problem into a mathematical model.

CO3 Understand Operations Research models and apply them to real-life problems.

CO4 Understand and implement the Transportation Models and Assignment Models at work- place.

CO5 Understand the characteristics of different types of decisions.

****

PROJECT MANAGEMENT

Subject Code	Theory			No of Period in one session: 42			Credits
2015605B	No. of Periods Per Week			Full Marks	:	100	02
	L	T	P/S	ESE	:	70	
	03	—	—	TA	:	10	
	—	—	—	CT	:	20	

Course Objectives:

Following are the objectives of this course:

- To develop an understanding of key project management skills and strategies.
- To make them understand the concepts of Project Management for planning and execution of projects.
- To make them understand the feasibility analysis in Project Management and network analysis tools for cost and time estimation.
- To enable them to comprehend the fundamentals of Contract Administration, Costing and Budgeting.
- To make them capable to analyze, apply and appreciate contemporary project management tools and methodologies in Indian context.

CONTENTS: THEORY

Unit	Name of Topics	Hrs.
Unit-I	**Concept of a project:** • Classification of projects- importance of project management- The project life cycle, establishing project priorities (scope- cost-time) project priority matrix- work break down structure.	**05**
Unit-II	**Capital budgeting process:** • Planning, Analysis, Selection, Financing Implementation- Review. Generation and screening of project ideas-market and demand analysis, Demand forecasting techniques. Market planning and marketing research process- Technical analysis	**10**
Unit-III	**Financial estimates and projections:** • Cost of projects-means of financing- estimates of sales and production, cost of production-working capital requirement and its financing-profitability projected cash flow statement and balance sheet. Break even analysis.	**07**
Unit-IV	**Basic techniques in capital budgeting:** • Non discounting and discounting methods- pay- back period- Accounting rate of return-net present value- Benefit cost ratio- internal rate of return. Project risk. Social cost-benefit analysis and economic rate of return. Non-financial justification of projects.	**08**
Unit-V	**Project administration:** • Progress payments, expenditure planning, project scheduling and network planning, use of Critical Path Method (CPM), schedule of payments and physical progress, time-cost trade off. • Concepts and uses of PERT cost as a function of time, Project Evaluation and Review Techniques, cost mechanisms. Determination of least cost duration. Post project evaluation.	**12**
	Total	**42 hrs.**

References:

1. Project planning, analysis, selection, implementation and review – Prasanna Chandra – Tata McGraw Hill
2. Project Management – the Managerial Process – Clifford F. Gray & Erik W. Larson - McGraw Hill
3. Project management - David I Cleland - McGraw Hill International Edition, 1999
4. Project Management – Gopala Krishnan – McMillan India Ltd.
5. Project Management-Harry-Maylor-Pearson Publication

Course outcomes:

At the end of the course, the student will be able to:

CO 1 : Understand the importance of projects and its phases.

CO 2 : Analyze projects from marketing, operational and financial perspectives.

CO 3 : Evaluate projects based on discount and non-discount methods.

CO 4 : Develop network diagrams for planning and execution of a given project

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

B) Course Title : Artificial Intelligence (Advance)

C) Pre- requisite Course(s) : Artificial Intelligence (Basic)

D) Rationale :

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

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

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

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

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

Board of Study	Course Code	Course Title	Scheme of Study (Hours/Week)					
			Classroom Instruction(CI)		Lab Instruction(LI)	Notional Hours (TW+SL)	Total Hours (CI+LI+TW+SL)	Total Credit (C)
			L	T				
	2000605B/2000608B/2000611B	Artificial intelligence (Advance)	03	-	04	02	09	05

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
	2000605B/2000608B/2000611B	Artificial Intelligence (Advance)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the

attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant Cos Number (s)
TSO 1a. Describe the basic terminology of Machinelearning TSO 1b. Explain the concept of dataset and ways to handle them TSO 1c. illustrate the process of dataset division TSO 1d. Explain process involved in machine learning	**Unit – 1: Introduction to machine learning** Concept of Machine Learning, Define Learning, Learn the Network, Evaluate the Network, datasets and ways to handle them, Feature sets, Dataset division: test, train and validation sets, cross validation. Applications of Machine Learning, processes involved in Machine Learning	**CO-1**
TSO 2a. Identify the category or class of aparticular dataset using KNN algorithm TSO 2b. Use Linear regression for predictiveanalysis TSO 2c. Predict the categorical dependent variable using Logistic Regression TSO 2d. Use SVM for classification problems inMachine Learning TSO 2e. determine the performance of the classification models TSO 2f. evaluate the performance of the classification model using ROC-curve TSO 2g Explain characteristics of Unsupervised learning. TSO 2h. Explain different clustering methodsTSO 2i. Implement K-means clustering algorithm to group the unlabeled dataset	**Unit 2: Supervised and unsupervised learning** **Supervised learning:** Introduction to Supervised Learning, K-Nearest Neighbor, Linear Regression, LogisticRegression, Support Vector Machine (SVM), Evaluation Measures: confusion matrix, precision, precision and recall, ROC-Curve (Receiver Operating Characteristic curve) **Unsupervised learning:** Introduction to Unsupervised Learning, Introduction to clustering, Types of Clustering: Hierarchical, Agglomerative Clustering and Divisive clustering; PartitionalClustering - K-means clustering. Expectation-Maximization (EM) Algorithm	**CO-2**
TSO 3a. Explain Structure and working of BiologicalNeural Network. TSO 3b. differentiate between Artificial Neural Network and Biological Neural Network TSO 3c. State key historical points in development ofANN TSO 3d. Explain the architecture of an artificialneural network	**Unit 3: Introduction to neural networks** Structure and working of Biological Neural Network, Fundamentals of Artificial Neural Networks & Applications, Characteristics ofArtificial Neural Networks, History of neuralnetwork research, characteristics of neural networks terminology.	**CO-3**
TSO 4a. Use neuron McCulloch – Pitts model indesigning logical operations TSO 4b. Apply Rosenblatt's Perceptron to solve linear classification problems	**Unit 4: Neural networks models and LearningMethods** Models of neuron McCulloch – Pitts model,	**CO-4**

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

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

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

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

Practical/Lab SessionOutcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 3.1 Perform clustering operations using k-means algorithm	3	a) Explore k-means algorithm for the small sample dataset. b) Explore k-means algorithm for Iris Dataset	**CO-2**
LSO 4.1 Perform clustering operations using EM algorithm	4	Apply EM algorithm to cluster a set of data stored in a .CSV file. Use the same data set for clustering using k-Means algorithm. Compare the results of these two algorithms and comment on the quality of clustering. You can add Python ML library classes/API in the program.	**CO-2**
LSO 5.1 Build artificial neural networkLSO 5.2 Test artificial neural network	5	Build an Artificial Neural Network by implementing theBackpropagation algorithm and test the same using appropriate data sets.	**CO-4**
LSO 6.1 Detect features or business intelligence in the input data using perceptron	6	Implement the perceptron algorithm from scratch in python.	**CO-4**
LSO 7.1 Use Tensors for given problems	7	Write a programme to implement two dimension and three-dimension Tensor.	**CO5**
LSO 8.1 Use basic features for tensor handling and manipulations	8	Write a programme to add and multiply two 4x4 matrix, you can Import “tens or flow” and “numpy”.	**CO5**
LSO 9.1 Test artificial intelligence (AI) algorithms through the use ofGoogle's TensorFlow machinelearning libraries.	9	Solve a classification problem on the Tens or flow playground. Hint: refer https://www.educba.com/tensorflow-playground/	**CO5**
LSO 10.1 Implement artificial intelligence(AI) algorithms through the useof Google's TensorFlow machine learning libraries LSO 10.2 perform predictive analysis using linear regression	10	Implement algorithm for linear regression in tens or flow	**CO5, CO2**

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

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

b. Micro Projects:

Use python programming for the solutions of Microproject problems

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

2. (a) Write a Python program to split the iris dataset into its attributes (X) and labels (y). The X variable contains the first four columns (i.e. attributes) and y contains the labels of the dataset.
   (b) Write a Python program using Scikit-learn to split the iris dataset into 70% train data and 30% test data. Out of total 150 records, the training set will contain 120 records and the test set contains 30 of those records. Print both datasets.

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

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

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

Legend:

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

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

: Mentioned under point- (O)

Note:

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

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

Unit Title and Number	Total Classroom Instruction(CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember(R)	**Understanding(U)**	**Application& above (A)**
Unit-1.0. Introduction to machine learning	7	**CO1**	11	5	4	2
Unit-2.0. Supervised and unsupervised learning	10	**CO2**	18	5	6	7
Unit-3.0. Introduction to neural networks	10	**CO3**	17	5	7	5
Unit-4.0.Neural networks models and Learning Methods	8	**CO4**	14	3	3	8
Unit-5.0. Tensor flow	10	**CO5**	10	2	6	2
Total Marks	**45**		**70**	**20**	**26**	**24**

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

O) Suggested Assessment Table for Laboratory (Practical):

SN	Laboratory Practical Titles		Relevant COs Number(s)	PLA/ELA		
				Performance		Viva - Voce (%)
				PRA* (%)	PDA** (%)	
1.	Write a program to implement k-Nearest Neighbor algorithm toclassify the iris data set. Print both correct and wrong predictions. Python ML library classes can be used for this problem.		CO-2	-	80	20
2.	(a) Implement SVM for Iris Dataset- download the dataset from(https://gist.github.com/netj/8836201) (b) Find confusion matrix and evaluation matrix for SVM		CO-2	-	80	20
3.	a) Explore k-means algorithm for the small sample dataset. b) Explore k-means algorithm for Iris Dataset		CO-2	20	70	10
4.	Apply EM algorithm to cluster a set of data stored in a .CSV file.Use the same data set for clustering using k-Means algorithm. Compare the results of these two algorithms and comment on the quality of clustering. You can add Python ML library classes/API in the program.		CO-2	-	80	20
5.	Build an Artificial Neural Network by implementing the Backpropagation algorithm and test the same using appropriatedata sets.		CO-4	10	70	20
6.	Implement the perceptron algorithm from scratch in python.		CO-4	10	70	20
7.	Write a programme to implement two dimension and three-dimension Tensor.		CO-5	-	80	20
8.	Write a programme to add and multiply two 4x4 matrix, you can Import “tens or flow” and “numpy”.		CO-5	-	80	20
9.	Solve a classification problem on the Tens or flow playground.		CO-5	20	70	10
10.	Implement algorithm for linear regression in tens or flow		CO-2, CO-5	10	70	20

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

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

P) Suggested 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.

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

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

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Machine Learning using Python	Manaranjan Pradhan, U Dinesh Kumar	Wiley, ISBN-10: 8126579900 ISBN-13: 978-8126579907
2.	Introduction to Machine Learning	Jeeva Jose	Khanna Book Publishing Co. (P) ltd, 2020.ISBN-10: 9389139066 ISBN-13: 978-9389139068
3.	Machine Learning for Dummies	John Paul Mueller and Luca Massaron, For Dummies,	For Dummies; 2nd edition,ISBN-10: 1119724015 ISBN-13: 978-1119724018
4.	Machine Learning	Rajeev Chopra	Khanna Book Publishing Co., 2021ISBN-10: 9789386173423 ISBN-13: 978-9386173423
6.	Learn TensorFlow 2.0: Implement Machine Learning and Deep LearningModels with Python	Pramod Singh, Avinashmanure	Apress, 978-1484255605 ISBN-10: 1484255607 ISBN-13: 978-1484255605
7	Artificial Intelligence: Concepts, **Techniques and Applications**	Alexis Keller	States Academic Press, **2022 ISBN-** 9781649649245
8	**Artificial Intelligence:** An Introduction	**Jacob** Pearson	Willford Press 2022 ISBN 9781682860911
9	**Fundamentals of** Machine Learning	Mia Williams	Willford Press 2022 ISBN 9781682860920
10	Artificial Intelligence: A Modern Approach	Emilia Stones	Larsen and Keller Education 2022 ISBN 9781641728525

(b) Online Educational Resources:

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

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

(c) Others:

Data Source:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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

******

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

B) Course Title : Internet of Things (Advance)

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

D) Rationale :

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

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

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

After completion of the course, the students will be able

to-CO-1 Use basic Python features in Programming.

CO-2 Use advance Python features in Programming.

CO-3 Explain features of Cloud and IoT data storage on it.

CO-4 Explain IoT Networking and its application.

CO-5 Develop IoT App for the given problem

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive LabAssessment (PLA)	End Laboratory Assessment	
	2000605 C/2000608C/2000611C	IoT (Advance)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction

(LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs)

upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.1. a. Write the steps to install Python. TSO.1. b. Explain given types of variables in python. TSO.1.c. Explain use and importance of Tuple, Dictionary, operators in python TSO.1. d. Explain use of array in python. TSO.1. e. Explain use of 2-Dimensional Array in python TSO.1. f Explain uses of given type of Conditionalstatement in python.	**Unit-1.0 Python basics: -** 1.1 Installation of Python 1.2 Variables, Print () function, Escape character sequence and run python Program 1.3 Python Tuple, Dictionary, operators 1.4 Python arrays, create, reverse and append data into it. 1.5 Python 2 Dimensional arrays. 1.6 Python Conditional statement.	**CO-1 and CO-5**
TSO.2. a. Explain uses of given type of do & whileloops in python TSO.2. b. Explain working of break, continue and pass statement in python TSO.2.c. Write the benefits of using OOPmethodology in python. TSO.2.d.Explain given type of string operation relatedto python. TSO.2.e.Explain given function in python TSO.2.f Explain use of Lambda function in python.	**Unit 2. Python Advance: -** 2.1 Python Do & while loops 2.2 Python break, continue, pass statements 2.2 Python OOPs Class, Object, Inheritance and Constructor 2.4 Python Strings Replace, Join, Split, Reverse, Uppercase, Lowercase, count, find, split and length 2.5 Python Functions, Built-in functions and user defined functions 2.6 Lambda function and uses	**CO-1 and C05**
TSO.3.a. Differentiate between Cloud and IoT cloud. TSO.3.b. Explain features of Cloud in IoT environmentTSO.3.c. List features of various types of Cloud TSO.3.d. List features of cloud services like SaaS, PaaS and IaaS TSO.3.f List advantages of cloud data storage. TSO.3.g Explain Arduino architecture and its applications. TSO.3.h Explain Raspberry pi architecture and its applications.	**Unit-3.0 Cloud features: -** 3.1 Cloud computing and IoT cloud 3.2 Benefits of cloud in IoT 3.3 Types of Cloud public, private and hybrid 3.4 Cloud services like SaaS, PaaS and IaaS 3.5 Cloud connectivity and Data storage on Cloud. 3.6 Arduino: Architecture, Programming, and Applications 3.7 Raspberry Pi Architecture, Programming, and Application basic level for IoT applications	**CO-1, CO-2 and CO-5**
TSO.4.a. Explain wired network TSO.4.b.Explain short range wireless networkTSO.4.c.Explain M2M communication TSO.4.d.Explain various generation of wireless network TSO.4.e.Explain the importance of LWPAN in IoT TSO.4.f Differentiate between SigFox & LoRaWANTSO.4.g Explain use of NB-IOT (Narrow Band IOT) TSO.4.h Create heterogenous network using RFID.	**Unit.4 IoT Networking and Application: -** 4.1 Wired and short-range wireless network 4.2 M2M – 2G, 3G, 4G & 5G networks 4.3 LPWAN – Low Power Wide Area Networks 4.4 SigFox & LoRaWAN. 4.5 NB-IOT (Narrow Band IOT) 4.6 RFID and Bar code basics- Components of an RFIDsystem-Data -Tags-Antennas- Connectors-Cables- Readers- encoder/ printers for smart labels- Controllers software 4.7 RFID advantages over Bar codes.	**CO-1 and CO-4**
TSO.5.a. Identify suitable framework for IoT app development	**Unit. 5 IoT App Development**: - 5.1 Framework selection for IoT app development	**CO-4 and**

		CO-5

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

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

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

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

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

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

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

b. Micro Projects:

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

c. Other Activities:

1. Seminar Topics: - “Future of wireless network.”

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

d. Self-learning topics:

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

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

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

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

Note:

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

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

Unit Title and Number	Total Classroom Instruction(CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember(R)	Understanding(U)	Application& above (A)
Unit-1. Python basics	5	CO1	7	2	2	3
Unit-2. Python Advance	5	Co1, CO2	7	2	2	3
Unit-3. Cloud features	14	CO3	21	8	8	5
Unit-4. Networking and Application	14	CO4, C03	21	5	7	9
Unit-5. IoT Applications	10	CO5, CO3 andCO4	14	3	6	5
Total Marks	**48**		**70**	**20**	**25**	**25**

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

O) Suggested Assessment Table for Laboratory (Practical):

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

12.	Write a python program which can print first 10 integers and its square using while/for loop.	CO-2	60	30	10

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

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

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

P) Suggested Instructional/ Implementation Strategies: Different Instructional/ Implementation Strategies 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, Toolsand Software	Broad Specifications	Relevant Experiment/PracticalNumber
1	Python software	Openly available as per instruction	As mentioned above list
2	Cables connecters and crimping tools	Cat 6e cable, RJ-45 connectors and Crimping Tool	
3	Bluetooth and infrared devices	Any mobile and wireless keyboard and mouse	
4	IoT free cloud	Free available	
5	Smart devices	Like meters, bulbs etc.	
6	Wireless access point	Wireless router or access point	
8	Arduino development board	Arduino Uno and Arduino Nano.	
6	Raspberry Pi	Raspberry Pi 4/ Raspberry Pi 3/ Raspberry Pi 2	

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1	Let Us Python	Kanetkar Yashavant	BPB Publications ISBN: 9789388511568, 9789388511568
2	IOT (Internet of things) and Its Application	P K Pandey	T Balaji Publication (1 January 2020) ISBN-10:8194136385 ISBN-13: 978-8194136385
3	Raspberry Pi Cookbook: Software andHardware Problems and Solutions	Simon Monk	Shroff/O'Reilly; Third edition (4 October 2019) ISBN-10: 9352139267 ISBN-13: 978-9352139262
4	Raspberry Pi Cookbook: Software andHardware Problems and Solutions,	Simon Monk	Shroff/O'Reilly; Third edition (4 October 2019) ISBN-10: 9352139267 ISBN-13: 978-9352139262
5	Cloud Computing: Concepts, Technology& Architecture	Erl	Pearson Education India; 1st edition (1 January 2014) ISBN-10: 9332535922 ISBN-13: 978-9332535923
6.	Fundamentals of Internet of Things	Eden Scott	States Academic Press 2023 ISBN 9781649649235

7	Internet of Things	Alaina Wilson	Murphy & Moore Publishing 2023 ISBN 9781649872731
8	Principles of Internet of Things	Hallie Parker	Larsen and Keller Education 2023 ISBN 9781641728312

(b) Online Educational Resources:

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

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

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

Dr. M. A. Rizvi (Coordinator)

******

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

B) Course Title : Drone Technology (Advanced)

C) Pre- requisite Course(s) : Drone Technology (Basics)

D) Rationale :

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

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

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

CO-1 Apply the concept of engineering mechanics for stability of drone.

CO-2 Design the structure of drone using GPS module and thermal Image camera.

CO-3 Operate drone using advance flight controller board.

CO-4 Perform drone maintenance and assembly.

CO-5 Use drone in advance applications like precision agriculture, security, IoT, etc.

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

Board of Study	Course Code	Course Title	Scheme of Study (Hours/Week)					
			Classroom Instruction (CI)		Lab Instruction(LI)	NotionalHours (TW+ SL)	Total Hours (CI+LI+TW+ SL)	Total Credits(C)
			L	T				
	2000605D/2000608D/2000611D	Drone Technology (Advance)	03	-	04	02	09	05

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work & Self-Learning Assessment(TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive LabAssessment (PLA)	End Laboratory Assessment (ELA)	
	2000605D/2000608D/2000611D	Drone Technology (Advance)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

should prepare checklist & rubrics for these activities.

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

J) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)		Units	Relevant COs Number (s)
TSO 1a. TSO 1b. TSO 1c. TSO 1d. TSO 1e. TSO 1f.	Draw free body diagram of quadcopter drone. Determine centroid of given drone structure. Determine center of gravity of different drone structure. Analyze different types of force acting drone system. Differentiate between static and dynamic force analysis. Explain how gyroscopic motion keepsdrone balanced and hovering.	**Unit-1.0 Engineering mechanics for Dronetechnology** 1.1 Drone Mechanics • Free body diagram of drone • Method of finding resultant of force system • Equilibrium of coplanar force system 1.2 Center of Gravity • Centroid of plane figure • Center of gravity of solid bodies 1.3 Force analysis in drone • Force analysis in drone • Forces of flight • Principle axes and rotation of aerial systems 1.4 Dynamics of machine • Static and dynamic force analysis • Gyroscopic motions	**CO-1**
TSO 2a.TSO 2b. TSO 2c. TSO 2d. TSO 2e. TSO 2f.	Describe properties and application of smart materials use in UAV frame. Calculate the diameter of the propeller for given drone frame size. Determine size of quadcopter frame and diameter of propeller of drone Describe working of GPS and its hardwareinterfacing. Write steps to interface GPS module for drone navigation. Describe different RF blocks and antennas used in RF transmitter and receiver.	**Unit-2.0 Drone Frame and components** 2.1 Drone frame design □ Calculation principle for drome frame sizes □ Quadcopter frame design □ Smart materials for UAV frame □ Green material uses in drone 2.2 Advance Drones component • GPS, Interfacing of GPS hardware • Thermal and chemical sensor • Tilt and LiDAR sensor 2.3 RF transmitter and receiver • RF blocks • RF antennas 2.4 Micro-electromechanical systems (MEMS) based sensor 2.5 HD and thermal Image camera	**CO-2**
TSO 3a.	Identify features and specifications of FCBuse in different application	**Unit-3.0 Advance flight controller Board (FCB)**	**CO-3**

Major Theory Session Outcomes (TSOs)		Units	Relevant COs Number (s)
TSO 3b. TSO 3c. TSO 3d. TSO 3e. TSO 3f.	Explain ports of any given advance flightcontroller board. Write steps of software installation of flight controller board. Describe installation and calibration steps of radio telemetry with FCB. Write steps of calibration of accelerometer and ESC with FCB. Describe interfacing of GPS with FCB.	3.1 Specification and ports of FCB 3.2 Software for FCB ▯ Software installation 3.3 Radio Communication with FCB ▯ Installation of Radio Telemetry ▯ Radio Calibration with FCB 3.4 Calibration of accelerometer 3.5 Calibration of ESC 3.6 Interface of motor with FCB using ESC 3.7 GPS interface with FCB 3.8 Safety features of advance FCB	
TSO 4a. TSO 4b. TSO 4c. TSO 4d.	Describe challenges comes in drone maintenance. Describe measuring devices and instrument use in drone maintenance. Describe measuring instrument used to measure electrical parameters in drone. Write sequence of steps use in assembling of drone.	**Unit-4.0 Maintenance and assembling of Drone** 4.1 Need and scope of drone maintenance 4.2 Types of maintenance 4.3 Routine drone maintenance and its checklist • Recording basic details • Structural inspection • Battery check • Software/firmware 4.4 Types of measuring instrument use in drone maintenance 4.5 Measurement of different electrical parameters related with drone hardware 4.6 Assembly of drones • Concept of interchangeability • Principle of gauging and their applicabilityin drone assembly • Parameters and profile measurements of standard propellers • Concepts of drone assembly using 3D modeling	**CO-4**
TSO 5a. TSO 5b. TSO 5c.	Describe function of autonomous drone using AI. Describe IoT enable UAV for surveillanceand data gathering. Explain drone applications based on cost saving, enhanced efficiency and profitability aspects.	**Unit-5.0 Advance Drone Application** 5.1 Application of AI in Drone Technology 5.2 IoT and Computer vision integrated Drone 5.3 Drone interface with smart-phone 5.4 Drone Applications in • Military • Precision Agriculture	**CO-5**

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

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

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

LSO 12.1 Measure voltage, current frequency using Digital Multimeter LSO 12.2 Measure peak to peak voltage, time period, and duty cycle using DSO and waveform generator.	12.	Measure various electric parameters in drone hardware	**CO-4**

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

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

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

b. Micro Projects:

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

c. Other Activities:

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

d. Self-learning topics:

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

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

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

Legend:

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

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

#: Mentioned under point-(O)

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

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

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

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies 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 andSoftware	Broad Specifications	Relevant Experiment/Practical Number
1.	Drone Frame	Tricopter/Quadcopter/Hexacopter	1-15
2.	Propellers	15 X 5.5 CW/Others	1-15
3.	GPS module	M8N Series	1-15
4.	Drone Camera	15-20 Megapixel	1-15
5.	Camera Gimble	3 Axis feature, 360 Degree movement	1-15
6.	Tilt Sensor	8-30 volt	1-15
7.	LiDER sensor	Range 75m to 200m	1-15
8.	Battery	Lithium Polymer Battery,8000 to 10000 mAh	1-15
9.	Motor	BLDC, 370kv	1-15
10.	Electronic speed Controller (ESC)	40 Amp	1-15
11.	Flight Controller Board	CC3D/Pixhawk/Others	1-15
12.	Transmitter and Receiver for radio signal	10 Channels and more, 2.4 GHz & 5.8 GHz	1-15
13.	Embedded system for AI application on UAV	Open Source Jetson Baseboard /Others	1-15

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author (s)	Publisher and Edition with ISBN
1.	Make: DIY Drone and Quadcopter Projects: A Collection of Drone-Based Essays, Tutorials, and Projects	Editors of Make	Shroff/Maker Media, First edition 2016,ISBN-978-9352133994
2.	Make: Getting Started with Drones: Build andCustomize Your Own Quadcopter	Terry Kilby & BelindaKilby	Shroff/Maker Media, First edition 2016,ISBN-978-9352133147
3.	Agricultural Drones: A Peaceful Pursuit	K R Krishna	Apple Academic Press,1st edition 2018,ISBN-978-1771885959
4.	Building Multicopter Video Drones: Build and fly multicopter drones to gather breathtaking videofootage	Ty Audronis	Packt Publishing Limited; Illustratededition,2014, ISBN-978-1782175438
5.	The Complete Guide to Drones	Adam Juniper	Ilex Press, Extended 2nd Edition,2018ISBN-9781781575383
6.	Unmanned Aircraft Systems - UAVS Design, Development and Deployment (Aerospace Series)	R Austin	John Wiley & Sons Inc, 1st edition, 2010,ISBN-978-0470058190
7	Drone Technology	Miranda Hall	NY Research Press 2023 ISBN 9781632389574

8	Introduction to UAV Systems	Rupert Baker	Willford Press 2023 ISBN 9781682860890
9	Theory, Design, and Applications of Unmanned Aerial Vehicles	Tyler Wood	Larsen and Keller Education 2023 ISBN 9781641728338

(b) Online Educational Resources:

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

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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

******

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

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

C) Pre- requisite Course(s) : 3D Printing and Design (Basic)

D) Rationale :

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

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

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

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

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

Board of Study	Course Code	Course Title	Scheme of Study (Hours/Week)					
			Classroom Instruction (CI)		Lab Instruction(LI)	NotionalHours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits(C)
			L	T				
	2000605E /2000608E /2000611E	3D Printing and Design (Advanced)	03	-	04	02	09	05

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work &Self-Learning Assessment (TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive LabAssessment (PLA)	End Laboratory Assessment (ELA)	
	2000605E /2000608E /2000611E	3D Printing and Design (Advanced)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

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

J) Theory Session Outcomes (TSOs) and Units:

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

Major Theory Session Outcomes (TSOs)	Units	Relevan tCOs Number(s)
TSO 4a. Explain powder fusion mechanism. *TSO 4b.* Explain working of a typical SLA based 3D Printer. *TSO 4c.* Justify use of SLA based 3D printing process and material for the given component. *TSO 4d.* Explain Net shape process. *TSO 4e.* Explain Binder Jet 3D printing process. *TSO 4f.* Justify use of Binder Jet 3D printing process and material for the given component. *TSO 4g.* Estimate the cost and time of the given SLS based 3D printed component.	**Unit-4.0 Powder based 3D Printing Processes** 4.1 Powder fusion mechanism. 4.2 Principle and working of Selective LaserSintering (SLS) process. 4.3 SLS based 3D printers. 4.4 Laser Engineering Net Shaping process. 4.5 Electron Beam Melting. 4.6 Binder Jet 3D Printing. 4.7 Materials and Process parameters for SLS based 3D printing processes. 4.8 Cost estimation of SLS based 3D printedcomponent.	**CO1, CO4**
TSO 5a. Justify the need of post processing in the given 3D printed component. *TSO 5b.* List the various post processing techniques. *TSO 5c.* List the steps to perform post processing. *TSO 5d.* Explain the given Cleaning related post processing approach for 3D printed component. *TSO 5e.* Explain the given Surface finishing related post processing approach for 3D printed component. *TSO 5f.* Apply simple inspection and testing techniques on the given 3D printed component. *TSO 5g.* Identify the type of defect(s) in the given 3D printed component.	**Unit-5.0 Post Processing and Quality** 5.1 Need of post processing: Functional and Aesthetic reasons. 5.2 Steps of Post Processing: Cleaning/Support removal, Fixing, Curing or hardening, Surfacefinishing, Colouring. 5.3 Cleaning: Support Removal (FDM and Material Jetting); Powder Removal (SLS and Powder BedFusion); Washing (SLA and Photo polymerisation). 5.4 Fixing: Filling, Gluing, Welding. 5.5 Surface finishing: Sanding, Polishing, Tumbling,Hydro dipping, Epoxy coating, Electro Plating, Vapour smoothing-Acetone treatment. 5.6 Colouring, Coating, Priming and Painting. 5.7 Inspection and testing: Digital, Visual, Physical. 5.8 Defects and their causes.	**CO1, CO2, CO3, CO4, CO5**

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

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

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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
available SLA Printer. *LSO 2.5.* Perform curing of the SLA based 3Dprinted component.			
LSO 3.1. Use the available 3D printing software. *LSO 3.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 3.3.* Set printing process parameters. *LSO 3.4.* Produce a complex component using available SLS Printer.	3.	Develop the assigned digital single complex component using SLS based 3D Printer and available material.	**CO1, CO4**
LSO 4.1. Use the available 3D printing software. *LSO 4.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 4.3.* Set printing process parameters. *LSO 4.4.* Produce a complex component using available FDM, SLA and SLS Printer. *LSO 4.5.* Perform Cost, Time, Surface finish and Strength estimations related to 3D printed components.	4.	Develop same digital single complex component using FDM, SLA and SLS based 3D Printers and compare the printed componentson the basis of Cost, Time, Surface finish, Strength.	**CO1, CO2, CO3, CO4**
LSO 5.1. Use the available 3D printing software. *LSO 5.2.* Select printing process parameters based on the type/make of Printer and raw material *LSO 5.3.* Select appropriate tolerance, fit and printing process parameters. *LSO 5.4.* Produce an assembly using available SLA/SLS Printer.	5.	Print one digital assembly on SLA/SLS based 3D Printer.	**CO2/CO3 /CO4**
LSO 6.1. Use of available 3D scanner. *LSO 6.2.* Develop 3D digital model using scanningapproach. *LSO 6.3.* Use the available 3D printing software. *LSO 6.4.* Produce a complex component using available SLA Printer.	6.	Scan the given real complex component and print it using FDM/SLA/SLS based 3D Printer.	**CO2, CO3, CO4**
LSO 7.1. Identify tools/devices/chemicals for post processing *LSO 7.2.* Perform post processing operations on printed component.	7.	Apply post processing techniques on the 3D printed component of experiment number 1 and/or 2 and/or 3.	**CO5**
LSO 8.1. Identify tools/devices/techniques for inspection and testing. *LSO 8.2.* Identify the defects in 3D printed components *LSO 8.3.* Apply remedial measures to bring soundness in the defective 3D printed component.	8.	Check the soundness of the 3D printed component of experiment number 1 and/or 2 and/or 3 using available devices/techniques.	**CO5**

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

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

b. Micro Projects:

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

c. Other Activities:

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

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

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

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

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

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

Legend:

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

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

#: Mentioned under point-(O)

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva - Voce (%)
			PRA* (%)	PDA** (%)	
1.	Develop the assigned digital single complex component using FDM based 3D Printer and available material.	CO1, CO2	30	60	10

2.	Develop the assigned digital single complex component using SLA based 3D Printer and available material.	CO1, CO3	30	60	10
3.	Develop the assigned digital single complex component using SLS based 3D Printer and available material.	CO1, CO4	30	60	10
4.	Develop same digital single complex component using FDM, SLA	CO1, CO2,	30	60	10

SN	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
	and SLS based 3D Printers and compare the printed components on the basis of Cost, Time, Surface finish, Strength.	CO3, CO4			
5.	Print one assembly on SLA/SLS based 3D Printer.	CO2/CO3 /CO4	30	60	10
6.	Scan the given real complex component and print it using FDM/SLA/SLS based 3D Printer.	CO2, CO3, CO4	40	50	10
7.	Apply post processing techniques on the 3D printed componentof experiment number 1 and/or 2 and/or 3.	CO5	40	50	10
8.	Check the soundness of the 3D printed component of experiment number 1 and/or 2 and/or 3 using available devices/techniques.	CO5	40	50	10

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

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

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

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

S. No.	Name of Equipment,Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
1.	High end computers	Processor Intel Core i7 with Open GL Graphics Card, RAM 32 GB, DDR3/DDR4, HDD 500 GB, Graphics Card NVIDIA OpenGL 4 GB, OS Windows 10	All
2.	Parametric Computer Aided Design software	CATIA/Solid works/NX/Creo **OR** Available with CoE	1 to 5
3.	FDM based 3D printer	Fused Deposition Modelling system with complete accessories; Build Volume-300 x 300 x 300mm or Higher; Layer Thickness-0.1 – 0.4 **OR** Available with CoE	1,4,5,6
4.	SLA based 3D printer	Printing Technology: SLA, 145 x 145 x 175mm build volume, Common layer thickness 25–100 µm, Dimensional Accuracy ± 0.5% (lower limit: ±0.10 mm), cure time of only 1-3s per layer, Material type: UV-sensitive liquid resin, Curing unit.	2,4,5,6
5.	SLS based 3D printer	Printing Technology: SLS., Build Volume: 130 x 130 x 180 mm, Recommended min. wall thickness: 0.8 mm, Powder Diameter: 60 Microns, Material Type: Nylon, TPU, Light Source: Laser Diode	3,4,5,6
6.	3D Printing Material	ABS/PLA, Resin based Photosensitive material, Polymer/metal/ceramic powder **OR** Available with CoE	1,2,3,4,5,6
7.	3D Printing software	Latest version of software like: Cura/PrusaSlicer/ideaMaker/Meshmixer/MeshLab **OR** Available with CoE	1 to 6

8.	3D Scanner and Processing software	Handheld 3D scanner, Accuracy up to 0.1 mm, Resolution up to 0.2 mm, Real time onscreen 3D model projection and processing, Wireless technology with an inbuilt touch screen and battery, Extended field of view for capturing both large and small objects, Processing Software **OR** Available with CoE	6

S. No.	Name of Equipment,Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
9.	Post processing equipments and tools	Deburring tools (tool handle & deburring blades), Electronic DigitalCaliper, Cleaning Needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removalspatula, Needle file, Cutting mat, Glue stick, Wire stripper, Chemicals, Etching agents etc.	7
10.	Inspection and Testing devices	• Visual inspection,Devices related to: • Scanning electron microscopy (SEM), CT system, X-ray, • Penetration testing, • Infrared thermography, • Leak or pressure testing for complex structures, • Eddy current, • Mechanical property inspection to measure tensile, yield, shear, fatigue, hardness, density, impact strenght • Metallography (Microstructure testing)	8

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Additive Manufacturing Technologies: RapidPrototyping to Direct Digital Manufacturing	Lan Gibson, David W.Rosen, Brent Stucker	Springer, 2010 ISBN: 9781493921133
2.	Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing	Andreas Gebhardt,	Hanser Publisher, 2011 ISBN: 156990507X, 9781569905074
3.	3D Printing and Design	Sabrie Soloman	Khanna Publishing House, DelhiISBN: 9789386173768
4.	3D Printing and Rapid Prototyping-Principlesand Applications	C.K. Chua, Kah Fai Leong	World Scientific, 2017 ISBN: 9789813146754
5.	Getting Started with 3D Printing: A Hands-onGuide to the Hardware, Software, and Services Behind the New Manufacturing Revolution	Liza Wallach Kloski, Nick Kloski	Make Community, LLC; 2nd edition,2021 ISBN: 9781680450200
6.	Laser-Induced Materials and Processes for Rapid Prototyping	L. Lu, J. Fuh, Y.S. Wong	Kulwer Academic Press, 2001ISBN: 9781461514695
7.	3D Printing: A Practical Guide	Clay Martin	Larsen and Keller Education 2023 ISBN 9781641728323
8.	Fundamentals of 3D Printing	Elizah Brooks	Clanrye International 2023 ISBN 9781647290943
9.	Principles of 3D Printing	Brady Hunter	NY Research Press 2023 ISBN 9781632389549

(b) Online Educational Resources:

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

7. https://www.youtube.com/watch?v=Oz0PoS5LPxg
8. https://www.youtube.com/watch?v=6ejjh0GdyDc

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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

******

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

D) Rationale **:**

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

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

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

CO-1. Apply the principles of communication for industrial automation.

CO-2. Test the output of the PLC ladder logic programs for the given application

CO-3. Maintain PLC systems

CO-4. Use SCADA for supervisory control and for acquiring data from the field.

CO-5. Develop simple automation systems

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

Board of Study	Course Code	Course Title	Scheme of Study (Hours/Week)					
			Classroom Instruction(CI)		Lab Instruction(LI)	NotionalHours (TW+ SL)	Total Hours (CI+LI+TW+ SL)	Total Credits(C)
			L	T				
	2000605F/ 2000608F/ 2000611F	Industrial Automation (Advance)	03	-	04	02	09	05

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work & Self-Learning Assessment(TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
	2000605F/2000608F/2000611F	Industrial Automation (Advance)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

I) Course Curriculum Detailing:

Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level andsession level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction

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

J) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO.1a Describe how does a PLC communicate? TSO.1b Differentiate between parallel and series communication TSO.1c Describe the data transfer mechanism for the given communication protocols. TSO.1d Describe the given communication protocol used in PLC communication. TSO.1e Summarize PLC to PLC communication procedure TSO.1f Describe the common procedureto interface the PLC with other given hardware.	**Unit-1.0 Industrial automation communication andInterfacing** 1.1 Analog and Digital Communications on Plant Floors 1.2 Introduction to Industrial Networking 1.3 RS232-422-485 standards for data communication 1.4 Industrial Ethernet 1.5 Concept of Fieldbus 1.6 MODBUS protocol 1.7 Highway Addressable Remote Transducer (HART)Protocol 1.8 Interfacing of Programmable Logic Controller with otherhardware	**CO-1**
TSO.2a Specify the proper I/O addressing format of the given PLC. TSO.2b Explain the use of different relay type instructions for the given operation. TSO.2c Describe how a program is executed with the help of Program Scan cycle TSO.2d Develop ladder logic program using arithmetic functions to perform the given operation. TSO.2e Develop ladder logic programs using logical and comparison instructions to perform the given operation TSO.2f Develop ladder logic programs using on delay, off delay and reset/retentive timer in a given PLC to create a delay in operation. TSO.2g Develop ladder logic programs using Up, Down and UP-down counter in a given PLC to count the number of products	**Unit-2.0 PLC Programming** 2.1 PLC I/O addressing in ladder logic 2.2 PLC programming instructions using ladder logic andrelay type instructions 2.3 Program Scan cycle 2.4 PLC arithmetic functions - Addition, subtraction, multiplication, division instructions, increment decrement, trigonometric 2.5 PLC logical functions - AND, OR, XOR, NOT functions, PLC compare and convert functions. 2.6 Programming Timer –Addressing a timer block, status bits, On delay, Off Delay and reset/retentive timer 2.7 Programming Counter- Addressing a counter block, status bits, Up and Down counter, up-down counter, counter examples, register basics 2.8 Develop ladder logic for various simple applications	**CO-2**
TSO.3a Describe Requirements for PLC enclosure. TSO.3b Describe Proper groundingtechniques. TSO.3c Describe noise reduction Techniques. TSO.3d Explain preventive maintenanceprocedure associated with PLC	**Unit-3.0 Installation and maintenance of PLC systems** 3.1 PLC enclosure, grounding requirements, noise generating inductive devices, leaky inputs and outputs, techniques to reduce electrical noise and leakage. 3.2 Introduction to PLC Trouble shooting and maintenance, trouble shooting of hardware and software. 3.3 Diagnostic LED Indicators in PLCs 3.4 Common problems	**CO-3**

Major Theory Session Outcomes (TSOs)	Units	Relevant tCOs Number(s)
system to reduce environmental impact TSO.3e Identify faults in the given PLC system TSO.3f Explain the procedure for Troubleshooting PLC system TSO.3g Prepare preventive maintenance plan for the PLC system TSO.3h Use safety equipment's. TSO.3i Follow safe practices	• Internal problems – Check for PLC Power Supply, Emergency Push Button, Power Supply Failure, Battery Failure, Electrical Noise Interference, Verify the PLC Program with the Master Program, Corrupted PLC Memory • External problems - Power failure, faulty grounding and electrical noise interference (RFI or EMI), Status of the Output Modules and their associated Circuitry, Status of the Input Modules and their associated Circuitry, Field Input and Output Devices, Communication Issues. • Environmental Conditions. Check for humidity, temperature, vibration, and noise-level limits specified by its manufacturer 3.5 Troubleshooting of Specific Components of the PLC System • Power Supply Troubleshooting • I/O Modules Troubleshooting • Troubleshooting PLC Program Errors • Troubleshooting the Working Environment of a PLC • Replacement of CPU 3.6 PLC trouble shooting flowchart 3.7 PLC maintenance – PLC maintenance checklist, preventive maintenance procedure, maintenance plan for the PLC system. 3.8 Safety procedure and safety equipment's.	
TSO.4.a Describe the function of given element of a SCADA system. TSO.4.b Interface the given PLC with SCADA system using the given Open Platform Communications (OPC). TSO.4.c Describe the steps to develop a simple SCADA screen for the given industrial application. TSO.4.d Describe the procedure to maintain the SCADA based PLC system for the given application.	**Unit-4.0 SCADA and DCS** 4.1 Introduction, need, benefits and typical applications of SCADA and DCS 4.2 SCADA Architecture - Remote Terminal Units (RTUs), Master Terminal Units, Various SCADA editors, Communication protocols for SCADA 4.3 Comparison of SCADA with DCS 4.4 Interfacing SCADA system with PLC- Typical connectiondiagram, Object Linking and Embedding for Process Control (OPC) architecture 4.5 Creating SCADA Screen HMI for simple object, Steps for linking SCADA object (defining Tags and items, creating trends etc.,) with PLC ladder program using OPC, configuring simple applications using SCADA: Traffic light control, water distribution, pipeline control, Power generation, transmission and distribution etc. 4.6 Procedure to maintain the SCADA based PLC system.	**CO-3**
TSO.5a Identify different components used for automation in the given system TSO.5b Select automation components for a given situation TSO.5c In the given manufacturing or service industry Identify the areas where automation is possible. TSO.5d Prepare plan for sustainable automation as per the requirement.	**Unit-5.0 Applications of Industrial Automation** 5.1 **Manufacturing-** Industrial Robots- welding robots, pick and place robots, Cabot's, Machine monitoring system, supply chain, Automated assembly system, Flexible Automation and programmable Automation. 5.2 **Health Care-** microscopic robots for medical diagnosis, automated medication dispensing devices, AESOP, ZEUS, RP_7(remote presence 7th generation),DaVinci 5.3 **Defense- guided rockets and missiles,** counter measures, UAV drones, launcher, radar antenna, engagement control system	**CO-5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
	5.4 **Automobile –B**reak monitoring system, Vehicle tracking system, Rear-view alarm to detect obstacles behind, Four-wheel drive, Traction control system, Dynamic steering response, Anti-lock braking system (ABS) Adaptive cruise control, Adaptive headlamps, Intelligent Parking Assist System, Driverless/Autonomous Cars 5.5 **Agriculture-** harvesters, irrigation systems, plowing machines, self-driving tractors, grain yield sensor 5.6 **Mining-** Mine planning system, mine picture compilation, mine control system, seismic imagining, laser imaging, Rig control system, automated drilling, automated exploration, automated truck	

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

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

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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 3.1 Use hygrometer to measure the humidity inside the panel *LSOs 3.2* Use thermometer to measure ambient temperature inside the panel *LSOs 3.3* Use tester to determine the voltage fluctuation at the power supply terminals is within specifications *LSOs 3.4* Test the ground connections of the given PLC. *LSOs 3.5* A given PLC is not working as per the logic instructions investigate the PLC to identify the cause of failure to showthe desired output *LSOs 3.6* Investigate the cause of Noise in the given PLC *LSOs 3.7* PLC goes on blackout out by losing itsoperating power. Troubleshoot the cause of failure. *LSOs 3.8* Troubleshoot the corrupted PLCmemory. *LSOs 3.9* Replace CPU and power supply fusesin a given PLC system.	13.	Troubleshooting of PLC system	**CO3**
LSOs 4.1 Download any open source SCADA software and install the same. *LSOs 4.2* Interpret the available components in symbol factory of SCADA software *LSOs 4.3* Create simple SCADA HMI applicationsand apply dynamic properties. (Select any Three from the given list) i. Turn on and off a tube light using a Switch ii. Apply filling and object size propertiesto a rectangle, square and round object iii. Move the object, fill the object using slider and meter reading. iv. Apply orientation property to a fan and control its direction using a slider. v. Move a square object horizontally first, then vertically and again horizontally by applying visibility property. *LSOs 4.4* Create historical and real time trends for the given automation	14.	Develop simple SCADA HMI applications usingany one open source SCADA software and apply dynamic properties	**CO4**
LSOs 5.1 Develop a smart irrigation device to detect the change in moisture level in the soil and controls the flow of water accordingly with a DC pump. *LSOs 5.2* Build an electronic device that can remotely control home appliances with your Bluetooth-enabled smartphone and a special Android application	15.	Develop simple automation systems for the given requirement (Select any Three from the given list)	**CO5**

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSOs 5.3 Develop a PLC program to control the robot in such a way that the robot can automatically pick and place components and works in syncwith the conveyor belt system. *LSOs 5.4* Develop a Automation system to Open and close the door in the shop *LSOs 5.5* Develop a line following robot with RFID sensor for supplying materialsand automating workflow. *LSOs 5.6* Develop smart street light controlling mechanism which willSwitch on/off the lights automatically depending on the intensity of the sunlight at that particular time of the day. *LSOs 5.7* Develop smart automated railway crossing system to detect train arrival and departure and send appropriate signals to the microcontroller.			

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

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

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

ii. It is required to have a pilot light glow, meeting all of the circuit requirements given below:
- All four circuit pressure Switches must be closed.
- At least two out of three circuit limit Switches must be closed.
- The reset Switch must not be closed.

iii. Using AND, OR, and NOT gates, design a logic circuit that will solve this hypothetical problem

iv. Prepare a comparison chart of different types of PLC

v. Prepare a maintenance plan for a given PLC system.

b. Micro Projects:

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

c. Other Activities:

1. Seminar Topics- PLC instructions, Timers and Counters used in a given PLC

2. Seminar Topics- Industrial Applications of PLC and SCADA, AGV, Application of automation in different area, trouble shooting of different types of PLC
3. Visits – Visit any industry with full or semi automation and prepare a report on industrial automation usedby the industry in the given section, components used, power requirement, output achieved and maintenance activities required.
4. Surveys- Carry out a market/internet survey of PLC and prepare the comparative technical specifications of any one type of PLC (Micro or Mini) of different manufacturer.
5. Product Development- Develop a prototype automatic railway crossing system

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

6. Also download any open source software for SCADA and install on your laptop/PC and carry out basic SCADA HMI programming
7. Surveys – Carry out a internet based survey to compare SCADA and DCS

d. Self-learning topics:

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

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

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

Legend:

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

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

#: Mentioned under point- (O)

Note:

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

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

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

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

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

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

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

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

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

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

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction to Programmable LogicControllers	Dunning, G.	Thomson /Delmar learning, New Delhi, 2005, ISBN 13: 9781401884260
2.	Programmable Logic Controllers	Petruzella, F.D.	McGraw Hill India, New Delhi, 2010,ISBN: 9780071067386
3.	Programmable Logic Controllers	Hackworth, John; Hackworth, Federic	PHI Learning, New Delhi, 2003, ISBN: 9780130607188
4.	Industrial automation and Process control	Stenerson Jon	PHI Learning, New Delhi, 2003, ISBN:9780130618900
5.	Programmable Logic Controller	Jadhav, V. R.	Khanna publishers, New Delhi, 2017, ISBN: 9788174092281
6.	Programmable Logic Controllers and Industrial Automation - An introduction,	Mitra, Madhuchandra; Sengupta, Samarjit,	Penram International Publication, 2015, ISBN: 9788187972174
7.	Control System	Nagrath & Gopal	New Age International Pvt Ltd, ISBN:9789386070111, 9789386070111
8.	Linear Control Systems with MATLABApplications, Publisher:	Manke, B. S.	Khanna Publishers, ISBN: 9788174093103, 9788174093103
9.	Supervisory Control and Data Acquisition	Boyar, S. A.	ISA Publication, USA, ISBN: 978-1936007097
10.	Practical SCADA for industry,	Bailey David; Wright Edwin	Newnes (an imprint of Elsevier), UK2003, ISBN:0750658053
11	Industrial Automation: Systems and Engineering	Geoffrey Williamson	States Academic Press , 2022 ISBN 9781649649270
12	Industrial Automation Technologies	Jane Taylor	States Academic Press 2023 ISBN 9781649649255
13	Introduction to Industrial Automation	Kian Pearson	Willford Press 2023, ISBN 9781682860864

(b) Online Educational Resources:

1. Software: - www.fossee.com

2. Software: - www.logixpro.com
3. Software: - www.plctutor.com
4. Software; - www.ellipse.com
5. PLC lecture: - https://www.youtube.com/watch?v=pPiXEfBO2qo
6. PLC tutorial: http://users.isr.ist.utl.pt/~jag/aulas/apil3/docs/API_I_C3_3_ST.pdf
7. https://www.youtube.com/watch?v=277wwYWolpw-PLC system troubleshooting and repair. Industrial control panel. PLC system repair.
8. https://www.youtube.com/watch?v=5Jmtvrch5Jg
9. https://www.youtube.com/watch?v=peyV9bwEaLY
10. https://www.youtube.com/watch?v=QdJhRmtKpxk&list=RDCMUCke36Liq- w5fboMHkq1APZw&index=3
11. https://www.youtube.com/watch?v=ygrrRwaJz3M

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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

*****

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

B) Course Title **:** Electric Vehicle (Advanced)

C) Prerequisite Course(s) **:** Electric Vehicle (Basics)

D) Rationale **:**

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

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

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

CO-1 Compute various parameters affecting Vehicle movement.

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

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

CO-4 Test electronic control unit system of EVs.

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

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

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

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive LabAssessment (PLA)	End Laboratory Assessment (ELA)	
	2000605G/2000608G/2000611G	Electric Vehicle (Advanced)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at the course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (SW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to the attainment of Course Outcomes

(COs) upon the completion of the course. While curriculum detailing, NEP 2020-related reforms like

Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) andothers must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units:

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

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

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

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

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 2.1 Test the operation of the Control Disc Braking system and control the regenerative braking system using a test rig. LSO 2.2 Test the performance (Speed v/s Braking Torque) of the Disc Braking System in Half step and Full step braking modes.	1.	• Testing of Control Disc Braking systemand Control Regenerative Braking system.	**CO2**
LSO 2.3 Test the performance of different types of propulsion motors.	2.	• Testing of Motors	
LSO 2.4 Test the continuity of the automotive wiring system in the EV	3.	• Testing of the automotive wiring system.	
LSO 3.1 Test the performance of a new set of batteries and aged batteries. LSO 3.2 Compare the performance of the battery and find the Fuel Gauge after discharging the battery. a. 0% - 100% b. 30% - 100% c. 50% - 100% LSO Evaluate the following parameters of the	4.	• Testing of Batteries used in EVs	**CO2, CO3**

3.3 given EV battery. a. Specific power b. Specific energy			

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

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

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

b. Micro Projects:

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

c. Other Activities:

1. **Seminar Topics**:
   - Safe disposal process of Used Batteries.
   - Charging Technologies used for charging the EV.
   - EV power transmission systems.
2. **Surveys** – Visit an electric vehicle manufacturing plant and prepare report on HVAC system used in EV.

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

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

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

Legend:
***:** Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.
******: Mentioned under point- (N)
#: Mentioned under point- (O)
Note:
- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COsmapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

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

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

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

O) Suggested Assessment Table for Laboratory (Practical):

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

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

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

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies 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 andSoftware	Broad Specifications	Relevant Experiment/Practical Number
1.	Disc Braking and Regenerativebraking system test rig	Test rig equipment for Demonstration of Disc Brakingand Regenerative Braking system operation.	1
2.	Disc Braking System	Test rig / Software for testing the performance of the disc braking system in Half step and Full step braking mode.	1
3.	Induction motor	Induction motor For EV applications with testing kit	2,5
4.	Switched reluctance motor	Switched reluctance motor for EV applications with testing kit	2,5

5.	Permanent magnet (PM) DC motors	Permanent magnet (PM) DC motors for EV applications with testing kit	2,5
6.	Automotive wiring system	Testing facility of automotive wiring system using software /actual EV systems	3

S. No.	Name of Equipment, Tools andSoftware	Broad Specifications	Relevant Experiment/Practical Number
7.	Lithium Ion and Lead-acid Batteries	12V, 7Ah with testing setup.	4
8.	Nickel-based batteries (metal hydride and cadmium battery).	12V, 7Ah with testing setup.	4
9.	Battery tester	For testing battery parameters	4
10.	Battery charger	Battery charger for EV	4
11.	Battery Management System	Training kit or simulation for BMS	4
12.	DC-DC Converter	48V to 12V bidirectional DC-DC Converter	4
13.	Power Analyser	To observe the impacts of G2V and V2G	5
14.	BMS setup	For Demonstration & training	4
15.	DC power supply	0-32V	5
16.	Charging Station Simulator	For Demonstration & training purposes.	5
17.	EC Unit with EV subsystems	Electronic Control Unit Hardware parts/ software for demonstrating the Connection of Electronic Control Unit components with EV subsystems.	6,7
18.	Facility to demonstrate the impact of the Grid on Vehicle Charging and Vehicle Charging on the Grid.	-	7

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Electric Vehicles: And the End of the ICE age	Anupam Singh	Kindle Edition ASIN: B07R3WFR28
2.	Wireless Power Transfer Technologies for ElectricVehicles (Key Technologies on New Energy Vehicles)	Xi Zhang, Chong Zhu,Haitao Song	Springer Verlag, Singapore; 1st ed.2022 edition (23 January 2022) ISBN-13: 978-9811683473
3.	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles	EHSANI	CRC Press; Third edition (1 January2019) ISBN-13: 978-0367137465
4.	Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles	John G. Hayes, G. AbasGoodarzi	Wiley; 1st edition (26 January 2018) ISBN-13: 978-1119063643
5.	New Perspectives on Electric Vehicles	Marian Găiceanu (Editor)	IntechOpen (30 March 2022) ISBN-13: 978-1839696145
6.	Electric and Hybrid Vehicles,	Tom Denton, Taylor &Francis	2nd Edition (2020) ISBN- 9780429296109
7.	Hybrid Electric Vehicles: Energy Management Strategies	S. Onori, L. Serrao and G.Rizzoni	Springer (2016) ISBN: 978-1-4471-6781-5

8.	Electric & Hybrid Vehicles	A.K. Babu	Khanna Publishing House, NewDelhi, 1st Edition (2018) ISBN: 9789386173713, 9386173719

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

(b) Online Educational Resources:

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

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

(c) Others:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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

******

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

B) Course Title : Robotics (Advance)

C) Pre- requisite Course(s) : Robotics (Basic)

D) Rationale :

Efficiency and quality are the demands of industry 4.0. Robotics is a constituent of Industry 4.0 which not only provides the former two but also is beneficial for hazardous and similar challenging situations. The use of robotic technology is developing at a very fast rate in all types of industries whether manufacturing, service or tertiary. Engineers should be competent to use the robotic technology for industry and society advantage. This course aims for the diploma engineers to have advanced skills in robotic applications and use in digital manufacturing.

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

After completion of the course, the students will be able

to-CO-1 Plan the use of robots in engineering

applications.

CO-2 Elucidate the conceptual place of the robotic components for engineering processes.

CO-3 Use robots for small automatic robotic applications.

CO-4 Compute the economics associated with use of robots in industries.

CO-5 Select appropriate robot for industrial requirements and other applications.

F) Suggested Course Articulation Matrix (CAM):

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

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

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

G) Teaching & Learning Scheme:

Board of Study	Course Code	Course Title	Scheme of Study (Hours/Week)					
			Classroom Instruction (CI)		Lab Instruction(LI)	NotionalHours (TW+SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
			L	**T**				
	2000605H	Robotics	03	-	04	02	09	05

	/2000608H /2000611H	(Advance)						

Legend:

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

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

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

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

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

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

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

H) Assessment Scheme:

Board of Study	Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment	
	2000605H /2000608H /2000611H	Robotics (Advance)	30	70	20	30	20	30	200

Legend:

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

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

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

Note:

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

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

J) Theory Session Outcomes (TSOs) and Units:

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Define the need and scope of industrial robots. TSO 1b. Describe the concept of robot dynamics with regards to methods for orientation and location of objects. TSO 1c. Analyse robot direct kinematics for the given 2 DOF planar manipulator. TSO 1d. List types of robots TSO 1e. List safety steps while handling the given robot. TSO 1f. Interface robots with the given welding machine. TSO 1g. Interface robots with the given painting machine. TSO 1h. Interface robots with the given assembly machine.	**Unit-1.0 Robot Kinematics, Dynamics and Industrial Applications** 1.1 Definition need and scope of Industrial robots 1.2 Robot dynamics – Methods for orientation and location of objects 1.3 Planar Robot Kinematics – Direct and inversekinematics for 2 Degrees of Freedom. 1.4 Safety while operating and handling robot	**CO2, CO3**
	1.5 Robot Industrial applications: • Welding Robots-Welding Guns, Welding Electrodes, Welding Power Sources, shielding gases, Robot interfacing • Spray painting Robots, assembly operation, cleaning.	
TSO 2a. Explain the techniques to control robot motion. TSO 2b. Describe the given robot drive system.TSO 2c. Describe the types of grippers. TSO 2d. Design grippers for specificapplication. TSO 2e. Test the designed gripper for the application. TSO 2f. Use Bar code technology for robotic applications. TSO 2g. Integrate radio frequency identification technology in robotic applications. TSO 2h. Assemble an automated guided vehicle for the given situation using standard components. TSO 2i. Assemble a simple automated storage and retrieval systems (ASRS) for the given situation using standard components.	**Unit– 2.0 Robot Drives, Control and Material Handling** 2.1 Controlling the Robot motion. 2.2 Position and velocity sensing devices. 2.3 Drive systems – Hydraulic and Pneumaticdrives 2.4 Linear and rotary actuators and control valves 2.5 Electro hydraulic servo valves, electric drives,motors 2.6 End effectors – Vacuum, magnetic and air operated grippers 2.7 Material Handling; automated guided vehicle systems, automated storage and retrieval systems (ASRS) 2.8 Bar code technology 2.9 Radio frequency identification technology.	**CO2, CO3**
TSO 3a. Differentiate between various work cell layouts. TSO 3b. Select work cell for specific robot withjustification. TSO 3c. Analyse robot cycle time. TSO 3d. Explain industrial applications of roboticcell. TSO 3e. Follow safety procedures in robotic cell.	**Unit– 3.0 Robot Cell Design and Application** 3.1 Robot work cell design, control and safety 3.2 Robot cell layouts 3.3 Multiple Robots and machine interference 3.4 Robot cycle time analysis 3.5 Industrial application of robotic cells	**CO3**
TSO 4a. List different programming languages for the robots TSO 4b. Describe artificial intelligence TSO 4c. Write a programme in the required language to operate a robot for the given task. TSO 4d. Optimise robot programming parameters.	**Unit– 4.0 Robot Programming and Economics of Robotization** 4.1 Characteristics of task level languages through programming methods 4.2 Motion interpolation 4.3 Artificial intelligence: Goals of artificialintelligence, AI techniques, problem	**CO1, CO4, CO5**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4e. Select a robot on the basis of cycle time analysis. TSO 4f. Conduct an economic analysis for use of robots. TSO 4g. Follow testing methods and acceptance rules for industrial robots.	representation in AI 4.4 Problem reduction and solution techniques. 4.5 Application of AI and KBES in Robots 4.6 Selection of Robots; Factors influencing the choice of a robot, selection of robot components, robot performance testing, work cycle time analysis 4.7 Economics analysis for robotics, costdata required for the analysis 4.8 Methods of economic analysis; Pay back method, equivalent uniform annual cost method, return on investment method. 4.9 Testing methods and acceptance rules for industrial robots	
TSO 5a. Describe applications of robots in healthcare and medicine. TSO 5b. Describe applications of robots in Construction industry. TSO 5c. Describe applications of robots in Underground coal mining. TSO 5d. Describe applications of robots in uutilities, military & firefighting operations. TSO 5e. Describe applications of robots in undersea and space TSO 5f. Describe applications of robots in brief in logistics, retail and hospitality, and smart cities. TSO 5g. Describe applications of robots in farming and agriculture in brief explain in brief the use of microrobots, nano robots, soft robots, humanoid robots	**Unit–5.0 Applications in Non-manufacturing Environments** 5.1 Applications of Robots in • Healthcare and medicine • Construction industry • Underground coal mines • Utilities, military & firefightingoperations • Undersea • Space • Logistics, • Retail and Hospitality • Smart Cities • Farming and Agriculture 5.2 Overview of Microrobots, nano robots, soft robots, humanoid robots	**CO5**

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

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

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

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

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

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

b. Micro Projects: A suggestive list of micro-projects is given here. Similar micro-projects that match the COs could be added by the concerned course teacher. The student should strive to

identify eco-friendly or recycled material prior to selection for robotic applications.

1. Develop coin separating robot.
2. Develop robot using radio frequency sensors for material handling.
3. Develop robot for land mine detection.
4. Develop a robot for car washing.

c. Other Activities:

1. Seminar Topics: Recent developments in the industrial applications of robotics
2. Visits: Visit a robotic exhibition.
3. Case Study: Identify a robotic application in automobiles and present a case study
4. Download videos related to simple robotic applications in domestic and industrial purposes.
5. Self-learning topics:
   - Robotic component manufacturers

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

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

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

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

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

Unit Number and Title	Total Classroom Instruction(CI) Hours	Relevant COs Number (s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding(U)	Application& above (A)
Unit-1.0 Robot Kinematics, Dynamics and Industrial Applications	12	**CO2, CO3**	16	6	5	5
Unit– 2.0 Robot Drives, Control and Material Handling	10	**CO2, CO3**	16	4	8	4

Unit– 3.0 Robot Cell Design and Application	8	**CO3**	12	2	4	6
Unit– 4.0 Robot Programming and Economics of Robotization	10	**CO1, CO4, CO5**	14	4	4	6
Unit– 5.0 Applications in Non-manufacturing Environments	8	**CO5**	12	4	4	4
Total Marks	**48**		**70**	**20**	**25**	**25**

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

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva - Voce (%)
			PRA* (%)	PDA** (%)	
1.	Identify different wireless sensor network in robotics viz. ZigBee, LoRa.	CO1, CO3	40	40	20
2.	Use different Radio Frequency (RF) Controlled Wireless Robots.	CO1, CO2	40	40	20
3.	Examine different voice operated robot with speaker identification technology.	CO1, CO3	40	40	20
4.	Design a computer-controlled pick and place robot (wireless)	CO1, CO4	40	40	20
5.	Design a Zigbee controlled Boat with wireless video and voice transmission.	CO2, CO3	40	40	20
6.	Design a PC controlled wireless Multipurpose robot for simple engineering applications.	CO3, CO4	40	40	20
7.	Design an unmanned arial photography system.	CO3, CO5	40	40	20
8.	Develop program for real time (online TPP) Palletizing and Depalletizing operations through robots.	CO5	40	40	20
9.	Develop TPP / Offline program for vision-based inspection forrobots.	CO4, CO5	40	40	20
10.	Program and simulate coordinated identification, inspection and part assembly for robots.	CO1, CO5	40	40	20
11.	Develop Obstacle avoidance robot Programming	CO1, CO5	40	40	20
12.	Program and simulate welding operation using robot simulation software.	CO1, CO5	40	40	20
13.	TPP / Offline program for drilling operation.	CO1, CO5	40	40	20
14.	Program to execute an industrial robot application using a given configuration.	CO1, CO5	40	40	20
15.	Analyse Direct Kinematics of 4-axis robot using availablesoftware.	CO2, CO3	40	40	20

Legend:

PRA*: Process Assessment

PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be

prepared by the course teacher for each experiment/practical to assess the student performance.

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

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

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

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

2.	6 Axis Articulated Robot(General Purpose-Welding, Assembly, Drilling) - 1 No	Link 1: 300 mm Link 2: 300 mm Joint actuator: DC Stepper Motor Transmission: Timing Belt Drive Position feedback: Proximity Switch Gripper actuator: Pneumatic Weight of robot: 50 Kg. Accuracy: ±0.3 Repeatability: ±0.2Tip Velocity range: 500 mm / minPay load capacity: 2 kg (including griper) J1 - Waist: ± 140°J2 - Shoulder: -100 - 60°J3 - Elbow: - 70 + 10°J4 - Wrist rotate: ± 70°J5 - Wrist pitch: ± 35°J6 - Wrist roll: ± 180°External I/O8 Programmable digital inputs8 Programmable digitaloutputs	8, 9, 14
3.	A mounted vision system with software (Free open source Robot simulation software)	Integrity Serial Bus System, CAN to Build Intelligent Device Network, Open Hardware Platform, Arduino, to control Robot sub-Systems of motor-sensor, movable Omni Wheel of Omni-Directional, Actuator operation control by DC Encoder Motor, DC-Motor control and operation by Accelerometer, Gyro, Ultrasonic and PSD sensor, Androx Studio; brushless ILM 70×10 Robo Drive DC motor; sensor-actuator units of ARMAR-4; SD-25-160-2A-GR-BB	3, 4, 5, 11

S.No.	Name of Equipment,Tools and Software	Broad Specifications	Relevant Experiment /Practical Number
		Harmonic Drive reduction gear unit high gear ratio of 160: 1; structural parts (white) are made out of high-strength aluminum, Hollow shaft with strain gauges for torque sensing, motor's magnetic incremental encoder (AMS5306), digital buses (SPI or 12C); Motor interface PCB includes a 13-Bit temperature-to-digital converter with a temperature range from −40°C to 125°C (Analog Devices ADT7302)	
4.	6-axis Robotics Trainer	Programmable robotic arm with an interactive frontpanel. Software to demonstrates functioning of the trainer as well as allows a user to develop their own programs. NV330; 8 bit microcontroller to ARM processors**;** Record and Play capability**;** Optional interfacing with PL**C;** Touch operated ON/OFF Switch**;** Auto set to home position**;** Applications can be developed**;**Data acquisition using USB	3, 4, 5, 13
5.	E-Yantra Firebird kit	• Fire Bird V 2560 Robot • Spark V Robot • Fire Bird V P89V51RD2 adapter card • Fire Bird V LPC2148 adapter card • LSM303 3 axis digital accelerometer and 3 axes magnetometers • L3G4200 3 axis digital gyroscope • Gyroscope, accelerometer and GPS interfacing module for the robot • GPS receiver • Zigbee Modules 100m range • Zigbee Modules Adapter • Metal-gear Servo Motors • Servo Motor Based Gripper kit for the Fire Bird Vrobot • Sharp infrared range sensor (10cm to 500cm) • Arduino Uno/Nano • Hexapod • 16 Programming Software (AVR studio, Keil, AVR Boot loader, Flash Magic)	1, 3, 5, 6, 7, 10
6.	Robot simulator for Robotics	Educational networking licensed Robotic system with simulation software	2, 8, 10
7.	Assorted sensors	Optical encoders, Acoustic sensors ,IR, Potentiometer, RTD, Thermistor, strain gauge, piezoelectric, etc.	4
8.	Vision equipment	Camera, Imaging Components: Point, Line, Planar and Volume Sensors	1, 4, 10
9.	Raspberry Pi kit	1.2GHz quad-core Broadcom BCM2837 CPU with 1GB DDR2 RAM with in-built Wi-Fi & Bluetooth Video Core IV 3D graphics core 40 pin extended pins - with 27 GPIO pins Micro SD slot Multiple ports: Four USB ports, full sized HDMI, four pole stereo output and composite video port, CSI camera port and DSI display port 10/100 BaseT Ethernet Micro-USB, power source 5V, 2A	7, 9

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction to Robotics Mechanics and Control	John Craig	Pearson Education 978-9356062191
2.	Robotics and controls	Mittal R.K., Nagrath I.J.	Tata McGraw Hill Education Pvt. Ltd.;2017; **978**-0070482937
3.	Robotics and Image Processing: AnIntroduction	Janaki Raman. P. A	Tata McGraw Hill Publishing companyLtd., 1998; 978-0074621677
4.	Industrial Robotics - Technology,Programming and Applications	Nicholas Odrey, Mitchell Weiss, Mikell Groover Roger Nagel, AshishDutta	McGraw Hill Education; 2nd Edition;978 -1259006210
5.	Robotic Engineering: an integrated approach	Richard D. Klafter, Thomas A. Thomas A. Chmielewski, Michael Negin	Prentice Hall of India, N. Delhi, 2009;978-8120308428
6.	Industrial Robotics Technology,Programming and Applications	Mikell P. Groover, Mitchell Weiss,Roger N. Nagel, Nicholas G. Odrey	McGraw-Hill Education, SecondEdition, 978-1259006210
7.	Robotics	Appuu Kuttan K. K.	Dreamtech Press, First Edition, 2020, 978-9389583281
8.	Introduction to Robotics: Analysis,Control, Applications	Saeed B. Niku	Wiley; Second Edition,978-8126533121
9.	Essentials of Robotics ProcessAutomation	S. Mukherjee	Khanna Publication, First Edition, 978-9386173751
10.	Robotics	R R Ghorpade, M M Bhoomkar	Nirali Prakashan 978-9388897020
11.	Mechatronics: Engineering Fundamentals	Allie Weaver	Murphy & Moore Publishing 2022 ISBN 9781649872758
12.	Elements of Robotics	Greg Scott	States Academic Press 2022 ISBN 9781649649261
13.	Robotics: Design, Construction and Applications	Allie Weaver	Willford Press 2022 ISBN 9781682860944
14.	Modern Robotics: Mechanics, Systems and Control	Julian Evans	Larsen and Keller Education 2022 ISBN 9781641728515
15.	Introduction to Mechatronics	Randy Dodd	Larsen and Keller Education 2022 ISBN 9781641728493
16.	Introduction to Robotics	Julian Evans	Larsen and Keller Education 2022 ISBN 9781641728503

(b) Online Educational Resources:

1. https://web.iitd.ac.in/~saha/ethiopia/appln.pdf
2. https://nptel.ac.in/courses/112105249
3. https://www.robotsscience.com/industrial/industrial-robots-types-applications-benefits-and-future/
4. https://www.marian.ac.in/public/images/uploads/pdf/online-class/MODULE-6%20ROBOTICS%20INDL_APPLNS-converted.pdf
5. https://forcedesign.biz/blog/5-common-industrial-robot-applications
6. https://www.hitechnectar.com/blogs/top-industrial-robotics-applications-role-of-robots-in-manufacturing/
7. https://en.wikipedia.org/wiki/Industrial_robot

8. https://www.youtube.com/watch?v=fH4VwTgfyrQ
9. https://www.youtube.com/watch?v=aW_BM_S0z4k
10. https://www.automate.org/industry-insights/smarter-robot-grasping-with-sensors-software-the-cloud
11. https://robots.ieee.org/robots/?t=all
12. https://www.youtube.com/watch?v=fc_Cynqr6jM

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

(c) Others:

1. Learning Packages:

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

2. Users' Guide:

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

3. Lab Manuals:

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

S) Course Curriculum Development Team (NITTTR, Bhopal)

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

******

ADVANCE MANUFACTURING PROCESS LAB

Subject Code	Practical						Credits
2025608A	No. of Periods Per Week			Full Marks	:	50	02
	L	T	P/S	Internal (PA)	:	20	
		—	04	External (ESE)	:	30	
	—	—	—		:		

Course objectives:

- To Know the working of Drilling machine, shaper, slotter, planer, milling and grinding machines and be in a position to operate the same.
- To make use of various measuring instruments for taking dimensions.
- To Practice different operations on drilling shaper, slotter, planer, milling and grinding machines.

Course Content:

S.No. Topics for practice

I Drilling Exercise (Three different sized holes for different materials maintaining uniformdistance between them)

II Milling-square-hexagon from round bars with indexing and without indexing

III Generation of spur gear teeth on a round bar

IV Simple planning exercise cutting 'T' slots (one model)

V Shaping a Hexagon on a round bar, key ways, grooves splines

VI Shaping step block cut dovetail to angles 60, 90, 120 degrees

VII Cylindrical grinding of external surface and internal surface using universal grinding machines VIII Grinding Cutting tools to the required angles

IX Grinding of milling cutters etc, on a tool and cutter grinder

X Grinding flat surface on a surface grinder using magnetic chuck and clamping devices

XI Dismantling some of the components of drilling machine and service, assemble the same

XII Dismantling some of the components of shaper head and then assemble the same

XIII Dismantling some of the components of Milling machines and service, assemble the same

XIV Servicing of universal grinding machine

Reference Books:

1. Elements of Workshop Technology (Volume I & II) – HajraChowdry&Bhattacharaya, Media Pro- moters, 11th Edition, 2007
2. Introduction of Basic Manufacturing Processes and Workshop Technology – Rajendersingh, New age International (P) Ltd. NewDelhi, 2006
3. Production Technology – HMT, 18th edition, Tata McGraw Hill, New Delhi
4. Manufacturing process – Myro N Begman,
5. 5 th edition, Tata McGraw Hill, New Delhi Course outcomes:

At the end of the course, the student will be able to:

CO1 Dismantle and assemble the components on drilling, shaping, milling and grinding machines.

CO2 Perform operations on drilling, shaping, milling and grinding machines.

CO3 Produce articles of industrial application such as Spur gear, square headed bolt, V- block

CO4 Make use of various measuring instruments for taking dimensions

TERM WORK
SEMINAR

Subject Code	Theory						Credits
2025609	No. of Periods Per Week			Full Marks	:	50	02
	L	T	P/S	Internal(PA)	:	15	
			04	External(ESE)	:	35	
					:		

Course objectives:

A seminar is a form of academic instruction, either at an academic institution or offered by a commercial or professional organization. It has the function of bringing together small groups for recurring meetings, focusing each time on some particular subject, in which everyone present is requested to participate. This is often accomplished through an ongoing Socratic dialogue with a seminar leader or instructor, or through a more formal presentation of research. It is essentially a place where assigned readings are discussed, questions can be raised and debates can be conducted.

The term *seminar* is also used to describe a research talk, often given by a visiting researcher and primarily attended by academics, research staff, and postgraduate students. Seminars often occur in regular series, but each seminar is typically given by a different speaker, on a topic of that speaker's choosing. Such seminars are not usually a part of a course of study and are therefore not usually associated with any assessment or credit. The term *colloquium* is often used interchangeably with seminar in this sense.

TERM WORK

MAJOR PROJECT.

Subject Code	Theory						Credits
2025610	No. of Periods Per Week			Full Marks	:	100	03
	L	T	P/S	Internal(PA)	:	30	
		—	_06	External(ESE)	:	70	
	—	—	—		:		

Course objectives:

The projects if done right can help enthusiastic electrical engineering students to develop the skills/profile needed for an exciting career in core technologies. Since practical skills are very important to work on core industries, experts tend to analyse candidate's performance based on their project experience during the interviews.

These projects provide an excellent opportunity to learn and showcase your practical skills to your future interviewers easily. If spent qualitatively you can build a very innovative electrical project and get a great learning experience. By doing so, you will not only develop an innovative project but also develop valuable skills needed for a successful career in core technologies related to electrical engineering. The best way to master a subject is by doing projects. Through a project you not only get a deeper understanding of the subject but also gain hands-on practical experience. If you are looking to do internships in college, thebest way to catch the companies attention is through projects.

Projects are generally done as a combined team effort. Two or more students work under a guide or a staff to get a certain result. By doing a project, you will

- Understand your subject better
- Get practical experience
- Chance to showcase your skills
- Learn about team work, communication skills and responsibilities

When companies look for interns, they prefer students who have good understanding of the subject with at least some hands-on experience. The best to achieve both is by doing projects.

There is no fixed time to do a project. You can do it right from your first year in college. If you are looking to do a technical project, then the best time to start would be mid second year. It’s not mandatory that you do many projects but make sure that you at least do one project. A lot of students tend to do few small projects from their second year and do a big project in their final year. By showcasing your projects, you can even look for internships while in college.

You can do any kind of projects based on your interests or subjects. The best way to go about this is to figure out what you are interested in so, the first step is to find your interest and then do projects in your area of interest.

Find your area of interest and then do a project in that field.

You can start by exploring different areas and then pick the field in which you are interested in. You can learn more about it and start working on small problems.

COURSE UNDER MOOCS/ NPTEL / OTHERS

<table>
<tr><td rowspan="4">Subject Code
2025611</td><td colspan="3">Theory</td><td colspan="3">No of Periods in One Session: 28</td><td>Credits</td></tr>
<tr><td colspan="3">No. of Periods Per Week</td><td>Full Marks</td><td>:</td><td>50</td><td rowspan="3">01</td></tr>
<tr><td>L</td><td>T</td><td>P/ S</td><td>Internal (PA)</td><td>:</td><td>20</td></tr>
<tr><td>-</td><td>-</td><td>02</td><td>External (ESE)</td><td>:</td><td>30</td></tr>
</table>