Course Code		**:**	**22UME712C**	**Control Engineering**	**Semester**	**:**	**07**
L:T:P		**:**	**3:0:0**		**Course Type**	**:**	**PCC**
Hours/Sem.	**Teaching**	**:**	**42 Hrs**		**CIE Marks**	**:**	**50**
	Learning (TW)	**:**	**42 Hrs**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06 Hrs**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90 Hrs**		**Credits**	**:**	**03**

Professional Competency:

Model, analyse and design linear feedback control systems using mathematical modelling, block diagram reduction, signal flow graph techniques, stability analysis, frequency response methods, root locus techniques and PID controllers to solve real-world engineering control problems.

Course Outcomes:

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

CO1: Develop mathematical models of mechanical and hydraulic systems and obtain transfer functions using Laplace transform techniques.

CO2: Analyse linear control systems using block diagram reduction, signal flow graphs and PID controllers to determine overall system behaviour.

CO3: Evaluate transient response, steady-state performance and stability characteristics of closed-loop control systems using time-domain analysis.

CO4: Analyse and design stable control systems using Root Locus, Bode Plot and Polar Plot techniques in frequency domain.

UNIT–I	**11 Hrs**

Introduction: Introduction to control system, Concepts of open loop and closed loop control system. Requirements of control system. Introduction to controllers, Types of controllers, Proportional controller. Integral controller, PI controllers, PID controllers.

Mathematical Models: Laplace Transforms, Differential equation, Transfer function. Mechanical Systems. Hydraulic systems, Interactive & Non-Interactive Hydraulic systems..

UNIT–II	**10 Hrs**

Block Diagrams: Introduction of Blocks diagrams, Rules of block diagrams, Multiple input & Multiple output, examples to reduction of block diagrams.

Signal flow Graphs: Introduction to signal flow graph, Manson's gain formula for TF, examples to find the TF using Manson's gain formula.

Transient & Steady state Analysis: Introduction, First order and second order systems, Step, ramp and impulse inputs, Importance of speed response, System stability using R.H. Criteria, Examples on System stability using R.H. Criteria.

UNIT-III	**11 Hrs**

Frequency Response Analysis: Introduction to polar plots, steps to draw the polar plot. Stability analysis in Polar plots, GM and PM, M&N circles, stability criteria.

Bode Plots: Introduction to Bode plots, Magnitude & Phase plots, GM and PM, Stability analysis in Bode plot. Examples on Bode plots.

UNIT-IV	**10 Hrs**

Root locus: Introduction, Definition of Root Locus, Rules for construction of Root Locus. Stability analysis, examples on Roots Loci and stability criteria.

System Compensation: Introduction, Series and feedback Compensation. Physical Devices for system compensation.

Text Books:

1. Bakshi, U. A., & Bakshi, V. U., Control Systems Engineering, Technical Publications, Pune, 5th Edition, 2020.
2. Nagrath, I. J., & Gopal, M., Control Systems Engineering, New Age International Publishers, 8th Edition, 2024.
3. Ogata, K., Modern Control Engineering, Pearson Education, 5th Edition, 2015.

Reference Books:

1. Dorf, R. C., & Bishop, R. H., Modern Control Systems, Pearson, 13th Edition, 2017.
2. Franklin, G. F., Powell, J. D., & Emami-Naeini, A., Feedback Control of Dynamic Systems, Pearson, 8th Edition, 2019.
3. Jairath, A. K., Problems and Solutions in Control Systems, CBS Publishers, 7th Edition, 2022.
4. Norman S. Nise, Control Systems Engineering, Wiley, 8th Edition, 2020.

Web links and Video Lectures (e-Resources):

1. NPTEL – Control Engineering https://archive.nptel.ac.in/courses/108/102/108102043/
2. NPTEL – Control Systems https://archive.nptel.ac.in/content/syllabus_pdf/108101037.pdf
3. NPTEL – Modern Control Engineering https://onlinecoursesarchive.nptel.ac.in/noc18_ee41/preview
4. MIT Open Course Ware – Feedback Control Systems https://ocw.mit.edu
5. MATLAB Control Systems Tutorials https://ctms.engin.umich.edu

Table: Matrix to describe the mapping of COs with POs (considering WKs) and PSOs

Course Outcomes (COs)	Program Outcomes and (WKs)											Program Specific Outcomes (PSOs)	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	**3** (WK1, WK2, WK3)	**3** (WK2, WK4)	1 (WK5)	–	2 (WK6)	–	–	–	–	1	2	3	2
CO2	2 (WK1, WK2)	**3** (WK2, WK4)	**3** (WK5)	1 (WK4)	**3** (WK6)	–	–	–	–	1	2	**3**	**3**
CO3	**3** (WK1, WK2)	**3** (WK3, WK4)	2 (WK5)	**3** (WK4)	2 (WK6)	–	–	–	–	1	2	**3**	**3**
CO4	**3** (WK1, WK2)	**3** (WK3, WK4)	**3** (WK5)	**3** (WK4)	**3** (WK6)	–	–	–	–	1	2	**3**	**3**

Course Code		**:**		**Heating, Ventilation, Air Conditioning**	**Semester**	**:**	**07**
L:T:P		**:**	**3:0:0**		**Course Type**	**:**	**PEC - III**
Hours/Sem.	**Teaching**	**:**	**42 Hrs**		**CIE Marks**	**:**	**50**
	Learning (TW)	**:**	**42 Hrs**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06 Hrs**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90 Hrs**		**Credits**	**:**	**03**

Professional Competency:

Apply engineering knowledge to analyze refrigeration and air-conditioning systems, estimate cooling loads, select suitable system components, and evaluate system performance with due consideration to energy efficiency, safety, and environmental sustainability.

Course Outcomes:

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

CO1: Analyze different air-craft refrigeration systems and explain the properties, applications and environmental issues of different refrigerants.

CO2: Analyse multi pressure refrigeration system used for refrigeration applications.

CO3: Discuss types of compressors, condensers, evaporators and expansion valves along with regulatory and safety controls and describes Trans critical and ejector refrigeration systems.

CO4: Estimate cooling load for air conditioning systems used with concern of design conditions and indoor quality of air.

UNIT–I	**11 Hrs**

Gas Cycle Refrigeration: Application to air-craft refrigeration, Simple system, Bootstrap, Regenerative, reduced ambient system, Concept of Dry Air Rated Temperature (DART)

Refrigerants: Introduction, Definition and requirement, Classification of refrigerants, Designation of refrigerants, Desirable properties of Refrigerants-Thermodynamic, Chemical and Physical. Properties of ideal refrigerant. Environmental issues like ODP, GWP & LCCP. Selection of environment friendly refrigerants, Alternative refrigerants, Secondary refrigerants, Anti-freeze solutions, Zeotropes and Azeotropes, Refrigerant recovery, reclaims, recycle and recharge.

UNIT–II	**10 Hrs**

Multistage or compound system: Need of multi staging, Two stage compression with flash gas removal, flash intercooler and complete multistage compression system.

Multi evaporator system: single compressor-individual expansion valve, single compressor-multiple expansion valve, individual compressor-multiple expansion valve, individual compressor with compound compression and flash inter cooling. (Limited to two evaporators). Ammonia-CO2 cascade cycle.

UNIT-III	**11 Hrs**

Major components of refrigeration cycle: Types of compressors, Characteristics of reciprocating and centrifugal compressors, Types of evaporators, Types of condensers and Types of expansion valves

Safety Controls: LP/HP cut-off, Low temperature control, Frost control, Motor overload control, Oil pressure failure control. Capacity control of different compressors

Advanced Refrigeration System: Transcritical cycle and their types, Simple ejector refrigeration system (analysis and numerical)

UNIT-IV	**10 Hrs**

Psychrometric Chart, Psychrometric processes using BPF, ADP, SHF, RSHF, GSHF, ESHF, ERSHF and adiabatic mixing of two air streams. Heat load estimation: - Air conditioning, heating & cooling load calculations

Envelop Load estimation: Concept of sol-air temperature, Time lag & Decrement method and ETD or CLTD methods

Thermal Comfort: Basic parameters, Thermodynamics of human body, Thermal comfort and Comfort charts, Factors affecting thermal comforts

Indoor Air Quality (IAQ): Indoor air contaminants, Basic strategies to improve indoor air quality **Outdoor Design Conditions:** Outdoor air requirements for occupants, Use of outdoor weather data in design, Outdoor weather characteristics and their influence

Text Books:

1. Arora C. P., Refrigeration and Air Conditioning, Tata McGraw-Hill.
2. Manohar Prasad, Refrigeration and Air Conditioning, Willey Eastern Ltd, 1983.
3. McQuiston, - Heating Ventilating and air Conditioning: Analysis and Design‖ 6th Edition, Wiley India.
4. Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai & Company, New Delhi.

Reference Books:

1. Dossat Ray J, Principles of refrigeration, S.I. version, Willey Eastern Ltd, 2000.
2. Stockers W.F and Jones J.W., Refrigeration and Air conditioning, McGraw Hill International editions 1982.
3. Threlkeld J.L, Thermal Environmental Engineering, Prentice Hall Inc., New Delhi.
4. Aanatnarayan, Basics of refrigeration and Air Conditioning, Tata McGraw Hill Publications.
5. Roger Legg, Air Conditioning System Design, Commissioning and Maintenance.

Web links and Video Lectures (e-Resources):

1. https://www.youtube.com/watch?v=xMkgzVR1Luo
2. https://www.youtube.com/watch?v=9-K9Y5b8M5c
3. https://www.youtube.com/watch?v=FEWF9N1LE6g&list=PLEaHqdgEVu6rgimtDDFGVeCfMPLp1q-TQ
4. https://www.youtube.com/watch?v=zqXgmVnI3L8&list=PLE2DA184A2E479885

Table: Matrix to describe the mapping of COs with POs (considering WKs) and PSOs

Course Outcomes (COs)	Program Outcomes and (WKs)											Program Specific Outcomes (PSOs)	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	**2** (WK1, WK2, WK3)	**2** (WK1, WK2, WK3)	–	–	**1** (WK2)	**1** (WK1)	**1** (WK9)	–	**1**	–	**1** (WK8)	**2**	**1**
CO2	**2** (WK1, WK2, WK3)	**2** (WK1, WK2, WK3)	**1** (WK5)	–	**2** (WK2, WK6)	**1** (WK5)	–	–	**1**	–	–	**2**	**2**
CO3	**2** (WK1, WK2, WK3)	**2** (WK1, WK2, WK3)	**1** (WK5)	**1** (WK8)	**2** (WK2, WK6)	**1** (WK7)	**1** (WK9)	–	**1**	–	**1** (WK8)	**2**	**2**
CO4	**2** (WK1, WK2, WK3)	**2** (WK1, WK2, WK3)	**2** (WK5)	**1** (WK8)	**2** (WK2, WK6)	**2** (WK1, WK5, WK7)	–	–	**1**	**1**	**1** (WK8)	**2**	**2**

Course Code		**:**	**22UME747E**	**Fluid Power Systems Design for Industry 4.0**	**Semester**	**:**	**07**
L:T:P		**:**	**2:0:2**		**Course Type**	**:**	**PEC _ III**
Hours/Sem.	**Teaching**	**:**	**56 Hrs**		**CIE Marks**	**:**	**50**
	Learning (TW+SL)	**:**	**28 Hrs**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06 Hrs**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90 Hrs**		**Credits**	**:**	**03**

Professional Competency:

Develop and integrate hydraulic and pneumatic fluid power systems using electro-hydraulic, electro-pneumatic, PLC and Industry 4.0 technologies for smart manufacturing applications.

Course Outcomes:

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

CO1: Determine the force, velocity and power of single and double acting cylinders with sensors and IoT as per Industry 4.0 principles for predictive and preventive maintenance in fluid power systems.

PrO1: Operate a variable displacement vane pump test rig to determine the hydraulic pump characteristic curve.

PrO2: Conduct pressure intensification test on a single-rod double-acting hydraulic cylinder and record the operating parameters.

CO2: Simulate electro-hydraulic metre-in and metre-out flow control circuits for applications in casting, metal forming and machining operations using simulation software tool.

PrO3: Construct and operate an electro-hydraulic meter-in hydraulic circuit using a 4⁄2 directional control valve (DCV) to regulate the inlet flow and control actuator speed under varying load conditions.

PrO4: Construct and operate an electro-hydraulic meter-out circuit using a 4⁄2 directional control valve (DCV) to regulate the outlet flow and control actuator speed under varying load conditions.

PrO5: Construct and operate an electro-hydraulic circuit using a 4⁄3 directional control valve (DCV) with a closed centre configuration for actuator position holding and system pressure maintenance.

PrO6: Construct and operate an electro-hydraulic circuit using a 4⁄3 directional control valve (DCV) with a tandem centre configuration for actuator holding and pump unloading in the neutral position.

PrO7: Operate a hydraulic motor using a 4⁄3 directional control valve (DCV) to control its direction and speed of rotation.

CO3: Simulate electro-pneumatic circuits using OR and AND gates for applications including twin-control entry gates, emergency stop systems in lifting platforms and conveyors, two-hand safety start in paper cutting machines and log splitters in agriculture and wood cutting using simulation software tool.

PrO8: Operate single-acting and double-acting pneumatic cylinders using directional control valves to achieve the required reciprocating motion.

PrO9: Operate a pneumatic memory valve to demonstrate its bistable switching and position-retaining characteristics.

PrO10: Construct and test pneumatic AND and OR logic circuits to verify their output responses for different input signal combinations.

CO4: Design pneumatic circuits along with PLC wiring and ladder diagrams for applications including

pressing, punching, pneumatic doors and pick-and-place robot arms.

PrO11: Develop and execute a PLC program to actuate a single-acting pneumatic cylinder.

PrO12: Develop and execute a PLC program to control the extension and retraction of a double-acting pneumatic cylinder.

UNIT–I	**06 Hrs.**

Introduction to Fluid Power Systems

Pascal's Law, Structure and working principles of hydraulic system and pneumatic system with pros and cons of each system. Comparison of electrical vs. mechanical vs. fluid power transmission systems. Numerical problems based on applications of Pascal's law (hydraulic lift in dentist chair, hand operated hydraulic car jack, car brake system, hydraulic elevator, bus/truck lifting for maintenance, etc.). Ethical and environmental awareness in fluid power systems.

Source of Hydraulic Power

Working principle of hydraulic pump and comparison with centrifugal pump. Overview of various types of hydraulic pumps (limited to classification).

Hydraulic Actuators and Motors

Linear Actuators (cylinders) and Rotary actuator (motors). Numerical problems involving pressure, velocity and power requirements of hydraulic cylinders.

UNIT–II	**07 Hrs.**

Control Components in Hydraulic Systems: Directional control valves, Pressure control valves and Flow control valves–Symbolic representation and Constructional features.

Introduction to Industry 4.0 in Fluid Power Systems: Overview of Industry 4.0, Role of sensors and internet of things (IOT) in monitoring and control of fluid power systems. Predictive and preventive maintenance concepts and applications. Numerical problems based on predictive and preventive maintenance scenarios (monitoring of landing gears of an aircraft, smart hydraulic elevator or lift, brake booster in train, hydraulic doors in the shopping malls, smart municipal garbage truck compactor, etc.).

Electrical Components in Fluid Power systems: Construction and working of normally open (NO) and normally closed (NC) contact switches. Function and use of relays and solenoids in fluid power circuits. Design and analysis of electrical circuits to operate multiple devices (control of platform lights based on train arrival, controlling ceiling operations like fans and lights commonly used in auditorium and smart homes, etc.) using above elements with different ON/OFF switching conditions simultaneously.

UNIT-III	**07 Hrs.**

Electro-Hydraulic Circuit Design and Analysis: Control of single-acting and double-acting hydraulic cylinders. Circuit design for manufacturing processes including casting, metal forming (rolling, extrusion, forging, drawing, bending, and powder compaction based on calculated deformation loads), and machining (drilling, machining, shaping and planning) operations. Simulation of metre-in and metre-out flow control circuits for these manufacturing processes using simulation software tool.

UNIT-IV	**08 Hrs.**

Electro-Pneumatic Circuit Design and Analysis: Introduction to the use of electro-pneumatic logic gates in automation systems. Design and implementation of circuits using OR gates (twin-control entry gates, emergency stop override system in lifting platforms and conveyors, etc.) and AND gates (two hand safety start in paper cutting machine, log splitters used in agriculture and wood cutting, etc.) through simulation using simulation software tool.

Introduction to Programmable Logic Controller (PLC): Overview of PLC components: Power supply, CPU, input/output modules, programming device, and memory. Working principles and operation of PLCs. Design the pneumatic circuit, PLC wiring diagram and ladder diagram for practical applications (pressing operation, bus/train pneumatic door, punching operation, pick and place robot arm, etc.).

Practical Module:	**Part-A**	**18 Hrs.**
1. Hydraulic pump/characteristic curve of variable displacement vane pump 2. Single rod cylinder/pressure intensification 3. Meter-in-circuit with single rod cylinder using 4/2 Directional Control Valve 4. Meter-out-circuit with single rod cylinder using 4/2 Directional Control Valve 5. Tandem Centre 4/3 Directional Control Valve 6. Closed Centre 4/3 Directional Control Valve 7. Hydraulic motor using a 4/3 Directional Control Valve		
Part-B		**10 Hrs.**
1. Single-acting and double-acting pneumatic cylinders 2. Memory Valve 3. Pneumatic AND and OR logic gates 4. PLC Control of a single acting pneumatic cylinder 5. PLC Control of a double acting pneumatic cylinder		
Text Books:		
1. Srinivasan Chandrasekaran, "Hydraulic and Pneumatic Control: Understanding the Industry 4.0 Approach", CRC Press, 1st Edition, 2023. 2. S. R. Majumdar, "Oil Hydraulic Systems-Principles and Maintenance", McGraw Hill Education, 1st Edition, 2017. 3. Anthony Esposito, "Fluid Power with Applications", Pearson Education Limited, 7th Edition, 2013.		
Reference Books:		
1. R. Rajasekar *et al.*, "Integration of Mechanical and Manufacturing Engineering with IoT: A Digital Transformation", Wiley-Scrivener, 1st Edition, 2023. 2. Frank D. Petruzella, Programmable Logic Controllers, McGraw-Hill Education, 5th Edition, 2017. 3. W. Bolton, Programmable Logic Controllers, Newnes/Elsevier, 6th Edition, 2015. 4. Andrew Parr, "Hydraulics and Pneumatics: A Technician's and Engineer's Guide", Butterworth-Heinemann, 3rd Edition, 2011. 5. Bosch Rexroth Training Manuals (for laboratory and industrial practice), 2010.		
Web Links and Video Lectures (e-Resources):		
1. https://onlinecourses.nptel.ac.in/e-learning/course/noc25_me58?unitId=17&lessonId=19 2. https://onlinecourses.nptel.ac.in/e-learning/course/noc25_me58?unitId=17&lessonId=20 3. https://onlinecourses.nptel.ac.in/e-learning/course/noc23_me105?unitId=77&lessonId=78 4. https://onlinecourses.nptel.ac.in/e-learning/course/noc25_me58?unitId=17&lessonId=21 5. https://onlinecourses.nptel.ac.in/e-learning/course/noc25_me58?unitId=45&lessonId=46 6. https://onlinecourses.nptel.ac.in/e-learning/course/noc25_me58?unitId=45&lessonId=47 7. https://onlinecourses.nptel.ac.in/e-learning/course/noc23_me105?unitId=90&lessonId=91 8. https://nptel.ac.in/courses/112107298?utm_source=chatgpt.com		

Table: Matrix to describe the mapping of COs with POs (considering WKs) and PSOs

Course Outcomes (COs)	Program Outcomes and (WKs)											Program Specific Outcomes (PSOs)	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3 (WK1, WK2, WK3, and WK4)	3 (WK1, WK2, WK3, and WK4)	-	-	-	-	-	1	-	-	1	-	2
CO2	-	2 (WK1,WK3, and WK4)	3 (WK5)	-	3 (WK6)	1 (WK1, WK5 and WK7)	1 (WK9)	1	1	-	1 (WK8)	-	2
CO3	-	2 (WK1, WK3, and WK4)	3 (WK5)	-	3 (WK6)	1 (WK1, WK5 and WK7)	1 (WK9)	1	1	-	1 (WK8)	-	2
CO4	-	2 (WK1, WK3, and WK4)	2 (WK5)	-	-	1 (WK1, WK5 and WK7)	-	1	1	-	1 (WK8)	-	2

Course Code		**:**	**22UME743E**	**Artificial Intelligence for Engineers**	**Semester**	**:**	**07**
L:T:P		**:**	**3:0:0**		**Course Type**	**:**	**PEC - III**
Hours/Sem.	**Teaching**	**:**	**42Hrs**		**CIE Marks**	**:**	**50**
	Learning (TW+SL)	**:**	**42Hrs**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06Hrs**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90Hrs**		**Credits**	**:**	**03**

Professional Competency:

Apply Artificial Intelligence principles, techniques, and tools to analyse, design, develop, and evaluate intelligent engineering solutions for solving real-world problems ethically, efficiently, and sustainably.

Course Outcomes (COs):

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

CO1: Understand the foundational concepts of Artificial Intelligence and its relevance to engineering applications.

CO2: Apply AI techniques such as search algorithms and knowledge representation to solve engineering problems.

CO3: Analyze basic machine learning models for mechanical engineering problems.

CO4: Evaluate the role of AI in real-world mechanical systems such as design, manufacturing, and automation.

UNIT-I Introduction to AI and Engineering Applications — **11 Hrs.**

Introduction to Design Automation: Conventional and automated design processes, Concurrent engineering and integrated product development, Product lifecycle management (PLM), Design for manufacturing and assembly (DFMA).

Digital Design Environment: Fundamentals of CAD systems, Parametric and feature-based modelling, **Product** Data Management (PDM), **Role** of design automation in manufacturing industries.

UNIT–II Problem Solving and Search Techniques — **10 Hrs.**

CAD Automation: Design automation concepts, Parametric design techniques, Automated drawing generation, Design templates and standardization.

Knowledge-Based Engineering: Fundamentals of Knowledge-Based Engineering (KBE), Rule-based design systems, Design knowledge capture and reuse, Applications of expert systems in engineering design.

UNIT–III Knowledge Representation and Learning — **10 Hrs.**

Additive Manufacturing and Design: Design for Additive Manufacturing (DfAM), Rapid prototyping concepts, Topology optimization, Industrial applications of additive manufacturing.

Simulation and Digital Twin: Virtual prototyping, Simulation-driven design, Digital Twin concepts, Product performance evaluation using simulation tools.

UNIT–IV AI in Mechanical Engineering Applications — **11 Hrs.**

AI in Design Automation: Introduction to Artificial Intelligence in engineering, Machine learning applications in design, AI-assisted design optimization, Case studies in intelligent product development.

Industry 4.0 and Smart Manufacturing: Industry 4.0 fundamentals, Internet of Things (IoT) in manufacturing, Cyber-Physical Systems (CPS) , Smart factories and future manufacturing trends.

Text Books :

1. S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Systems and Evolutionary Algorithms: Synthesis and Applications, 2nd Edition, PHI Learning Pvt. Ltd., New Delhi, 2017.
2. Elaine Rich, Kevin Knight and Shivashankar B. Nair, Artificial Intelligence, 3rd Edition, McGraw Hill Education (India), 2017.

3. Deepak Khemani, A First Course in Artificial Intelligence, McGraw Hill Education (India), 2013 (Reprint 2014).
4. P. K. Sinha and Priti Sinha, Artificial Intelligence, BPB Publications, 2020.

Reference Books :

1. Stuart Russell, Peter Norvig, Artificial Intelligence – A Modern Approach, Pearson
2. Rajiv Chopra, Machine Learning, Khanna Book Publishing, 2021.Aurélien Géron, Hands-On Machine Learning, O'Reilly
3. Research articles/case studies on AI in mechanical systems
4. V. S. Janakiraman, Artificial Intelligence and Expert Systems, PHI Learning, 2012.

Web links and Video Lectures (e-Resources):

- https://youtu.be/m9lPatLXE8s
- https://youtu.be/kXlr6ydiPAQ
- https://youtu.be/ydd5sRIeA3Q
- https://youtu.be/gDUKNIIimoc

CO–PO Mapping (Indicative):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PSO1	PSO2
CO1	**3** (WK1, WK2, WK3, WK4)	**2** (WK1, WK2, WK3)	–	–	**1** (WK5)	–	–	–	–	–	–	**2**	–
CO2	**3** (WK1, WK2, WK3, WK4)	**3** (WK2, WK3, WK4)	**2** (WK4, WK5)	**2** (WK4, WK5)	**1** (WK5, WK6)	–	–	–	–	–	–	**2**	-
CO3	**2** (WK1, WK2)	**3** (WK2, WK3, WK4)	**3** (WK4, WK5)	**3** (WK4, WK5, WK8)	**3** (WK5, WK6)	–	–	–	–	–	–	-	**2**
CO4	**2** (WK1, WK2)	**3** (WK2, WK3, WK4)	**2** (WK4, WK5)	**2** (WK5, WK8)	**3** (WK5, WK6, WK7)	**1** (WK6, WK7)	**2** (WK7)	–	–	–	–	-	**3**

Course Code		:	22ume744E	Renewable Energy Sources	Semester	:	07
L:T:P		:	3:0:0		Course Type	:	PEC - III
Hours/Sem.	Teaching	:	42 Hrs		CIE Marks	:	50
	Learning (TW)	:	42 Hrs		SEE Marks	:	50
	Exam	:	06 Hrs		Total Marks	:	100
	Total Hrs.	:	90 Hrs		Credits	:	03

Professional Competency:

This course enables mechanical engineering students to apply the fundamental principles of renewable and non-conventional energy systems to analyze, evaluate, and select appropriate sustainable energy technologies for engineering applications.

Course Outcomes:

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

CO1: Evaluate conventional and non-conventional energy resources and determine the characteristics and measurement of solar radiation relevant to renewable energy applications.

CO2: Apply the principles of solar radiation geometry to analyse solar angles and assess the performance of solar thermal energy conversion systems.

CO3: Analyse the operating principles, performance characteristics, and limitations of wind, tidal, and ocean thermal energy conversion technologies.

CO4: Evaluate biomass energy systems, fuel cells, and photovoltaic technologies for their suitability and effectiveness in sustainable energy applications.

UNIT–I	12 Hrs

Introduction: Energy sources, need for non-conventional energy sources, energy alternatives, advantages, and disadvantages.

Solar Radiation: Extra-Terrestrial radiation, solar constant, beam, diffuse and global radiation, Measurement of Solar Radiation: Pyrometer, shading ring pyrheliometer, sunshine recorder, principle of working.

UNIT–II	10 Hrs

Solar Radiation Geometry: Solar time, latitude, declination angle, altitude, surface azimuth angle, hour angle, zenith angle, angle of incidence, day length, simple problems.

Solar Thermal Conversion: Collection and storage, thermal collection devices, liquid flat plate collectors, concentrating collectors (cylindrical, parabolic, paraboloid) power generation.

UNIT-III	10 Hrs

Wind and tidal energy: Properties of wind, availability of wind energy in India, wind velocity and power from wind; major problems associated with wind power, wind machines; Types of wind machines and their characteristics, horizontal and vertical axis windmills. Fundamental characteristics of tidal power, harnessing tidal energy, limitations. Ocean Thermal Energy Conversion: Principle of working, problems associated with OTEC.

UNIT-IV	10 Hrs

Energy from Biomass:

Biogas production from waste biomass, Use of biogas in IC engines, advantages of anaerobic digestion, floating drum (constant pressure) type, fixed dome (constant volume) type biogas plants, comparison.

Fuel cell: Principle of working. Applications.

Photovoltaics: Solar cells, efficiency, applications, advantages,and disadvantages.

Text Books:
1. Non-Convention Energy Resources B H Khan McGraw Hill Education (India) Pvt. Ltd. 3rd Edition. 2. Solar energy Subhas P Sukhatme Tata McGraw Hill 2nd Edition, 1996. 3. Non-Conventional Energy Sources G.D Rai Khanna Publishers 2003.
Reference Books:
1. Ramesh R & Kumar K U, Renewable Energy Technologies, Narosa Publishing House, New Delhi, 2004 2. Wakil MM, Power Plant Technology, Mc Graw Hill Book Co, New Delhi, 2004. 3. Non – Conventional Energy Sources. Rai.
Web links and Video Lectures (e-Resources):
1. MIT Open CourseWare (energy-related courses): MIT OpenCourseWare 2. NPTEL courses on Renewable Energy and Solar Energy: NPTEL 3. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy: DOE EERE 4. International Renewable Energy Agency (IRENA): IRENA 5. Video lectures on renewable energy by NPTEL: NPTEL YouTube Channel

Table: Matrix to describe the mapping of COs with POs (considering WKs) and PSOs

CO \ Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	Dominant WKs
CO1	3	1	–	–	–	–	2	–	–	–	–	2	–	WK1, WK2
CO2	3	3	2	1	1	–	2	–	–	–	–	3	1	WK1–WK4
CO3	2	3	1	1	–	–	3	–	–	–	–	2	2	WK1–WK4
CO4	2	2	2	1	1	–	3	–	–	–	–	2	3	WK1–WK5

Course Code		**:**	**22UME751E**	**Product Design & Rapid Prototyping**	**Semester**	**:**	**06**
L:T:P		**:**	**3:0:0**		**Course Type**	**:**	**PEC - II**
Hours/Sem.	**Teaching**	**:**	**42Hrs**		**CIE Marks**	**:**	**50**
	Learning (TW+SL)	**:**	**42Hrs**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06Hrs**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90Hrs**		**Credits**	**:**	**03**

Professional Competency:

Develop the ability to apply product design principles, Design for Manufacture and Assembly (DFMA), and rapid prototyping technologies to design, evaluate, and realize engineering products that are manufacturable, functional, sustainable, and industry-oriented.

Course Outcomes:

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

CO1: Explain the fundamental concepts, objectives, requirements and product development process, including Design for Manufacture and Concurrent Engineering.

CO2: Apply Design for Manufacture and Assembly (DFMA), maintainability, environment, safety and ergonomic principles in product design.

CO3: Analyze prototype development, rapid prototyping principles and stereo lithography systems for engineering applications.

CO4: Evaluate different rapid prototyping technologies such as SLS, FDM, LOM and SGC for suitable product development applications.

UNIT-I	**11 Hrs.**

Introduction to Product Design: Definition, importance, objectives and essential requirements of product design. Product designer and project team. Steps in new product development, characteristics of successful product development, duration and cost of product development, challenges in product development, Design for Manufacture (DFM), Design for Remanufacture, Sequential Engineering and Concurrent Engineering.

Design for Manufacture and Assembly (DFMA): History of DFMA, implementation of Design for Assembly, Design for Manufacture, working methodology of DFMA and advantages of DFMA in product development.

Design Considerations: Design for Maintainability, Design for Environment, Design for Safety, Vision and Illumination Design.

UNIT–II	**10 Hrs.**

Development Processes and Organizations: Introduction to product development process, generic development process, market-pull and technology-push products, usefulness of a well-defined development process, tasks and responsibilities of marketing, design and manufacturing teams.

Concept Development: Front-end process, adopting generic product development process, process flow diagrams for different product variants (market-pull, technology-push and complex systems), functional, project and matrix product development organizations.

UNIT–III	**11 Hrs.**

Introduction to Additive Manufacturing: Prototype fundamentals, definition and types of prototypes, need for time compression in product development, Rapid Prototyping (RP) fundamentals, RP wheel, history and growth of Rapid Prototyping industry, applications of RP.

Rapid Prototyping Processes: Basic principles of rapid prototyping, classification of RP systems, advantages and limitations.

Stereo lithography (SLA): Principle, process details, materials used, advantages, disadvantages and applications.

UNIT–IV	**11 Hrs.**

Selective Laser Sintering (SLS): Principle, process details, materials used, advantages, disadvantages and applications.

Fused Deposition Modelling (FDM): Principle, process details, materials used, advantages, disadvantages and applications.
Laminated Object Manufacturing (LOM): Principle, process details, materials used, advantages, disadvantages and applications.
Solid Ground Curing (SGC): Principle of operation, machine details, advantages, disadvantages and applications.

Text Books :

1. Karl T. Ulrich and Steven D. Eppinger, Product Design and Development, 7th Edition, McGraw-Hill, 2020.
2. C. K. Chua, K. F. Leong and C. S. Lim, Rapid Prototyping: Principles and Applications, 3rd Edition, World Scientific Publishing

Reference Books :

1. **Ian Gibson, David Rosen and Brent Stucker**, *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping and Direct Digital Manufacturing*, 3rd Edition, Springer, 2021
2. **Andreas Gebhardt and Jan-Steffen Hötter,** *Additive Manufacturing: 3D Printing for Prototyping and Manufacturing,* Hanser Publications, 2016

Web links and Video Lectures (e-Resources):

1. https://www.youtube.com/watch?v=HN9GtL21rb4&list=PLSGws_74K018yZOnbSaqWJZ837QyBB7vu
2. https://www.youtube.com/watch?v=JNzvLWC2cGQ
3. https://www.youtube.com/watch?v=Fi7RXDUuX7I&list=PLQmc-I2-FO2Gnp2s74U5fBjfHDg1tUbOh
4. https://www.youtube.com/results?search_query=additive+manufacturing

Table: Matrix to describe the mapping of COs with POs (considering WKs) and PSOs

Course Outcomes (COs)	Program Outcomes and (WKs)											Program Specific Outcomes (PSOs)	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3 (WK1, WK2, WK3, WK4)	2 (WK1, WK2, WK3, WK4)	1 (WK5)	–	2 (WK6)	1 (WK7)	–	–	–	–	–	2	2
CO2	2 (WK1, WK2, WK3, WK4)	3 (WK1, WK2, WK3, WK4)	2 (WK5)	2 (WK5)	3 (WK6)	1 (WK7)	–	–	–	–	–	2	3
CO3	3 (WK1, WK2, WK3, WK4)	2 (WK1, WK2, WK3, WK4)	3 (WK5)	2 (WK5)	2 (WK6)	–	–	–	–	–	–	2	2
CO4	2 (WK1, WK2, WK3, WK4)	3 (WK1, WK2, WK3, WK4)	3 (WK5)	2 (WK5)	3 (WK6)	2 (WK5, WK7)	–	–	–	–	–	3	2

Course Code		**:**	**22UME752E**	**NON DESTRUCTIVE TESTING**	**Semester**	**:**	**07**
L:T:P		**:**	**3:0:0**		**Course Type**	**:**	**PEC - III**
Hours/Sem.	**Teaching**	**:**	**42Hrs**		**CIE Marks**	**:**	**50**
	Learning (TW+SL)	**:**	**42Hrs**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06Hrs**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90Hrs**		**Credits**	**:**	**03**

Professional Competency:

Apply appropriate non-destructive testing (NDT) techniques to inspect engineering components, identify defects, evaluate test results, and prepare inspection reports for industrial quality assurance and reliability.

Course Outcomes (COs):

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

CO1: To have a basic knowledge of surface N D E techniques which enable to carry out various inspection in accordance with the established procedures.

CO2: Differentiate various defect types and select the appropriate N D T methods for better evaluation

CO3: Documentation of the testing and evaluation of the results for further analysis

CO4: Students will be able to understand significance and suitability of various non destructive testing methods in industrial application.

UNIT-I **11 Hrs.**

Introduction to ND Testing: Information gathered from NDT, Defects in manufacturing Advantages and disadvantages of NDT, Comparison of destructive & Non-destructive tests, Methods of NDT, Common application of NDT, Flaw detection & evaluation, leak detection & evaluation, Non Destructive Evaluation, visual inspection

Replication microscopy technique for Non Destructive Evaluation: Specimen preparation, replication techniques, and micro structural analysis

UNIT–II **10 Hrs.**

Liquid Penetrant Inspection: Principles, penetrant methods, procedure, materials used, equipment, parameters and applications.

Magnetic Particle Inspection: Principle, general procedure, advantages & limitations , applications , magnetic field generation, types of magnetic particles and suspension liquids, Direction of the Magnetic Field ,Importance of Magnetic Field Direction

UNIT–III **10 Hrs.**

Radiography Inspection: principle, X-ray radiography, equipment, Gamma-ray radiography, real time radiography & film radiography , radiation safety ,advantages, disadvantages and applications of radiography

Computed tomography: Principles, capabilities, comparison to other NDE methods, CT equipments, industrial computed tomography applications

UNIT–IV **11 Hrs.**

Ultrasonic Inspection: Basic equipment, advantages & limitations, inspection methods pulse echo A, B, C scans transmission transducers & couplants.

Thermal Inspection: Principles, equipment, inspection methods applications.

Eddy Current Inspection: Principles of operation, procedure, advantages & limitations, operating variables, inspection coils, eddy current instruments, application examples.

Text Books :

1. American Society for Metals (ASM). Nondestructive Evaluation and Quality Control, ASM Metals Handbook, Vol. 17, 9th Edition, ASM International, Materials Park, Ohio, USA, 2001.
2. McGonnagle, J. J. Nondestructive Testing, Gordon and Breach Science Publishers, New York, Revised

Edition, 1982.
3. Baldev Raj, T. Jayakumar, and M. Thavasimuthu. Practical Non-Destructive Testing, 3rd Edition, Narosa Publishing House, New Delhi, 2018.
4. Hellier, Charles. Handbook of Nondestructive Evaluation, 2nd Edition, McGraw-Hill Education, New York, 2013.

Reference Books :

1.Non Destructive Evalution And Quality Control, Metals Hand Book, American Society Of Metals, 9th , Edition 2001

2.Non Destructive –Garden And Reach, Mc Gonnagle Jj Newyork

Web links and Video Lectures (e-Resources):

https://www.youtube.com/@twiglobal
https://www.youtube.com/@nptelhrd
https://www.youtube.com/@EVIDENTIndustrial
https://www.youtube.com/@ASNTInfo

CO–PO Mapping (Indicative):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO 11	PSO 1	PS O2
CO1	3 (WK1, WK2, WK3, WK4)	1 (WK1, WK2, WK3)	–	–	3 (WK5)	–	3 (WK7)	1 (WK7)	3 (WK6)	1 (WK9)	–	2 (WK5)	–
CO2	2 (WK1, WK2, WK3, WK4)	1 (WK2, WK3, WK4)	–	1 (WK4, WK5)	1 (WK5, WK6)	–	2 (WK7)	–	3 (WK6)	–	–	2 (WK5)	–
CO3	3 (WK1, WK2)	–	–	2 (WK4, WK5, WK8)	–	1 (WK5 , WK6)	1 (WK7)	2 (WK7)	2 (WK6)	–	–	–	2 (WK 5)
CO4	1 (WK1, WK2)	2 (WK2, WK3, WK4)	1 (WK4, WK5)	2 (WK5, WK8)	–	–	–	1 (WK7)	–	2 (WK9)	–	1 (WK5)	1 (WK 5)

Course Code		**:**	**22UME753E**	**Project Management**	**Semester**	**:**	**VI**
L:T:P*		**:**	**3 : 0 : 0**		**Course Type**	**:**	**PEC-IV**
Hours/Sem.	**Teaching**	**:**	**42 Hrs.**		**CIE Marks**	**:**	**50**
	Learning (TW+SL)	**:**	**42 Hrs.**		**SEE Marks**	**:**	**50**
	Exam	**:**	**06 Hrs.**		**Total Marks**	**:**	**100**
	Total Hrs.	**:**	**90 Hrs.**		**Credits**	**:**	**03**

Professional Competency:

Develop the ability to plan, organize, execute, and monitor projects efficiently by applying project management principles, tools, and techniques. Enhance leadership, teamwork, communication, and decision-making skills to deliver projects successfully within scope, time, cost, and quality constraints.

Course Outcomes:

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

CO1: Demonstrate the Concepts of PM in terms of Project Life Cycle, Project Managers, Selection of Projects, Market Survey, Demand Forecasting and Choice of technology needed for projects.

CO2: Identify and Analyze the Skills, Abilities, Authorities and Responsibilities of a project manager. Reinforce project implementation techniques through Gantt chart, PERT and CPM.

CO3: Exhibit attitude towards Co-ordination, Communication & information system required for a project. Perform scheduling, monitoring, and controlling the work-progress of a project.

CO4: Demonstrate effective & integrative Strategies, types & possible evaluation of project termination and display ethical dimensions of project inventory management.

UNIT–I	**11Hrs.**

Projects in Contemporary Organization: Introduction, Three Project Objectives, The Definition of a Project, Why Project Management? The Project Life Cycle, Risk during the Project Life Cycle, The Vital Dozen for Project Managers.

The Project manager: Project Management and the Project manager: Introduction, Project Responsibilities, Project Manager-Career Paths, Special demands on the Project Manager, Selecting the Project Manager, The Project Management Office (PMO), Purposes of PMO, Tasks of PMO, The Project Team.

UNIT–II	**10Hrs.**

Project Initiation: Strategic Management and Project Selection: Project selection and Criteria of choice, The Nature of project selection models, Types of Project selection models, Numeric Models: Payback Period, Average Rate of Return, Discounted Cash Flow or Net Present Value, Internal Rate of Return, Profitability Index, Non-Numeric Models: The Sacred Cow, The Operating Necessity, The Competitive Necessity, The Product Line Extension, Comparative Benefit Model, Project Portfolio Process, Project Proposals.

Project Initiation: Project Organization and Planning: Functional Organization, Project Organization, Matrix Organization, Mixed Organization systems, Organizing Risk Management, Steps in Project planning, Project plan elements.

UNIT–III	**11Hrs.**

Project Implementation: Scheduling and Control: Introduction to project scheduling, Network Techniques: PERT and CPM, Constructing Network Diagram Calculating activity times, Critical path and critical time, Problems to calculate project duration and finding critical path.

Project Implementation: Budgeting and Cost Estimating: Estimating project budgets: Top-Down budgeting, Bottom-Up budgeting, Work Element costing, An Iterative budgeting process

UNIT–IV	**10Hrs.**

Project Auditing: Purposes or need of evaluation, The project audit, The project audit life cycle, Audit report: Preparation and Use.

Project Termination: Varieties of project termination, Termination by Extinction, Termination by Addition, Termination by Integration, Termination by Starvation, When to terminate a project, Termination process, Final report of project history

Text Books:

1. Jack R. Meredith & Scott M. Shafer, Project Management: A Strategic Managerial Approach, Wiley publishers, 11th Edition, 2022.
2. Project Management Institute (PMI) (2025), A Guide to the Project Management Body of Knowledge (PMBOK® Guide), PMI, 8th Edition, 2025.

Reference Books:

1. Harold Kerzner, Project Management: A Systems Approach to Planning, Scheduling, and Controlling, Wiley, 14th Edition, 2025.
2. Erik W. Larson, Clifford F. Gray and Pinyarat Sirisom boonsuk, Project Management: A Socio-Technical Approach, McGraw-Hill, 9th Edition, 2025.
3. Jack Gido, Joseph P. Clements and James P. Clements, Successful Project Management, Cengage Learning, 8th Edition, 2022.
4. James P. Lewis, Fundamentals of Project Management, HarperCollins Leadership, 6th Edition, 2021.
5. John M. Nicholas & Herman Steyn, Project Management for Engineering, Business and Technology, 6th Edition, 2020, Routledge
6. David I. Cleland & Lewis R. Ireland, Project Management: Strategic Design and Implementation, 6th Edition, 2006, McGraw-Hill

Web Links and Video Lectures (e-Resources):

1. https://www.youtube.com/watch?v=3W4aAcwLbrk
2. https://www.youtube.com/watch?v=rPQQ7eeba7U
3. https://www.youtube.com/playlist?list=PL38ngI1g1aXrVejeUNr4ampazkoPUhKR0
4. https://www.youtube.com/watch?v=uWPIsaYpY7U
5. https://www.youtube.com/watch?v=HrEIcyJUs6c

Table 5: Matrix to describe the mapping of COs with POs (considering WKs) and PSOs

Course Outcomes (COs)	Program Outcomes and (WKs)											Program Specific Outcomes (PSOs)	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	**2** (WK1, WK2, WK3, WK4)	**3** (WK1, WK2, WK3, WK4)	**2** (WK5)	**1** (WK5)	–	**1** (WK1, WK5, WK7)	–	**1**	**1**	**1**	**1** (WK8)	**2**	**2**
CO2	–	**2** (WK1, WK2, WK3, WK4)	**3** (WK5)	**2** (WK5)	**3** (WK6)	**2** (WK1, WK5, WK7)	–	**1**	**2**	**1**	**1** (WK8)	**3**	**2**
CO3	–	**2** (WK1, WK2, WK3, WK4)	**3** (WK5)	**2** (WK5)	**3** (WK6)	**2** (WK1, WK5, WK7)	**1**	**1**	**3**	**2**	**1** (WK8)	**2**	**3**
CO4	–	**2** (WK1, WK2, WK3, WK4)	**2** (WK5)	**2** (WK5)	**2** (WK6)	**2** (WK1, WK5, WK7)	**2**	**2**	**2**	**2**	**2** (WK8)	**2**	**3**

Course Code		:	22UME754E	Operations Management	Semester	:	07
L:T:P		:	3:0:0		Course Type	:	PEC - III
Hours/Sem.	Teaching	:	42Hrs		CIE Marks	:	50
	Learning (TW+SL)	:	42Hrs		SEE Marks	:	50
	Exam	:	06Hrs		Total Marks	:	100
	Total Hrs.	:	90Hrs		Credits	:	03

Professional Competency:

Apply operations management principles, forecasting techniques, facility planning methods, production system design, and modern manufacturing practices to improve productivity, quality, and operational efficiency in manufacturing and service organizations.

Course Outcomes:

CO1: Explain the principles of operations management, production systems, product design, and productivity improvement techniques.
CO2: Apply forecasting models and facility location techniques to support production planning and decision-making.
CO3: Analyze plant layouts and assembly line balancing methods to improve manufacturing system performance.
CO4: Evaluate modern production management techniques such as JIT, Lean Manufacturing, Kaizen, and Total Quality Management for continuous process improvement.

UNIT-I	10 Hrs.

INTRODUCTION: Functional subsystems of organization, System concept of production, Types of production system, Productivity, strategic management, World class manufacturing.
PRODUCT DESIGN AND ANALYSIS: New product development concepts, Process planning and design, Value analysis/Value engineering, Make or buy decision, Ergonomic consideration in product design

UNIT–II	11 Hrs.

FORECASTING: Nature and use of forecasting, Sources of data, Demand patterns, Factors affecting forecast, types of forecasting, Forecasting Models – Linear Regression, Simple moving average, weighted moving average, e, Single exponential smoothing, Double exponential smoothing, Adjusted exponential smoothing and Delphi method.
FACILITY LOCATION: Introduction, factors influencing plant location, break even analysis, single facility location problem, Minimax location problem and gravity location problem.

UNIT–III	11 Hrs.

PLANT LAYOUT: Introduction, Classification of layout, Layout design procedures – Computerized Relative Allocation of Facilities Technique (CRAFT), Automated Layout Design Program (ALDEP) and, Computerized Relationship Layout Planning (CORELAP).
LINE BALANCING: Concept of mass production system, objective of assembly line balancing, rank positional weight method and the COMSOL Algorithm.

UNIT–IV	10 Hrs.

MODERN PRODUCTION MANAGEMENT TOOLS: Just-In-Time manufacturing – introduction and overview of JIT, basic principles, push/pull production, Kanban systems (pull systems). Total Quality Management – scope of TQM, benefits of TQM, quality control activities during product cycle, operating quality costs. Kaizen – Key elements of kaizen, classification of kaizen, steps of implementation of kaizen Blitz, guidelines of kaizen team, benefits of kaizen. Lean Manufacturing – steps of lean manufacturing, components of lean manufacturing.

Text Books:
1. R. Panneerselvam, **"Production and Operations Management"**, PHI Learning Pvt. Ltd., 3rd Edition, 2019. 2. Richard B. Chase, F. Robert Jacobs & Nicholas J. Aquilano, **"Operations and Supply Chain Management"**, McGraw-Hill Education, 16th Edition, 2021. 3. William J. Stevenson, **"Operations Management"**, McGraw-Hill Education, 14th Edition, 2021.
Reference Books:
1. Elsayed A. Elsayed & Thomas O. Boucher, **"Analysis and Control of Production Systems"**, Pearson Education. 2. R. B. Khanna, **"Production and Operations Management"**, PHI Learning. 3. S. N. Chary, **"Production and Operations Management"**, McGraw-Hill Education.
Web Links and Video Lectures (e-Resources):
1. PTEL – Operations Management 2. NPTEL – Production Planning and Control 3. MIT OpenCourseWare – Operations Management 4. APICS Learning Resources 5. ASQ (American Society for Quality)

Matrix Describing the Mapping of COs with POs (Considering WKs) and PSOs

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO 10**	**PO 11**	**PS O1**	**PS O2**
CO1	3 (WK1, WK2, WK3)	3 (WK2, WK4)	2 (WK5)	–	2 (WK6)	–	–	–	–	1	2	3	2
CO2	3 (WK1, WK2, WK3)	3 (WK2, WK4)	3 (WK5)	2 (WK8)	3 (WK6)	1 (WK7)	–	–	–	1	2	3	3
CO3	3 (WK2, WK3, WK4)	3 (WK4, WK8)	3 (WK5)	3 (WK8)	3 (WK6)	2 (WK7)	1 (WK7)	–	–	1	2	3	3
CO4	2 (WK2, WK3)	3 (WK4, WK8)	2 (WK5)	3 (WK8)	3 (WK6)	2 (WK7)	2 (WK7)	1 (WK9)	–	2	2	3	3
CO5	3 (WK1, WK2, WK3)	3 (WK2, WK4)	2 (WK5)	–	2 (WK6)	–	–	–	–	1	2	3	2