R23 Regulations

B.Tech Curriculum - OPEN ELECTIVES

Offered by the department of **Mechanical Engg**

S.No	Category	Titles
1	Open Elective -1	Entrepreneurship Development & Venture Creation 1. Sustainable Energy Technologies 2. Applied Operations Research 3. Nano Technology 4. Thermal Management of Electronic systems 5. Entrepreneurship
2	Open Elective-2	1. Introduction to Industrial Robotics 2. Industrial Management 3. Additive Manufacturing 4. Vehicle Technology 5. Industrial Safety
3	Open Elective-3	1. Finite Element Methods 2. Introduction to Mechatronics 3. Product design and development 4. Advanced Materials 5. Introduction to Smart Manufacturing
4	Open Elective-4	1. Optimization Techniques 2. Advanced Manufacturing Processes 3. Total Quality Management 4. Operations Management 5. Energy Auditing 6. Quantum Science and Technology

III Year I Semester	SUSTAINBLE ENERGY TECHNOLOGIES	L	T	P	C
		3	0	0	3

Course objectives:

1. To demonstrate the importance the impact of solar radiation, solar PVmodules
2. To understand the principles of storage in PV systems
3. To discuss solar energy storage systems and their applications.
4. To get knowledge in wind energy and bio-mass
5. To gain insights in geothermal energy, ocean energy and fuel cells.

UNIT – 1

SOLAR RADIATION: Role and potential of new and renewable sources, the solar energy option, Environmental impact of solar power, structure of the sun, the solar constant, sun-earth relationships, coordinate systems and coordinates of the sun, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation and sun shine, solar radiation data, numerical problems.

SOLAR PV MODULES AND PV SYSTEMS:

PV Module Circuit Design, Module Structure, Packing Density, Interconnections, Mismatch and Temperature Effects, Electrical and Mechanical Insulation, Lifetime of PV Modules, Degradation and Failure, PV Module Parameters, Efficiency of PV Module, Solar PV Systems-Design of Off Grid Solar Power Plant. Installation and Maintenance.

UNIT – 2

STORAGE IN PV SYSTEMS:

Battery Operation, Types of Batteries, Battery Parameters, Application and Selection of Batteries for Solar PV System, Battery Maintenance and Measurements, Battery Installation for PV System.

UNIT – 3

SOLAR ENERGY COLLECTION: Flat plate and concentrating collectors, classification of concentrating collectors, orientation.

SOLAR ENERGY STORAGE AND APPLICATIONS: Different methods, sensible, latent heat and stratified storage, solar ponds, solar applications- solar heating/cooling technique, solar distillation and drying, solar cookers, central power tower concept and solar chimney.

UNIT – 4

WIND ENERGY: Sources and potentials, horizontal and vertical axis windmills, performance characteristics, betz criteria, types of winds, wind data measurement.

BIO-MASS: Principles of bio-conversion, anaerobic/aerobic digestion, types of bio-gas digesters, gas yield, utilization for cooking, bio fuels, I.C. engine operation and economic aspects.

UNIT – 5

GEOTHERMAL ENERGY: Origin, Applications, Types of Geothermal Resources, Relative Merits

OCEAN ENERGY: Ocean Thermal Energy; Open Cycle & Closed Cycle OTEC Plants, Environmental Impacts, Challenges

FUEL CELLS: Introduction, Applications, Classification, Different Types of Fuel Cells Such as Phosphoric Acid Fuel Cell, Alkaline Fuel Cell, PEM Fuel Cell, MC Fuel Cell.

Text Books:

1. Solar Energy – Principles of Thermal Collection and Storage/Sukhatme S.P. and J.K.Nayak/TMH
2. Non-Conventional Energy Resources- Khan B.H/ Tata McGraw Hill, New Delhi, 2006
3. Green Manufacturing Processes and Systems - J. Paulo Davim/Springer 2013

References:

1. Principles of Solar Engineering - D.Yogi Goswami, Frank Krieth& John F Kreider / Taylor &Francis
2. Non-Conventional Energy - Ashok V Desai /New Age International (P) Ltd
3. Renewable Energy Technologies -Ramesh & Kumar /Narosa
4. Non-conventional Energy Source- G.D Roy/Standard Publishers

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

CO1	Illustrate the importance of solar radiation and solar PV modules.
CO2	Discuss the storage methods in PV systems
CO3	Explain the solar energy storage for different applications
CO4	Understand the principles of wind energy, and bio-mass energy.
CO5	Attain knowledge in geothermal energy, ocean energy and fuel cells.

III Year I Semester	APPLIED OPERATIONS RESEARCH	L	T	P	C
		3	0	0	3

Course Objectives: To

1. Understand Linear Programming models
2. Learn Transportation and sequencing problems
3. Solve replacement problems and analyze games theory models
4. Understand waiting line and project management problems
5. Learn dynamic programming and simulation.

UNIT – 1

INTRODUCTION - definition– characteristics and phases – types of operation research models – applications.

Linear programming: Problem formulation – graphical solution – simplex method – artificial variables techniques -two–phase method, big-M method – duality principle.

UNIT – 2

TRANSPORTATION PROBLEM: Formulation – optimal solution, unbalanced transportation problem – degeneracy, assignment problem – formulation – optimal solution - variants of assignment problem- travelling salesman problem.

SEQUENCING – Introduction – flow –shop sequencing – *n* jobs through two machines – *n* jobs through three machines – job shop sequencing – two jobs through 'm' machines.

UNIT – 3

REPLACEMENT THEORY: Introduction – replacement of items that deteriorate with time – when money value is not counted and counted – replacement of items that fail completely, group replacement.

GAME THEORY: Introduction – mini. max (max. mini) – criterion and optimal strategy – solution of games with saddle points – rectangular games without saddle points – 2 x 2 games – dominance principle – m x 2 & 2 x n games -graphical method.

UNIT – 4

WAITING LINES: Introduction – single channel – poison arrivals – exponential service times – with infinite population and finite population models– multichannel – poison arrivals – exponential service times with infinite population single channel.

PROJECT MANAGEMENT: Basics for construction of network diagram,Program Evaluation and Review Technique (PERT), Critical Path Method (CPM) – PERT Vs. CPM, determination of floats- Project crashing and its procedure.

UNIT – 5

DYNAMIC PROGRAMMING: Introduction – Bellman's principle of optimality – applications of dynamic programming-shortest path problem – linear programming problem.

SIMULATION: Definition – types of simulation models – phases of simulation– applications of simulation – inventory and queuing problems – advantages and disadvantages

Text Books:

1. Operations Research-An Introduction/Hamdy A Taha/Pearson publishers

2. Operations Research –Theory & publications / S.D.Sharma Kedarnath/McMillan publishers India Ltd

References:

1. Introduction to O.R/Hiller & Libermann/TMH
2. Operations Research /A.M. Natarajan, P. Balasubramani, A. Tamilarasi /Pearson Education.
3. Operations Research: Methods & Problems / Maurice Saseini, ArhurYaspan& Lawrence Friedman/Wiley
4. Operations Research / R.Pannerselvam/ PHI Publications.
5. Operations Research / Wagner/ PHI Publications.
6. Operation Research /J.K.Sharma/Macmillan Publ.
7. Operations Research/ Pai/ Oxford Publications
8. Operations Research/S Kalavathy / Vikas Publishers
9. Operations Research / DS Cheema/University Science Press
10. Operations Research / Ravindran, Philips, Solberg / Wiley publishers

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

CO1 Understand Linear Programming models

CO2 Interpret Transportation and sequencing problems

CO3 Solve replacement problems and analyze queuing models

CO4 Understand game theory and inventory problems

CO5 Interpret dynamic programming and simulation.

III Year I Semester	NANO TECHNOLOGY	L	T	P	C
		3	0	0	3

Course Objectives:

1. To understand the classification of Nano structured Materials
2. To understand the unique properties of Nano materials
3. To interpret the Synthesis Routes - Bottom up and Top down approaches
4. To identify the tools to characterize Nano materials
5. To understand the applications of Nano materials

UNIT – 1

INTRODUCTION: History and Scope, Classification of Nano structured Materials, Fascinating Nanostructures, and applications of nano-materials, challenges and future prospects.

UNIT – 2

UNIQUE PROPERTIES OF NANO MATERIALS: Microstructure and Defects in Nano crystalline Materials: Dislocations, Twins, stacking faults and voids, Grain Boundaries, triple and disclinations. Effect of Nano-dimensions on Materials Behavior: Elastic properties, Melting Point, Diffusivity, Grain growth characteristics, enhanced solid solubility. Magnetic Properties: Soft magnetic nanocrystalline alloy, Permanent magnetic nanocrystalline materials, Giant Magnetic Resonance, Electrical Properties, Optical Properties, Thermal Properties and Mechanical Properties.

UNIT – 3

SYNTHESIS ROUTES: Bottom up approaches: Physical Vapor Deposition, Inert Gas Condensation, Laser Ablation, Chemical Vapor Deposition, Molecular Beam Epitaxy, Sol-gel method, Self-assembly. Top down approaches: Mechanical alloying, Nano-lithography. Consolidation of Nano powders: Shock wave consolidation, Hot iso-static pressing and Cold iso-static pressing, Spark plasma sintering.

UNIT – 4

TOOLS TO CHARACTERIZE NANOMATERIALS: X-Ray Diffraction (XRD), Small Angle X-ray scattering, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunneling Microscope (STM), Field Ion Microscope (FEM), Three-dimensional Atom Probe (3DAP), Nano indentation.

UNIT – 5

APPLICATIONS OF NANO MATERIALS: Nano-electronics, Micro- and Nano-electromechanical systems (MEMS/NEMS),Nano sensors, Nano catalysts, Food and Agricultural Industry, Cosmetic and Consumer Goods, Structure and Engineering, Automotive Industry, Water-Treatment and the environment, Nano-medical applications, Textiles, Paints, Energy, Defense and Space Applications, Concerns and challenges of Nanotechnology

TEXT BOOKS:

1. Introduction to Nano Technology by Charles. P. Poole Jr& Frank J. Owens.Wiley India Pvt. Ltd.
2. Nano Materials- A.K.Bandyopadhyay/ New Age Publishers.
3. Nano Essentials- T.Pradeep/TMH

REFERENCE BOOKS:

1. Solid State physics by Pillai, Wiley Eastern Ltd.
2. Introduction to solid state physics 7th edition by Kittel. John Wiley & sons (Asia) Pvt Ltd.

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

CO1 Understand the classification of nanostructured Materials

CO2 Understand the unique properties of nano materials

CO3 Interpret the Synthesis Routes - Bottom up and Top down approaches

CO4 Identify the tools to characterize nano materials

CO5 Understand the applications of nano materials

III Year I Semester	THERMAL MANAGEMENT OF ELECTRONIC SYSTEMS	L	T	P	C
		3	0	0	3

Course Objective:

1. To understand the basics of heat transfer and analyze heat transfer through fins
2. To acquire the knowledge on Free and forced convective systems.
3. To understand the air cooling and single phase liquid cooling systems with case studies.
4. To demonstrate the concepts of two phase cooling and heat pipes.
5. To understand thermo electric coolers, mini and micro channels.

UNIT – 1

Introduction of Heat Transfer: Modes – Conduction, Convection and Radiation – Basic Laws – Applications of Heat Transfer.

Basics of Conduction –Conduction equation – Thermal analogy – Lumped heat capacity analysis - Heat conduction with phase change - Thermal Resistance – Extended Surfaces – Uniform cross section fins – Fin efficiency – Selection and design of fins

UNIT – 2

Forced and Free Convection – Heat transfer coefficient - Parameters effecting heat transfer – Thermal Properties of fluids - Combined Modes.

Radiation – Stefan- Boltzmann Law – Kirchoff's law and Emissivity – Radiation between Black Isothermal Surfaces – Radiation between Grey Isothermal Surfaces – Extreme Climatic conditions - Radiation at normal ambient Temperature measurement and its Instrumentation.

UNIT – 3

Printed Circuit boards – Chip packaging – thermal Resistance – Board Cooling methods – Board thermal Analysis – Equivalent thermal Conductivity.

Air Cooling – Fans – Heat transfer Enhancement – Air handling systems - Blowers

Single Phase Cooling – Coolant Selection – Natural Convection – Forced Convection - Air Cooling - Convective cooling in Small systems – Forced cooling in medium and large systems – Liquid cooling in high power modules – Case Studies.

UNIT – 4

Two Phase Cooling – Direct Immersion Cooling – Basics of Pool Boiling – Enhancement of Pool Boiling – Flow Boiling.

Heat Pipes – Operation Principles – Useful Characteristics – Operating Limits and Temperatures – Operation Methods – Applications – Micro Heat Pipes.

UNIT – 5

Thermo Electric coolers: Basics theories – Thermo electric effect – Operation Principles.

Phase change materials, Thermal Interface materials, Heat Spreaders and Heat Sinks – Working Principles

Mini and Micro Channels. Use of nano fluids in electronic cooling.

Text Books:

1. Thermal Analysis and Control of Electronic Equipment – Allan D. Kraus and Avram BarCohen, McGraw Hill, New York, NY, 1983.
2. Fundamentals of Microelectronics Packaging – Ed: Rao Tummala, McGraw Hill, New York, NY, 2001.
3. Packaging of Electronic Systems – James W. Dally, McGraw Hill, New York, NY, 1990.

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

CO1	Understand the basics of heat transfer and analyze heat transfer through fins
CO2	Acquire the knowledge on Free and forced convective systems
CO3	Understand the air cooling and single phase liquid cooling systems with case studies
CO4	Demonstrate the concepts of Two phase cooling and heat pipes
CO5	Understand thermo electric coolers, mini and micro channels

III Year I Semester	ENTREPRENEURSHIP	L	T	P	C
		3	0	0	3

Course objective:

1) To develop and strengthen entrepreneurial quality and motivation in students.
2) To impart basic entrepreneurial skills and understandings to run a business efficiently and effectively.

UNIT-I : ENTREPRENEURAL COMPETENCE

Entrepreneurship concept – Entrepreneurship as a Career – Entrepreneurial Personality - Characteristics of Successful, Entrepreneur – Knowledge and Skills of Entrepreneur.

UNIT-II: ENTREPRENEURAL ENVIRONMENT

Business Environment - Role of Family and Society - Entrepreneurship Development Training and Other Support Organisational Services.

UNIT-III: INDUSTRIAL POLACIES

Central and State Government Industrial Policies and Regulations - International Business.

UNIT-IV: BUSINESS PLAN PREPARATION

Sources of Product for Business - Prefeasibility Study - Criteria for Selection of Product - Ownership - Capital - Budgeting Project Profile Preparation - Matching Entrepreneur with the Project - Feasibility Report Preparation and Evaluation Criteria.

UNIT- V: LAUNCHING OF SMALL BUSINESS

Finance and Human Resource Mobilization Operations Planning - Market and Channel Selection - Growth Strategies - Product Launching – Incubation, Venture capital, IT startups. Monitoring and Evaluation of Business - Preventing Sickness and Rehabilitation of Business Units- Effective Management of small Business.

TEXT BOOKS

1. Hisrich, Entrepreneurship, Tata McGraw Hill, New Delhi, 2001.
2. S.S.Khanka, Entrepreneurial Development, S.Chand and Company Limited, New Delhi, 2001.

REFERENCES

1. Mathew Manimala, Entrepreneurship Theory at the Crossroads, Paradigms & Praxis, Biztrantra ,2nd Edition ,2005
2. Prasanna Chandra, Projects – Planning, Analysis, Selection, Implementation and Reviews, Tata McGraw-Hill, 1996.
3. P.Saravanavel, Entrepreneurial Development, Ess Pee kay Publishing House, Chennai - 1997.
4. Arya Kumar. Entrepreneurship. Pearson. 2012 5. Donald F Kuratko, T.V Rao. Entrepreneurship: A South Asian perspective. Cengage Learning. 2012

III Year II Semester	INTRODUCTION TO INDUSTRIAL ROBOTICS	L	T	P	C
		3	0	0	3

Course Objectives: To

1. Discuss various applications and components of industrial robot systems
2. Learn about the types of actuators used in robotics
3. Calculate the forward kinematics and inverse kinematics.
4. Learn about programming principles and languages for a robot control system
5. Discuss the applications of image processing and machine vision in robotics.

UNIT – 1

INTRODUCTION: Automation and Robotics, CAD/CAM and Robotics – An overview of Robotics – present and future applications – classification by coordinate system and control system.

COMPONENTS OF THE INDUSTRIAL ROBOTICS:

Robot anatomy, work volume, components, number of degrees of freedom - robot drive systems, function line diagram representation of robot arms, common types of arms –– requirements and challenges of end effectors, determination of the end effectors.

UNIT – 2

ROBOT ACTUATORS AND FEED BACK COMPONENTS:

Actuators: Pneumatic, Hydraulic actuators, electric& stepper motors. Comparison of Electric, Hydraulic and Pneumatic types of actuation devices.

Feedback components: position sensors–potentiometers, resolvers, encoders–Velocity sensors.

UNIT – 3

MOTIO ANANALYSIS: Homogeneous transformations as applicable to rotation and translation – problems.

MANIPULATOR KINEMATICS: Specifications of matrices, D-H notation joint coordinates and world coordinates Forward and inverse kinematics–problems.

UNIT – 4

GENERAL CONSIDERATIONS IN PATH DESCRIPTION AND GENERATION: Trajectory planning and avoidance of obstacles, path planning, Skew motion, joint integrated motion –straight line motion–Robot programming, languages and software packages-description of paths with a robot programming language.

UNIT – 5

IMAGE PROCESSING AND MACHINE VISION: Introduction to Machine Vision, Sensing and Digitizing function in Machine Vision, Training and Vision System, Robotic Applications.

TEXTBOOKS:

1. Industrial Robotics/GrooverMP/Pearson Edu.

2. Robotics and Control /MittalR K &Nagrathi J /TMH.

REFERENCES:

1. Robotics/Fu KS/ McGraw Hill.
2. Robotic Engineering /Richard D. Klafter, PrenticeHall
3. Robot Analysis and Control/ H. Asada and J.J.E. Slotine/BSP Books Pvt.Ltd.
4. Introduction to Robotics/John J Craig/PearsonEdu.

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

CO1 Discuss various applications and components of industrial robot systems

CO2 Learn about the types of actuators used in robotics

CO3 Calculate the forward kinematics and inverse kinematics.

CO4 Learn about programming principles and languages for a robot control system

CO5 Discuss the applications of image processing and machine vision in robotics.

III Year II Semester	INDUSTRIAL MANAGEMENT	L	T	P	C
		3	0	0	3

Course Objectives: The objectives of the course are to

1) Introduce the scope and role of industrial engineering and the techniques for optimal design of layouts.
2) Illustrate how work study is used to improve productivity
3) Explain TQM and quality control techniques
4) Introduce financial management aspects and
5) Discuss human resource management and value analysis.

UNIT– I

INTRODUCTION: Definition of industrial engineering (I.E), development, applications, role of an industrial engineer, differences between production management and industrial engineering, quantitative tools of IE and productivity measurement. concepts of management, importance, functions of management, scientific management, Taylor's principles, theory X and theory Y, Fayol's principles of management.

PLANT LAYOUT: Factors governing plant location, types of production layouts, advantages and disadvantages of process layout and product layout, applications, quantitative techniques for optimal design of layouts, plant maintenance, preventive and break down maintenance.

UNIT–II

WORK STUDY: Importance, types of production, applications, work study, method study and time study, work sampling, PMTS, micro-motion study, rating techniques, MTM, work factor system, principles of Ergonomics, flow process charts, string diagrams and Therbligs.

UNIT–III

STATISTICAL QUALITY CONTROL: Quality control, Quality assurance and its importance, SQC, attribute sampling inspection with single and double sampling, Control charts – $\bar{X}$ and R –charts X and S charts and their applications, numerical examples.

TOTAL QUALITY MANAGEMENT: zero defect concept, quality circles, implementation, applications, ISO quality systems. Six Sigma–definition, basic concepts

UNIT– IV

FINANCIAL MANAGEMENT: Scope and nature of financial management, Sources of finance, Ratio analysis, Management of working capital, estimation of working capital requirements, stock management, Cost accounting and control, budget and budgetary control, Capital budgeting – Nature of Investment Decisions – Investment Evaluation criteria- NPV, IRR, PI, Payback Period, and ARR, numerical problems.

UNIT–V

HUMAN RESOURCEMANAGEMENT: Concept of human resource management, personnel management and industrial relations, functions of personnel management, Job-evaluation, its importance and types, merit rating, quantitative methods, wage incentive plans, and types.

VALUE ANALYSIS: Value engineering, implementation procedure, enterprise resource planning and supply chain management.

Text Books:

1.Industrial Engineering and Management/ O.P Khanna /Khanna Publishers.
2.Industrial Engineering and Production Management/Mart and Telsang / S.Chand&Company Ltd. New Delhi.

Reference Books:

1) Industrial Management/ Bhattacharya DK/ Vikas publishers
2) Operations Management/ J.GMonks / McGrawHilPublishers.
3) Industrial Engineering and Management Science/T.R. Banga, S.C.Sharma, N. K. Agarwal /Khanna Publishers
4) Principles of Management / KoontzO'Donnel/ McGraw Hill Publishers.
5) Statistical Quality Control / Gupta/ Khanna Publishers
6) Industrial Engineering and Management/ NVSRaju/ CengagePublishers

Course Outcomes: After completing this course, students will be able to:

1) Learn about how to design the optimal layout
2) Demonstrate work study methods
3) Explain Quality Control techniques
4) Discuss the financial management aspects and
5) Understand the human resource management methods.

III Year II Semester	ADDITIVE MANUFACTURING	L	T	P	C
		3	0	0	3

Course Objectives:

1. To understand the principles of prototyping, classification of RP processes and liquid-based RP systems
2. To understand and apply different types of solid-based RP systems.
3. To understand and apply powder-based RP systems.
4. To understand and apply various rapid tooling techniques.
5. To understand different types of data formats and to explore the applications of AM processes in various fields.

UNIT – 1

INTRODUCTION: Prototyping fundamentals, historical development, fundamentals of rapid prototyping, advantages and limitations of rapid prototyping, commonly used terms, classification of RP process.

LIQUID-BASED RAPID PROTOTYPING SYSTEMS: Stereo lithography Apparatus (SLA): models and specifications, process, working principle, photopolymers, photo polymerization, layering technology, laser and laser scanning, applications, advantages and disadvantages, case studies. Solid Ground Curing (SGC): models and specifications, process, working principle, applications, advantages and disadvantages, case studies.

UNIT – 2

SOLID-BASED RAPID PROTOTYPING SYSTEMS: Laminated object manufacturing (LOM) - models and specifications, process, working principle, applications, advantages and disadvantages, case studies. Fused deposition modelling (FDM) - models and specifications, process, working principle, applications, advantages and disadvantages, case studies.

UNIT – 3

POWDER BASED RAPID PROTOTYPING SYSTEMS: Selective laser sintering (SLS): models and specifications, process, working principle, applications, advantages and disadvantages, case studies. three dimensional printing (3DP): models and specifications, process, working principle, applications, advantages and disadvantages, case studies.

UNIT – 4

RAPID TOOLING: Introduction to rapid tooling (RT), conventional tooling Vs RT, Need for RT. rapid tooling classification: indirect rapid tooling methods: spray metal deposition, RTV epoxy tools, Ceramic tools, investment casting, spin casting, die casting, sand casting process. Direct rapid tooling: Direct AIM, LOM Tools, and Direct Metal Tooling using 3DP.

UNIT – 5

RAPID PROTOTYPING DATA FORMATS: STL Format, STL File Problems, consequence of building valid and invalid tessellated models, STL file Repairs: Generic Solution, other Translators, and Newly Proposed Formats.

RP APPLICATIONS: Application in engineering, analysis and planning, aerospace industry, automotive industry, jewelry industry, coin industry, GIS application, RP medical and bioengineering applications: customized implants and prosthesis, forensic sciences.

Text Books:

1.Rapid prototyping: Principles and Applications /Chua C.K., Leong K.F. and LIM C.S/World Scientific publications

References:

1. Rapid Manufacturing / D.T. Pham and S.S. Dimov/Springer
2. Wohlers Report 2000 /Terry T Wohlers/Wohlers Associates
3. Rapid Prototyping & Manufacturing / Paul F.Jacobs/ASME Press
4. Rapid Prototyping / Chua and Liou

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

CO1	Understand the principles of prototyping, classification of RP processes and liquid-based RP systems.
CO2	Understand and apply different types of solid-based RP systems.
CO3	Apply powder-based RP systems.
CO4	Analyze and apply various rapid tooling techniques.
CO5	Understand different types of data formats and explore the applications of AM processes in various fields.

III Year I Semester	VEHICLE TECHNOLOGY	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1.To study the advanced engine technologies
2.To learn various advanced combustion technologies and its benefits
3.To learn the methods of using low carbon fuels and its significance
4.To learn and understand the hybrid and electric vehicle configurations
5.To study the application of fuel cell technology in automotives

UNIT – I: ADVANCED ENGINE TECHNOLOGY

Gasoline Direct Injection, Common Rail Direct Injection, Variable Compression Ratio Turbocharged Engines, Electric Turbochargers, VVT, Intelligent Cylinder De-activation, After Treatment Technologies, Electric EGR, Current EMS architecture.

UNIT – II: COMBUSTION TECHNOLOGY

Spark Ignition combustion, Compression Ignition Combustion, Conventional Dual Fuel Combustion, Low Temperature Combustion Concepts– Controlled Auto Ignition, Homogeneous Charge Compression Ignition, Premixed Charge Compression Ignition, Partially Premixed Compression Ignition, Reactivity Controlled Compression Ignition, Gasoline Direct Injection Compression Ignition.

UNIT – III: LOW CARBON FUEL TECHNOLOGY

Alcohol Fuels, Ammonia Fuel and Combustion, Methane Technology, Dimethyl Ether, Hydrogen Fuel Technology, Challenges, and way forward

UNIT – IV: HYBRID AND ELECTRIC VEHICLE (BATTERY POWERED)

Conventional Hybrids (Conventional ICE + Battery), Modern Hybrids (RCCI/GDCI Engine + Battery), Pure Electric Vehicle Technology – Challenges and Way forward

UNIT – V: FUEL CELL TECHNOLOGY

Fuel cells for automotive applications - Technology advances in fuel cell vehicle systems - Onboard hydrogen storage - Liquid hydrogen and compressed hydrogen - Metal hydrides, Fuel cell control system - Alkaline fuel cell - Road map to market.

TEXT BOOKS:

1.Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2.Rakesh Kumar Maurya, Characteristics and Control of Low Temperature Combustion Engines. ISBN 978-3-319-68507-6 , SPRINGER

REFERENCES:

1.Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2.James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003
3.Rand D.A.J, Woods, R & Dell RM Batteries for Electric vehicles, John Wiley & Sons, 1998
4.Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
5.James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003

Course Outcomes*:* At the end of the course the students would be able to

1. Discuss the latest trends in engine technology
2. Discuss the need of advanced combustion technologies and its impact on reducing carbon foot-print on the environment.
3. Analyzing the basic characteristics of low carbon fuels, its impact over conventional fuels and in achieving sustainable development goals.
4. Discuss the working and energy flow in various hybrid and electric configurations.
5. Analyzing the need for fuel cell technology in automotive applications.

III Year II Semester	INDUSTRIAL SAFETY	L	T	P	C
		3	0	0	3

Course objectives:

1) To understand the concepts of industrial safety and management.
2) To demonstrate the accident preventions and protective equipment.
3) To understand and apply the knowledge of safety acts
4) To have the knowledge about fire prevention and protection systems
5) To understand and apply fire safety principles in buildings

UNIT-I

INTRODUCTION TO THE DEVELOPMENT OF INDUSTRIAL SAFETY AND MANAGEMENT: History and development of Industrial safety: Implementation of factories act, Safety and productivity, Safety organizations. Safety committees and structure, Role of management and role of Govt.in industrial safety.

UNIT-II

ACCIDENT PREVENTIONS AND PROTECTIVE EQUIPMENT: Personal protective equipment, Survey the plant for locations, Part of body to be protected, Education and training in safety, Prevention causes and cost of accident, Housekeeping, First aid, Accident reporting, Investigations. Industrial psychology in accident prevention, Safety trials, Safety related to operations.

UNIT-III

SAFETY ACTS: Features of Factory Act, Introduction of Explosive Act, Boiler Act, ESI Act, Workman's compensation Act, Industrial hygiene, Occupational safety, Diseases prevention, Ergonomics, Occupational diseases, stress, fatigue, health, safety and the physical environment, Engineering methods of controlling chemical hazards, safety and the physical environment, Control of industrial noise and protection against it, Code and regulations for worker safety and health, codes for safety of systems.

UNIT-IV

FIRE PREVENTION AND PROTECTION: Sources of ignition – fire triangle – principles of fire extinguishing – active and passive fire protection systems – various classes of fires – A, B, C, D, E-Fire extinguishing agents- Water, Foam, Dry chemical powder, Carbon-dioxide Halon alternatives Halocarbon compounds-Inert gases, dry powders – types of fire extinguishers – fire stoppers –hydrant pipes – hoses – monitors – fire watchers – layout of stand pipes – fire station-fire alarms and sirens – maintenance of fire trucks – foam generators – escape from fire rescue operations – fire drills –first aid for burns.

UNIT-V

BUILDING FIRE SAFETY: Objectives of fire safe building design, Fire load, fire resistant material and fire testing – structural fire protection – structural integrity – concept of egress design -exit– width calculations –fire certificates – fire safety requirements for high rise buildings.

TEXT BOOKS*:*

1. Industrial Maintenance Management Srivastava, S.K.- S.Chandand Co.
2. Occupational Safety Management and Engineering Willie Hammer–PrenticeHall

3. Purandare D.D & Abhay D.Purandare, “Handbook on Industrial Fire Safety” P&A publications, NewDelhi, 2006.
4. McElroy,FrankE.,“Accident Prevention Manual for Industrial Operations”, NSC, Chicago, 1988.
5. Green, A.E.,“High Risk Safety Technology”, John Wiley and Sons, 1984.

REFERENCE BOOKS*:*

1. Installation, Servicing and Maintenance Bhattacharya, S.N.-S.Chandand Co.
2. Jain VK “Fire Safety in Building” New Age International 1996.
3. Reliability, Maintenance and Safety Engineering by Dr.A. K.Guptha
4. A Text book of Reliability and Maintenance Engineering by Alakesh Manna

Course outcomes:

CO1: Students learn the concepts of industrial safety and management.
CO2: Learn about the smart machines and smart sensors
CO3: Apply IoT to Industry 4.0 and they are able to make a system tailor-made as per requirement of the industry
CO4: Students learn about fire prevention and protection systems.
CO5: Students learn and apply the fire safety principles in buildings

IV Year I Semester	FINITE ELEMENT METHODS (Open Elective – III)	L	T	P	C
		3	0	0	3

Course Objectives: The student will acquire the knowledge

- Introduce fundamentals of FEM including stress-strain relations and variational methods.
- Teach weighted residual methods and energy principles for solving 1D problems.
- Introduce bar element formulation and discretization techniques in FEM.
- Teach 2D finite element modeling using CST and rectangular elements.
- Introduce higher order and iso-parametric elements with natural coordinates and numerical integration.

UNIT CONTENTS

UNIT – 1 **VARIATIONAL METHODS:** Introduction to finite element method, stress and equilibrium, strain –displacement relations, stress–strain relations, plane stress and plane strain conditions, variational methods.

UNIT – 2 **WEIGHTED RESIDUAL METHODS:** solving differential equations using weighted residual methods, concept of potential energy, one dimensional problems.

UNIT – 3 **1D-ELEMENTS:** Bar element formulation, Discretization of domain, element shapes, discretization procedures, assembly of stiffness matrix, band width, node numbering, mesh generation, interpolation functions, local and global coordinates, convergence requirements, treatment of boundary conditions.

UNIT – 4 **2D- ELEMENTS:** Finite element modeling of two dimensional stress analysis with constant strain triangles and treatment of boundary conditions.
Finite element modeling of four noded rectangular element.

UNIT – 5 **HIGHER ORDER AND ISO-PARAMETRIC ELEMENTS:** One dimensional, quadratic and cubic elements in natural coordinates, two dimensional four node iso-parametric elements and numerical integration.

Text Books:

1. The Finite Element Methods in Engineering /SSRao/Pergamon.

References:

1. Finite Element Method with applications in Engineering / YM Desai, Eldho& Shah /Pearson publishers
2. An introduction to Finite Element Method /JNReddy/McGrawHill
3. The Finite Element Method for Engineers–KennethH.Huebner, Donald L. Dewhirst,

Douglas E. Smith and TedG. Byrom/John Wiley & sons (ASIA)PteLtd.
4. Finite Element Analysis: Theory and Application with Ansys, Saeed Moaveniu, Pearson Education
5. Finite Element Methods / Chen
6. Finite Element Analysis: for students & Practicing Engineers / G.LakshmiNarasaiah / BSP Books Pvt. Ltd.

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

CO1 Explain stress-strain relations and apply variational methods in FEM formulations.
CO2 Apply weighted residual methods and potential energy principles to 1D FEM problems.
CO3 Formulate bar element stiffness matrix and perform mesh generation with appropriate boundary conditions.
CO4 Model 2D stress problems using CST and four-node rectangular elements with boundary conditions.
CO5 Apply quadratic, cubic, and iso-parametric elements using numerical integration in FEM.

IV Year I Semester	INTRODUCTION TO MECHATRONICS (Open Elective - III)	L	T	P	C
		3	0	0	3

Course Objectives: The student will acquire the knowledge

- Introduce mechatronics systems, their components, and various sensors used for measurement.
- Explain solid-state devices and analog signal conditioning using op-amps.
- Explore fluid power and mechanical actuation systems with their control mechanisms.
- Teach digital electronics, microcontrollers, and PLC-based control systems.
- Introduce data acquisition, digital signal processing, and mechatronic system design.

UNIT **CONTENTS**

UNIT – 1 **MECHATRONICS SYSTEMS**: Elements & levels of mechatronics system, Mechatronics design process, system, measurement systems, control systems, microprocessor-based controllers, advantages and disadvantages of mechatronics systems. Sensors and transducers, types, displacement, position, proximity, velocity, motion, force, acceleration, torque, fluid pressure, liquid flow, liquid level, temperature and light sensors.

UNIT – 2 **SOLID STATE ELECTRONIC DEVICES:** PN junction diode, BJT, FET, DIAC, TRIAC and LEDs. Analog signal conditioning, operational amplifiers, noise reduction, filtering

UNIT – 3 **HYDRAULIC AND PNEUMATIC ACTUATING SYSTEMS:** Fluid systems, Hydraulic systems, and pneumatic systems, components, control valves, electro-pneumatic, hydro-pneumatic, electro-hydraulic servo systems. Mechanical actuating systems and electrical actuating systems – basic principles and elements.

UNIT – 4 **DIGITAL ELECTRONICS AND SYSTEMS:** Digital logic control, microprocessors and micro controllers, programming, process controllers, programmable logic controllers, PLCs versus computers, application of PLCs for control.

UNIT – 5 **SYSTEM AND INTERFACING AND DATA ACQUISITION:** Data Acquisition Systems, Analog to Digital and Digital to Analog conversions; Digital Signal Processing – data flow in DSPs, block diagrams, typical layouts, Interfacing motor drives. Design of mechatronics systems & future trends.

Text Books:

1. MECHATRONICS Integrated Mechanical Electronics Systems/KP Ramachandran, GK Vijaya Raghavan& MS Balasundaram/WILEY India Edition

References:

1. Mechatronics /Smaili A, Mrad F/ Oxford Higher Education, Oxford University Press
2. Mechatronics Source Book / Newton C Braga/ThomsonPublications, Chennai.
3. Mechatronics – N. Shanmugam / Anuradha Agencies Publishers.
4. Mechatronics System Design / Devdas shetty/Richard/Thomson.
5. Mechatronics/M.D.Singh/J.G.Joshi/PHI.
6. Mechatronics – Electronic Control Systems in Mechanical and Electrical Engg. 4th Edition / W. Bolton/ Pearson,2012
7. Mechatronics – Principles and Application / Godfrey C. Onwubolu/Elsevier, Indianprint

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

CO1 Identify components of mechatronics systems and explain working principles of various sensors.

CO2 Analyze characteristics of electronic devices and apply signal conditioning techniques.

CO3 Describe operation of hydraulic, pneumatic, and mechanical actuating systems.

CO4 Develop basic logic control systems using microcontrollers and PLCs.

CO5 Design basic mechatronic systems incorporating data acquisition and interfacing techniques.

IV Year I Semester	PRODUCT DESIGN AND DEVELOPMENT (Open Elective - III)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES: The student will acquire the knowledge

- Introduce fundamental tools, standards, and practices in product design, engineering drawings, BOM, and project management.
- Familiarize students with global material standards, manufacturing processes, and product analysis tools.
- Teach the structured approach to product design from RFQ to initial sample submission with relevant documentation.
- Emphasize quality testing, customer validation, and risk assessment in new product qualification.
- Highlight the importance of standardized reporting, prototyping, reverse engineering, and concurrent engineering in NPD.

UNIT CONTENTS

UNIT – 1 **FUNDAMENTALS OF PRODUCT DESIGN AND DEVELOPMENT**: Introduction – Reading of Drawing – Grid reading, Revisions, ECN (Engg. Change Note), Component material grade, Specifications, customer specific requirements – Basics of monitoring of NPD applying Gantt chart, Critical path analysis – Fundamentals of BOM (Bill of Materials), Engg. BOM & Manufacturing BOM. Basics of MIS software and their application in industries like SAP, MS Dynamics, Oracle ERP Cloud – QFD.

UNIT – 2 **MATERIAL SPECIFICATIONS, ANALYSIS & PROCESS**: Material specification standards – ISO, DIN, JIS, ASTM, EN, etc. – Awareness on various manufacturing process like Metal castings & Forming, Machining (Conventional, 3 Axis, 4 Axis, 5 Axis,), Fabrications, Welding process. Qualifications of parts mechanical, physical & Chemical properties and their test report preparation and submission. Fundamentals of DFMEA & PFMEA, Fundamentals of FEA, Bend Analysis, Hot Distortion, Metal and Material Flow, Fill and Solidification analysis.

UNIT – 3 **ESSENTIALS OF PRODUCT DESIGN AND DEVELOPMENT**: RFQ (Request of Quotation) Processing – Feasibility Studies & reporting – CFT (Cross Function Team) discussion on new product and reporting – Concept design, Machine selection for tool making, Machining – Manufacturing Process selection, Machining Planning, cutting tool selection – Various Inspection methods – Manual measuring, CMM – GOM (Geometric Optical Measuring), Lay out marking and Cut section analysis. Tool Design and Detail drawings preparation, release of details to machine shop and CAM programing. Tool assembly and shop floor trials. Initial sample submission with PPAP documents.

UNIT – 4 **CRITERIONS OF PRODUCT DESIGN AND DEVELOPMENT**: New product qualification for Dimensions, Mechanical & Physical Properties, Internal Soundness proving through X-Ray, Radiography, Ultrasonic Testing, MPT, etc. Agreement with customer for testing frequencies. Market Survey on similar products, Risk analysis, validating samples with simulation results, Lesson Learned & Horizontal deployment in NPD (New Product Development).

UNIT – 5 **REPORTING & FORWARD-THINKING OF NPD**: Detailed study on PPAP with 18 elements reporting, APQP and its 5 Sections, APQP vs PPAP, Importance of SOP (Standard Operating Procedure) – Purpose & documents, deployment in shop floor. Prototyping & RPT - Concepts, Application and its advantages, 3D Printing – resin models, Sand cores for foundries; Reverse Engineering. Cloud points generation, converting cloud data to 3D model – Advantages & Limitation of RE, CE (Concurrent Engineering) – Basics, Application and its advantages in NPD (to reduce development lead time, time to Market, Improve productivity and product cost.)

TEXT BOOKS:

1. Product Development – Sten Jonsson
2. Product Design & Development – Karl T. Ulrich, Maria C. Young, Steven D. Eppinger

REFERENCES:

1. Revolutionizing Product Development – Steven C Wheelwright & Kim B. Clark
2. Toyota Product Development System – James Morgan & Jeffrey K. Liker
3. Winning at New Products – Robert Brands 3rd Edition
4. Product Design & Value Engineering – Dr. M.A. Bulsara &Dr. H.R. Thakkar

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

CO1 Understand drawing interpretation, BOM structure, Gantt charts, QFD, and industrial MIS tools like SAP and Oracle ERP.

CO2 Identify material standards, manufacturing methods, and apply DFMEA, PFMEA, and FEA fundamentals in product evaluation.

CO3 Demonstrate the ability to process RFQs, select tools/machines, plan manufacturing, and prepare PPAP documents.

CO4 Evaluate product performance using testing methods and apply lessons learned for NPD improvement.

CO5 Prepare comprehensive reports (PPAP, APQP), utilize prototyping/RPT tools, and apply RE & CE to enhance product development.

IV Year I Semester	ADVANCED MATERIALS (Open Elective - III)	L	T	P	C
		3	0	0	3

Course Objectives: The students will acquire the knowledge:

- Introduce various metallic materials, their applications in extreme environments, and innovative forms like metallic foams.
- Provide knowledge of natural and synthetic polymers, ceramics, their structures, processing, and industrial applications.
- Explain the fundamentals, classifications, and reinforcements of composite materials and their engineering relevance.
- Introduce shape memory alloys and functionally graded materials, focusing on their effects, properties, and applications.
- Explore the principles, unique properties, and applications of nanomaterials compared to their bulk counterparts.

UNIT	CONTENTS
UNIT – 1	**ADVANCED METALS & ALLOYS:** Metallic materials- super alloys, titanium and Nickel based alloys and intermetallics, Materials for cryogenic application, Materials for space environment, Evaluation of materials for extreme environment, Introduction to metallic foams.
UNIT – 2	**CERAMICS**: Applications - characteristics- classification-Processing of ceramics- Powder preparations- consolidation- hot compaction-drying-sintering-finishing of ceramics, Al_2O_3, silicon nitride Si3N4 and Cermets, Areas of applications.
UNIT – 3	**COMPOSITE MATERIALS**: Introduction, polymer matrix composites, metal matrix composites, ceramic matrix composites, carbon–carbon composites, fiber- reinforced composites and nature-made composites, and applications. **REINFORCEMENTS:** Fibres- glass, silica, kevlar, carbon, boron, silicon carbide, and born carbide fibres.
UNIT – 4	**SHAPE MEMORY ALLOYS:** Introduction-shape memory effect-classification of shape memory alloys-composition-properties and applications of shape memory alloys. **FUNCTIONALLY GRADED MATERIALS**: Types of functionally graded materials-classification different systems-preparation-properties and applications of functionally graded materials.

UNIT – 5 **NANO MATERIALS:** Introduction-properties at nano scales-advantages & disadvantages applications in comparison with bulk materials (nano – structure, wires, tubes, composites). state of art nano advanced- topic delivered by student.

Text Books:

1. Nano material /A.K. Bandyopadyay/New age Publishers
2. Material science and Technology: A comprehensive treatment/Robert W.Cahn,/VCH
3. Engineering Mechanics of Composite Materials / Isaac and M Daniel/Oxford University Press

References:

1. Mechanics of Composite Materials / R. M. Jones/ Mc Graw Hill Company, New York, 1975.
2. Analysis of Laminated Composite Structures / L. R. Calcote/Van Nostrand Rainfold,NY 1969
3. Analysis and performance of fibre Composites /B. D. Agarwal and L. J. Broutman /Wiley-Interscience, New York, 1980
4. Mechanics of Composite Materials - Second Edition (Mechanical Engineering) /AutarK.Kaw /CRC Press

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

CO1 Identify and evaluate high-performance metals and alloys used in aerospace, cryogenics, and advanced engineering applications.

CO2 Classify and compare polymers and ceramics based on properties, processing techniques, and their functional uses.

CO3 Distinguish between various composite systems and reinforcement types, and identify their specific industrial applications.

CO4 Understand the composition, classification, and application areas of SMAs and FGMs in modern materials engineering.

CO5 Analyze nano-scale material behavior, assess their benefits and limitations, and present advanced nano topics through seminars.

IV Year I Semester	INTRODUCTION TO SMART MANUFACTURING (Open Elective - III)	L	T	P	C
		3	0	0	3

Course Objectives: The students will acquire the knowledge:

- Introduce the fundamentals and evolution of smart manufacturing with Industry 4.0 technologies.
- Explain the structure and functions of smart machines and sensors in industrial applications.
- Introduce CPS and its 5C architecture for implementing intelligent manufacturing systems.
- Teach digital twin technology, machine learning, and predictive maintenance in smart factories.
- Provide knowledge on IoT networking protocols and connectivity infrastructure for industrial automation.

UNIT	CONTENTS
UNIT – 1	**CONCEPTS OF SMART MANUFACTURING:** Definition and key characteristics of smart manufacturing, Corporate adaptation processes, manufacturing challenges, challenges vs technologies, Stages in smart manufacturing. Minimizing Six big losses in manufacturing with Industry 4.0, and their benefits
UNIT – 2	**SMART MACHINES AND SMART SENSORS:** Concept and Functions of a Smart, Machine Salient features and Critical Subsystems of a Smart Machine, Smart sensors; smart sensors ecosystem, need, benefits and applications of sensors in industry, Sensing for Manufacturing Process in IIoT, Block Diagram of aIoT Sensing Device, Sensors in IIoT Applications, Smart Machine Interfaces
UNIT – 3	**ARCHITECTURE OF CYBER- PHYSICAL SYSTEM (CPS):** Functions of CPS, 5C Architecture; Smart Connection Level, Data-to- Information Level, Cyber Level, Cognition Level, Configuration Level. Design of PHM based CPS systems. Comparison of today's factory and Industry 4.0 factory by the implementation of 5C CPS architecture
UNIT – 4	**DIGITAL TWINS:** Introduction, applications of digital twins, impact zones of digital twins in manufacturing (factories/plants and OEMs), advantages of digital twins, basic steps of digital twin technology **MACHINE LEARNING (ML) AND ARTIFICIAL INTELLIGENCE (AI) IN MANUFACTURING**: Introduction, benefits and applicationsof ML in industries, common approaches of ML; supervised and unsupervised, semi-supervised and reinforced ML.

PREDICTIVE MAINTENANCE: Introduction of predictive maintenance, difference between preventive and predictive maintenance, working and various components of predictive maintenance, benefits and tools of predictive maintenance. Common approaches to IoT predictive maintenance; Rule-based (condition monitoring) and AI (artificial intelligence) based predictive maintenance.

UNIT – 5 **IoT CONNECTIVITY FOR INDUSTRY 4.0:** Industrial communication requirement and its infrastructure, an overview of different types of networks, mesh network in industrial IoT, IoT protocols and the internet, TCP/IP (transmission control protocol/internet protocol) model, IoT connectivity standards: common protocols, application layer protocols, internet/network layer protocols, physical layer IoT protocols, choosing the right IoT connectivity protocol

Text Books:

1. Industry 4.0 The Industrial Internet of Things by Alasdair Gilchrist, Apress
2. Industrial Internet of Things, Cyber Manufacturing System by Sabina Jeschke, Christian Brecher, Houbing Song Danda B. Rawat, Springer

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

CO1 Explain the stages, challenges, and benefits of smart manufacturing and methods to reduce production losses.

CO2 Identify smart machine components and describe sensor roles and interfaces in IIoT-based manufacturing systems.

CO3 Analyze CPS architecture and compare traditional and Industry 4.0 factories using 5C implementation.

CO4 Apply digital twins, ML/AI techniques, and predictive maintenance tools including AR for system reliability.

CO5 Evaluate IoT communication protocols and select suitable connectivity models for smart manufacturing.

IV Year I Semester	OPTIMIZATION TECHNIQUES (Open Elective - IV)	L	T	P	C
		3	0	0	3

Course Objectives: The student will acquire the knowledge

- Introduce basic concepts, types, and formulations of optimization problems with classical solution methods.
- Explore numerical techniques for solving unconstrained optimization problems.
- Present methods for solving optimization problems with equality and inequality constraints.
- Teach the theory and solution techniques for unconstrained and constrained geometric programming problems.
- Introduce integer programming and zero-one programming with solution strategies.

UNIT CONTENTS

UNIT – 1 **INTRODUCTION TO OPTIMIZATION:** Engineering applications of optimization- statement of an optimization problem- classification of optimization problem- optimization techniques.

CLASSICAL OPTIMIZATION TECHNIQUES: Single variable optimization- multivariable optimization with equality constraints- multivariable optimization with inequality constraints.

UNIT – 2 **UNCONSTRAINED OPTIMIZATION TECHNIQUES:** Pattern search method- Rosenbrock's method of rotating coordinates- Simplex method- Descent methods- Gradient of function- Steepest Descent method.

UNIT – 3 **CONSTRAINED OPTIMIZATION TECHNIQUES:** Characteristics of constrained problem methods of feasible directions - basic approach in the penalty function method- interior penalty function method- convex programming problem- exterior penalty function method.

UNIT – 4 **GEOMETRIC PROGRAMMING (G.P):** Solution of an unconstrained geometric programming, differential calculus method and arithmetic method. primal dual relationship and sufficiency conditions. Solution of a constrained geometric programming problem (G.P.P). Complimentary geometric programming (C.G.P)

UNIT – 5 **INTEGER PROGRAMMING (I.P):** Graphical representation. Gomory's cutting plane method. Algorithm for zero-one programming problem. Integer non-linear programming.

TEXT BOOK:

1. Optimization Theory and Applications/ S.S.Rao/Wiley Eastern Limited, New Delhi.

REFERENCES:

1. Engineering Optimization / Kalyanmanai Deb/Prentice Hall of India, New Delhi.
2. Optimization Techniques-Theory and applications/C.Mohan&Kusum Deep/New Age International
3. Operations Research /S.D.Sharma / MacMillan Publishers

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

CO1	Classify optimization problems and apply classical techniques for single and multivariable optimization.
CO2	Solve unconstrained problems using methods like pattern search, Rosenbrock's, simplex, and steepest descent.
CO3	Apply penalty methods, feasible direction methods, and solve convex programming problems.
CO4	Solve G.P. and C.G.P problems using primal-dual concepts and differential or arithmetic methods.
CO5	Solve integer and zero-one programming problems using Gomory's cutting plane and other algorithms.

IV Year I Semester	ADVANCED MANUFACTURING PROCESSES (Open Elective - IV)	L	T	P	C
		3	0	0	3

Course Objectives: The student will acquire the knowledge

- Introduce various surface coating methods, their applications, and economic aspects.
- Explain the processing methods for ceramics and composites used in engineering applications.
- Explore microelectronics fabrication steps from wafer preparation to packaging and CAD.
- Introduce nanomaterials, their synthesis techniques, and applications in manufacturing.
- Provide knowledge of rapid prototyping techniques and their use in product development.

UNIT	CONTENTS
UNIT – 1	**COATING TECHNIQUES:** Scope, Cleaners, Methods of cleaning, Surface coating types, ceramic and organic methods of coating, and economics of coating. Electro forming, Chemical vapor deposition, Physical vapor deposition, thermal spraying, Ion implantation, diffusion coating, Diamond coating and cladding.
UNIT – 2	**PROCESSING OF CERAMICS:** Applications, characteristics, classification, Processing of particulate ceramics, Powder preparations, consolidation, hot compaction, drying, sintering, and finishing of ceramics, Areas of application. **PROCESSING OF COMPOSITES:** Composite Layers, Particulate and fiber reinforced composites, Elastomers, Reinforced plastics, MMC, CMC, Polymer matrix composites.
UNIT – 3	**FABRICATION OF MICROELECTRONIC DEVICES**: Crystal growth and wafer preparation, Film Deposition oxidation, lithography, bonding and packaging, reliability and yield, Printed Circuit boards, computer aided design in micro electronics, surface mount technology, Integrated circuit economics.
UNIT – 4	**NANOMANUFACTURING:** Nanotubes, Nanoparticles, nanowires, Lithography, Eletrospinning, mechanical milling, Inert gas condensation, sputtering, laser ablation, Arc discharge, Sol-gel methods, working, applications, advantages.
UNIT – 5	**RAPID PROTOTYPING:** Working Principles, Methods, Stereo Lithography, Laser Sintering, Fused Deposition Method, Applications and Limitations, Rapid tooling, Techniques of rapid manufacturing.

TEXT BOOKS:

1. Manufacturing Engineering and Technology Kalpakijian / Adisson Wesley, 1995.
2. Process and Materials of Manufacturing / R. A. Lindburg / 1th edition, PHI 1990.

REFERENCES:

1. Microelectronic packaging handbook / Rao. R. Thummala and Eugene, J. Rymaszewski / Van Nostrand Renihold,
2. MEMS & Micro Systems Design and manufacture / Tai — Run Hsu / TMGH
3. Advanced Machining Processes / V.K.Jain / Allied Publications.
4. Introduction to Manufacturing Processes / John A ScheyIMcGraw Hill.

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

CO1 Apply and distinguish different coating techniques such as CVD, PVD, thermal spraying, and ion implantation for industrial surfaces.

CO2 Understand and apply the manufacturing processes of ceramics and composite materials, including powder consolidation and reinforcement types.

CO3 Analyze and describe the manufacturing sequence of microelectronic devices including lithography, PCB design, and surface mount technology.

CO4 Understand various nanomanufacturing techniques and evaluate their applications, advantages, and working principles.

CO5 Explain the working principles and limitations of rapid prototyping technologies such as stereolithography and laser sintering.

IV Year I Semester	TOTAL QUALITY MANAGEMENT (Open Elective - IV)	L	T	P	C
		3	0	0	3

Course Objectives: The student will acquire the knowledge

- Introduce the fundamentals of TQM and the role of process quality and statistical control in business performance.
- Emphasize customer satisfaction, loyalty, and benchmarking practices for continuous improvement.
- Explain how to organize and transition a company toward TQM using systems thinking and productivity tools.
- Teach the concept and classification of quality costs and their role in quality management.
- Provide knowledge of ISO 9000 standards and the certification process for global quality assurance.

UNIT CONTENTS

UNIT – 1 **INTRODUCTION:** The concept of TQM, Quality and Business performance, attitude and involvement of top management, communication, culture and management systems. Management of Process Quality: Definition of quality, Quality Control, a brief history, Product Inspection vs, Process Control, Statistical Quality Control, Control Charts and Acceptance Sampling.

UNIT – 2 **CUSTOMER FOCUS AND SATISFACTION**: The importance of customer satisfaction and loyalty- Crating satisfied customers, Understanding the customer needs, Process Vs. Customer, internal customer conflict, quality focus, Customer Satisfaction, role of Marketing and Sales, Buyer – Supplier relationships. Bench Marketing: Evolution of Bench Marketing, meaning of Bench marketing, benefits of bench marketing, the bench marketing process, pitfalls of bench marketing.

UNIT – 3 **ORGANIZING FOR TQM**: The systems approach, Organizing for quality implementation, making the transition from a traditional to a TQM organizing, Quality Circles. Productivity, Quality and Reengineering: The leverage of Productivity and Quality, Management systems Vs. Technology, Measuring Productivity, Improving Productivity Re-engineering.

UNIT – 4 **3-D OBJECT REPRESENTATION:** spline representation, Hermitem **THE COST OF QUALITY:** Definition of the Cost of Quality, Quality Costs, Measuring Quality Costs, use of Quality Cost Information, Accounting Systems and Quality Management.

UNIT – 5 **ISO9000:** Universal Standards of Quality: ISO around the world, The ISO9000 ANSI/ASQCQ-Series Standards, benefits of ISO9000 certification, the third party audit, Documentation ISO9000 and services, the cost of certification implementing the system

TEXT BOOKS:

1. Total Quality Management / Joel E.Ross/Taylor and Franscis Limited
2. Total Quality Management/P.N.Mukherjee/PHI

REFERENCES:

1. Beyond TQM / Robert L.Flood
2. Statistical Quality Control / E.L. Grant / McGraw Hill.
3. Total Quality Management- A Practical Approach/H. Lal
4. Quality Management/KanishkaBedi/Oxford University Press/2011
5. Total Engineering Quality Management/Sunil Sharma/Macmillan

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

CO1 Understand TQM principles and apply process control tools like control charts and acceptance sampling.

CO2 Evaluate customer-focused strategies and implement benchmarking processes to enhance quality.

CO3 Implement organizational changes for TQM and assess productivity improvements through quality circles and reengineering.

CO4 Analyze and utilize quality cost data to drive managerial decisions and quality improvements.

CO5 Understand and apply ISO 9000 certification procedures and assess their impact on business quality systems.

IV Year I Semester	OPERATIONS MANAGEMENT (Open Elective - IV)	L	T	P	C
		3	0	0	3

Course Objectives: The student will acquire the knowledge

- Introduce forecasting methods, production system types, and aggregate planning strategies.
- Explain scheduling policies and materials management techniques for effective production control.
- Teach inventory control models, MRP systems, and modern management concepts like Lean and ERP.
- Introduce statistical and philosophical approaches to quality control and management.
- Provide tools for optimization using linear programming, transportation models, and scheduling algorithms.

UNIT	CONTENTS
UNIT – 1	**FORECASTING**: Introduction, types of forecasting and their uses, General principles of forecasting, forecasting techniques: qualitative and quantitative methods of Forecasting. **PRODUCTION SYSTEMS:** Types of production systems: job, batch, mass and flow type production. **AGGREGATE PLANNING:** Introduction, aggregate planning strategies, aggregate planning methods, problems
UNIT – 2	**SCHEDULING:** Introduction, difference with loading, scheduling policies, techniques, standard scheduling methods. **MATERIALS MANAGEMENT:** Introduction, functions of materials management, inventory, inventory management, types of inventories, Selective inventory control techniques: ABC analysis, VED analysis.
UNIT – 3	**INVENTORY CONTROL:** P and Q Systems, Basic Economic Order Quantity model, Price break model, assumptions and problems **MATERIAL REQUIREMENT PLANNING**: Introduction, Inputs, outputs and MRP logic. **CONTEMPORARY MANAGEMENT TECHNIQUES:** Introduction to Lean, JIT, ERP and Supply chain Management.
UNIT – 4	**QUALITY MANAGEMENT:** Quality engineering, Taguchi Principles, SQC – X bar, p and c charts, problems, Juran's principles Introduction to quality acceptance sampling. Deming's Philosophy, Introduction to Total quality management, Quality Function Deployment, Introduction to six sigma and ISO 9000 2015 standards.

UNIT – 5 **OPTIMIZATION:** Linear Programming – Graphical and simplex method – problems, Demonstration of Transportation and Assignment Models, Travelling Salesman problem.

TEXT BOOKS:

1. Modern Production/ operations managements / Baffa& Rakesh Sarin
2. Operations Management – an Integrated Approach, International student Version, R. Dan Reid and Nada R. Sanders, John Wiley & Sons
3. Production and Operations management by K. C. Jain, Wiley
4. Operations Management by William J. Stevenson, McGraw-Hill Companies 2015
5. Operations Management by Jay Heizer , Barry Render, Chuck Munson , Amit Sachan Twelfth Edition, Pearson, 2017

REFERENCES:

1. Maynard‘s Industrial Engineering Handbook, Kjell B. Zandin, Fifth Edition 2001, The McGraw-Hill Companies, Inc.
2. Operations Management S.N. Chary.
3. Inventory Control Theory and Practice / Martin K. Starr and David W. Miller.

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

CO1 Apply forecasting and aggregate planning techniques to select appropriate production systems.

CO2 Develop scheduling plans and apply inventory classification methods like ABC and VED analysis.

CO3 Analyze inventory decisions using EOQ and implement MRP logic and Lean concepts.

CO4 Use tools like control charts and sampling to manage quality and understand TQM and Six Sigma principles.

CO5 Solve real-world problems using LPP, transportation, assignment, and travelling salesman models.

IV Year I Semester	ENERGY AUDITING (Open Elective - IV)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

- Introduce global and national energy scenarios, energy auditing needs, and the role of energy managers.
- Explain electricity tariff systems and energy-saving techniques in electrical networks.
- Provide knowledge of combustion and conservation methods in major thermal systems.
- Discuss conservation measures in various electrical utilities and support systems.
- Explain monitoring, targeting, labelling, and economic evaluation of energy projects.

UNIT	CONTENTS
UNIT – 1	**INTRODUCTION**: Energy scenario of World, India and TN - Environmental aspects of Energy Generation – Material and Energy balancing - Energy Auditing: Need, Types, Methodology and Barriers. Role of Energy Managers. Basic instruments for Energy Auditing.
UNIT – 2	**ELECTRICAL SUPPLY SYSTEMS**: Electricity Tariff structures – Typical Billing - Demand Side Management - HT and LT supply - Power Factor – Energy conservation in Transformers – Harmonics
UNIT – 3	**ENERGY CONSERVATION IN MAJOR THERMAL UTILITIES**: Stoichiometry - Combustion principles. Energy conservation in: Boilers - Steam Distribution Systems - Furnaces - Thermic Fluid Heaters – Cooling Towers – D.G. sets. Insulation and Refractories - Waste Heat Recovery Devices.
UNIT – 4	**ENERGY CONSERVATION IN MAJOR ELECTRICAL UTILITIES**: Energy conservation in: Motors - Pumps – Fans – Blowers - Compressed Air Systems - Refrigeration and Air Conditioning Systems - Illumination systems
UNIT – 5	**ENERGY MONITORING, TARGETING, LABELLING AND ECONOMICS**: Elements of Monitoring & Targeting System – CUSUM - Energy / Cost index diagram – Energy Labelling - Energy Economics – Cost of production and Life Cycle Costing - Economic evaluation techniques – Discounting and Non-Discounting - ESCO concept – PAT scheme

TEXT BOOKS:

1. Guide book for National Certification Examination for “Energy Managers and Energy Auditors” (4 Volumes). Available at http://www.em-ea.org/gbook1.asp. This website is

administered by Bureau of Energy Efficiency (BEE), a statutory body under Ministry of Power, Government of India.
2. K. Nagabhushan Raju, Industrial Energy Conservation Techniques: (concepts, Applications and Case Studies), Atlantic Publishers &Dist, 2007.

REFERENCES:

1. Abbi Y P, Shashank Jain., Handbook on Energy Audit and Environment Management, TERI Press, 2006.
2. Albert Thumann and Paul Mehta D, "Handbook of Energy Engineering", 7thEdition, The Fairmont Press, 2013.
3. Murphy.W.R. and McKay.G, "Energy Management", Butterworth, London 1982.
4. Paul W.O'Callaghan, Design and management for energy conservation: A handbook for energy managers, plant engineers, and designers, Pergamon Press, 1981.
5. Steve Doty, Wayne Turner C, Energy Management Handbook 7th Edition, The Fairmont Press, 2009

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

CO1 Analyze energy consumption patterns and perform basic energy audits using suitable tools.

CO2 Evaluate power systems for conservation opportunities and apply DSM and PF improvement strategies.

CO3 Apply energy-saving techniques in boilers, furnaces, steam systems, and waste heat recovery units.

CO4 Recommend energy-efficient practices for motors, compressors, HVAC, and lighting systems.

CO5 Perform energy performance analysis using economic tools and understand schemes like PAT and ESCO.

IV Year – I Semester	QUANTUM SCIENCE AND TECHNOLOGY	L	T	P	C
		3	0	0	3

Prerequisites: Basic Physics, Linear Algebra, and Introduction to Modern Physics

Course Objectives:

1. To introduce fundamental concepts of quantum mechanics and its mathematical formalism.
2. To explore quantum computing and communication principles and technologies.
3. To understand the physical implementation and limitations of quantum systems.
4. To enable students to relate quantum theory to practical applications in computing, cryptography, and sensing.
5. To familiarize students with the emerging trends in quantum technologies.

Course Outcomes:

After completing this course, students will be able to:

CO1. Explain core principles of quantum mechanics and their technological implications.

CO2. Analyze quantum phenomena like superposition and entanglement.

CO3. Apply mathematical tools to model and solve quantum systems.

CO4. Demonstrate understanding of quantum algorithms and quantum circuits.

CO5. Evaluate potential applications and challenges in quantum communication and sensing.

Unit 1: Fundamentals of Quantum Mechanics: Historical background: Blackbody radiation, photoelectric effect, and Compton scattering; Dual nature of light and matter; De Broglie hypothesis; Schrödinger equation; Free particle, infinite potential well, step potential; Operators and observables: position, momentum, Hamiltonian; Commutation relations and uncertainty principle; Quantum postulates and measurement theory; Eigenvalues, eigenfunctions.

Unit 2: Quantum Information Theory: Classical vs. quantum information; Qubit representation using Bloch sphere; Quantum superposition and quantum entanglement; Dirac notation (bra-ket), tensor products, and composite systems; Bell states and EPR paradox; Quantum gates: Pauli-X, Y, Z; Hadamard; Phase; T; CNOT; Quantum circuit models and notation; Measurement in computational basis; Quantum teleportation and no-cloning theorem; Quantum state tomography (introductory)

Unit 3: Quantum Computing: Classical computing review and limitations; Quantum parallelism and interference; Deutsch and Deutsch-Jozsa algorithms; Grover's search algorithm, Oracle and amplitude amplification; Shor's factoring algorithm (overview and significance); Quantum Fourier Transform (QFT); Quantum error correction: Bit-flip, phase-

flip, and Shor's 9-qubit code; Introduction to quantum programming: Qiskit, Cirq, IBM Quantum Experience (overview)

Unit 4: Quantum Communication: Introduction to quantum cryptography; Quantum key distribution (QKD): BB84 protocol; Entanglement-based QKD: Ekert protocol (E91); Eavesdropping and security of QKD; Quantum teleportation (circuit and protocol); Quantum dense coding; Quantum networks and entanglement swapping; Role of quantum repeaters; Single-photon sources and detectors; Implementation challenges (loss, decoherence, noise)

Unit 5: Quantum Technologies and Applications: Quantum sensors: magnetometry, gravimetry; Quantum metrology: standard time, atomic clocks; Quantum imaging and lithography; Quantum materials: topological insulators, graphene, quantum dots; NV centers in diamonds for sensing; Hardware platforms: Superconducting qubits, Trapped ions, Photonic quantum processors; Quantum supremacy and NISQ era; Global initiatives: IBM, Google, D-Wave, IonQ, India's NQM; Ethical concerns and future prospects

Text Books:

1. **"Quantum Computation and Quantum Information"** by Michael A. Nielsen and Isaac L. Chuang
2. **"Quantum Mechanics: Concepts and Applications"** by Nouredine Zettili

Online Learning Resources:

1. https://nptel.ac.in/courses/104104082
2. https://nptel.ac.in/courses/115104096
3. https://nptel.ac.in/courses/122106034