Syllabus for the Elective courses offered by Department of Mechanical Engineering

Course Title	Course Code	Structure (I-P-C)		
Computer-Aided Design & Manufacturing (CAD/CAM)	ME401	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand the need and applications of computers in design and manufacturing.
CO2	Design engineering components using geometric modelling techniques.
CO3	Apply geometric transformation techniques for better design understanding.
CO4	Understand the concept of group technology and flexible manufacturing system
CO5	Develop CNC programs to manufacture industrial components.
CO6	Understand the computer-aided process planning and computer-integrated manufacturing

Syllabus:

Introduction to Computer-Aided Design: The Design Process, Product Life Cycle, Application of CAD, Hardware Requirements of CAD – Principles of Interactive Computer Graphics; Overview of Hardware Available for use in CAD.

Product Data Exchange: Graphics Standards − GKS, Bitmaps, Open GL, Data Standards − IGES, STEP, CALS, DXF, STL, Communication Standards − LAN, WAN.

Geometric Modeling − Curves: Types of Mathematical Representation of Curves, Analytical Curves − Lines, Circle, Ellipse, Parabola, Hyperbola; Synthetic Curves − Hermite Cubic Splines, Bezier Curves, B-splines, NURBS

Geometric Modeling − Surfaces: Analytical Surfaces, Surfaces of Revolution, Mathematical Representation of Surfaces, Surface Model, Surface Entities, Surface Representation; Parametric Representation of Surfaces, Plane Surface, Rule Surface; Surface of Revolution, Tabulated Cylinder.

Geometric Modeling − Solid: Solid Representation, Boundary Representation (B-rep), Constructive Solid Geometry (CSG), and Sweep Representation.

2-D and 3-D Geometric Transformations: Translation, Rotation, Scaling, Mirror Concatenation, and Coordinate Transformations.

Computer Numerical Control (CNC): Introduction to Computer Numerical Control (CNC) − Origin, History, and Applications, CNC Programming: Part Programming Fundamentals, Manual Part Programming, APT Programming, Geometric & Motion commands, Post Processor Commands.

Group Technology: Introduction to Group Technology, Part Classification & Coding Systems: OPITZ, MICLASS.

Flexible Manufacturing System (FMS): Components of FMS, FMS Equipment & Control, FMS Case Studies.

Computer Aided Process Planning (CAPP): Introduction to CAPP, Variant & Generative Methods of CAPP, Hybrid CAPP, Advantages of CAPP.

Computer Integrated Manufacturing: Elements of CIM, Computer Integrated Production Planning Systems, CIM Case Studies.

Text Book(s) and References:

1. M. P. Groover & E. W. Zimmers, CAD-CAM – Prentice Hall, ISBN: 978-81-758-465, 2008
2. P. N. Rao, CAD/CAM Principles & Applications, McGraw Hill, New Delhi, 2010.
3. S D Sharma, Operations Research, Kedarnath, Ramnath & Co., Meerut, 2010.
4. I. Zeid & R Sivasubramanian, CAD/CAM Theory and Practice, TMH, New Delhi, 2009.
5. I. Zeid, Mastering CAD/CAM, Special Indian Edition 2007, Tata McGraw-Hill Publishing Company Ltd., New Delhi.

Course Title	Course Code	Structure (I-P-C)		
Refrigeration and Air Conditioning	ME402	**3**	**0**	**3**

Pre-requisite, if any: Thermodynamics

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

CO1	Understand the basic concepts of refrigeration and their applications.
CO2	Evaluate the performance parameters of different types of refrigeration systems.
CO3	Identify the desirable refrigerant and its use in various refrigeration systems.
CO4	Analyze the psychrometric properties and processes used in Air Conditioning systems.
CO5	Design of Air Conditioning systems for human comfort conditions.

Syllabus:

INTRODUCTION

FUNDAMENTALS OF REFRIGERATION: Introduction- Necessity and applications, unit of refrigeration and C.O.P-Heat Engine, Refrigerator and Heat pump-Types of Refrigeration systems, and its Applications. REFRIGERANTS: Classification of refrigerants- Desirable properties-Nomenclature-Commonly used refrigerants- Alternate refrigerants –Green house effect, global warming. AIR REFRIGERATION SYSTEM: Introduction-Air refrigeration system working on Reversed Carnot cycle – Air refrigeration system working on Bell Coleman cycle- COP- Open and Dense air systems, Applications.

VAPOUR COMPRESSION REFRIGERATION SYSTEM

Working principle-Simple vapour compression refrigeration cycle – COP- Representation of cycle on T-s and P-h charts- Effect of Sub cooling and Superheating --Actual Vapour compression cycle and its applications.

VCR SYSTEM COMPONENTS: Compressors- Classification -Working -Condensers– Classification - Working-Evaporators –Classification-Working, Expansion devices –Types-Working.

OTHER REFRIGERATION SYSTEMS

VAPOUR ABSORPTION REFRIGERATION SYSTEM: Description and working of Aqua- Ammonia system- Calculation of maximum COP- Lithium Bromide- Water system-Principle of operation of three fluid absorption system, Applications.

STEAM JET REFRIGERATION SYSTEM: Principle of working –Analysis- Applications. NON-CONVENTIONAL REFRIGERATION SYSTEMS- Thermo electric Refrigeration, Vortex tube refrigeration, Adiabatic demagnetization Refrigeration.

PSYCHROMETRIC PROPERTIES AND PROCESSES

Properties of moist Air-Gibbs Dalton law, Specific humidity, Dew point temperature, Degree of saturation, Relative humidity, Enthalpy, Humid specific heat, Wet bulb temperature Thermodynamic wet bulb temperature, Psychrometric chart; Psychrometric of air-conditioning processes, mixing of air streams.

AIR CONDITIONING SYSTEMS

Introduction-Components of Air conditioning system- Classification of Air conditioning systems-Central and Unitary systems- Summer, Winter and Year round systems- Cooling load estimation. DESIGN OF AIR CONDITION SYSTEMS: Summer air conditioning –ADP-System with Ventilated and re-circulated air with and without bypass factor- RSHF, GSHF and ESHF.

Text Book(s) and References:

1. R. Dossat, Principles of Refrigeration - - Pearson 4^{th} Edition 2001
2. Wilbert F.Stoecker, Jerold W. J.Jones, MGH, 1986.
3. ASHRAE Hand book, Fundamentals, 2010
4. JonesW.P., "Air conditioning engineering", 5th edition, Elsevier Butterworth-Heinemann, 2007
5. C. P. Arora. , Refrigeration and air conditioning - TMH, 2^{nd} Edition, 2000.
6. S. C. Arora, Domkundwar, A course in refrigeration and air conditioning-Dhanapat Rai& sons 5^{th} Edition, 1997

Course Title	Course Code	Structure (I-P-C)		
Automobile Engineering Systems	ME403	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Acquire the basic knowledge of the anatomy of an Automobile and its components.
CO2	Understand the working principles of suspension, transmission, control systems of an automobile.
CO3	Realize the functions of various electrical and electronic systems used in automobiles.
CO4	Understand the role of alternative fuels and pollution free vehicles.

Syllabus:

Introduction: Principles of Engine operation, engine parts, cooling systems, lubrication systems, fuel systems, Emission standard and Testing.

Structures: Construction, function, loading, principles of suspension systems and mechanics.

Transmission systems: Clutch, Fly-wheel, Gear boxes-types and construction.

Vehicle controls: Steering geometry and types, Brakes- types and construction.

Auto electrical and electronics: Battery generator, starting motor, lighting and ignition, Electronic Fuel injection.

Alternative concepts: Alternative fuels, basics of electric and hybrid vehicles, fuel cells.

Text Book(s) and References:

1. J. Heitner, "Automotive Mechanics", 2nd Edition, CBS Publisher, 2006.
2. H. Heisler, "Advanced Vehicle Technology", 2nd Edition, Butterworth-Heinemann Series, 2002.
3. Kirpal Singh, "Automobile Engineering - Vol I & II", 13^{th} Edition, Standard Publishers Distributors, 2014.
4. David A Crolla, "Automotive Engineering", 1st edition, Butterworth-Heinemann series, 2009.
5. "Automotive handbook", 3rd Edition, Robert Bosch GmbH, S.A.E., 1993.

Course Title	Course Code	Structure (I-P-C)		
Designing Intelligent Systems	ME404	**3**	**0**	**3**

Pre-requisite, if any: Systems Thinking for Design

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

CO1	Principles of Complex and living systems
CO2	Concepts such as Information intensity & Knowledge
CO3	Introduction to emerging digital technologies
CO4	Apply these ideas in design

Syllabus:

Design Metaphors & Patterns (incl biomimetic), Metaphors such as living systems, complex networks, viable systems

Key principles governing living / complex systems (Self-organization, self- production, recursion, fractal)

Increasing information-intensity in products

Concept of information intensity vs material/energy intensity

Self-learning, usage patterns, early warning systems

Using data, voice, collaborative technologies (semantic, big data, speech, Remote-help, Indic computing), Internet-of-things

Synthesizing the above ideas for creative design

Course Title	Course Code	Structure (I-P-C)		
Design for Quality and Reliability	ME405	**3**	**0**	**3**

Pre-requisite, if any: Nil

Course Objective: The objectives of the course are to help engineering students understand the concepts of quality & reliability and also evaluate the overall reliability of a system from component reliability.

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

CO1	Conclude whether a process is in statistically control state
CO2	Assess the capability of process to meet the design requirement
CO3	Use various probability density distributions significant to reliability calculations
CO4	Calculate the individual component and system reliability
CO5	Assess the ways in which a product/process can fail through conducting FMEA

Syllabus:

Concepts of Product Quality, Quality Function Deployment / House of Quality, Six Sigma.

Concepts of Reliability, Basic concepts of repairable and non-repairable systems, Reliability, Availability and Maintainability.

Failure data analysis, Fitting discrete and continuous distributions to failure data sets, Weibull analysis, estimation of important reliability parameters.

Calculation of System Reliability from Component reliabilities, Reliability Logic Diagrams, Fault-tree analysis.

Preventive and Predictive maintenance, Failure Modes and Effects Analysis.

References:

1. Louis Cohen, Joseph P. Ficalora, "Quality Function Deployment and Six Sigma: A QFD Handbook", Second Edition, Prentice Hall, 2009.
2. V. N. A.Naikan, "Reliability Engineering and Life Testing", PHI Learning, 2010.
3. SingiresuS. Rao, "Reliability Engineering", PearsonEducation,2014.
4. Patrick O Connor, "Practical Reliability Engineering", John Wiley,2009.
5. B.L. Hansen and P.M. Ghare, "Quality Control and Applications", Prentice Hall, 1997.

Course Title	Course Code	Structure (I-P-C)		
Information Systems in Manufacturing	ME521	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Apply computer models of common engineering information types
CO2	Find importance and be able to critically discuss the role of management information systems
CO3	Extend the information systems roles to design, engineering, and manufacturing problems
CO4	Find engineering data management issues across the extended enterprise.
CO5	Evaluate and determine data management models for all global and local enterprises
CO6	Demonstrate an appreciation of the complex relationship between information systems and organization.

Syllabus:

Manufacturing organizations and management: Networked enterprises, Globalization challenges and opportunities, Dimensions of Information systems

Approaches to study information system: Technical and Behavioural approach. Organizations, management, and the networked enterprise: Information systems in global business today, Global e-business: Use of information systems in manufacturing functions, information system, organizations, and strategy, ethical and social issue in information systems.

Information Technology Infrastructure: IT Infrastructure and Emerging Technologies, Foundations of Business Intelligence: Databases and Information Management, Telecommunications, the Internet, and Wireless Technology, Securing Information Systems, shop floor communications.

Key System Applications: Achieving Operational Excellence and Customer Intimacy: Enterprise Applications, E-Commerce: Digital Markets, Digital Goods, Managing Knowledge and Collaboration, Enhancing Decision Making.

Smart manufacturing and connected enterprise: ISA 95, Functional and physical sub-divisions, Global connected supply chain, mass customization, customer co-creation. Case studies of information systems for key manufacturing functions: Life cycle, supply chain, enterprise, quality, maintenance, materials, energy and sustainability information systems.

Text Book(s) and References:

1. K. Laudon and J. Laudon, Management Information Systems, 14th edition, Pearson Higher Education, 2016, ISBN: 9780136093688.
2. F. Cecelja, Manufacturing Information and Data Systems, 1st edition, Butterworth Heinemann, 2002, ISBN: 9781857180312.
3. T. O. Boucher and A. Yalçin, Design of Industrial Information Systems, 1st edition, Elsevier, 2006, ISBN: 9780123704924.
4. K. E. Kurbel, Enterprise Resource Planning and Supply Chain Management: Functions, Business Processes and Software for Manufacturing Companies, 1st edition, Springer, 2013, ISBN: 9783662509869.
5. R. Zurawski, Integration Technologies for Industrial Automated Systems, 1st edition, CRC Press, 2006, ISBN: 9780849392627.

Course Title	Course Code	Structure (I-P-C)		
Inspection and Testing in Manufacturing	ME522	**3**	**0**	**3**

Pre-requisite, if any: Engineering Metrology

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

CO1	Understand each of the testing and inspection methods
CO2	Find the importance and able to critically discuss the need for material testing
CO3	Extend the inspection and testing systems / methods to real time design, engineering, and manufacturing problems
CO4	Find engineering solutions across the extended manufactured component.
CO5	Evaluate and determine suitability and purpose of different testing methods
CO6	Demonstrate a novel method to understand the relationship between design and manufactured component availing NDT techniques.

Syllabus:

Types and purposes of testing of manufactured components: Precautions in inspections, Accuracy of measurement and important terms; Destructive Physical Analysis (DPA): Suitability and purpose;

Review of Mechanical testing methods: Tensile Testing (TT); Compression test, Charpy Impact test, Hardness Testing (HT) - Micro and Nano-hardness test, Stress Rupture Testing (SRT); Toughness, Fatigue and Fracture toughness test, Bend test, Creep test, Chemical tests, Macrographs study; ASTM standard test methods: Tensile test, Charpy Impact test, Micro-hardness evaluation, Fracture toughness test, Crack growth rate study, Flexural strength of beam;

Introduction to NDT: Visual Optical methods, Dye penetrant testing, Methods of application, Developer; Magnetic particle testing, Magnetization methods, Field indicators, Particle application, Inspection; Eddy current testing, Faraday's law, Inductance, Lenz's law, Self and Mutual Inductance, Impedance plane, Inspection system;

Acoustics and wave induced material testing: Ultrasonic testing: Basics of ultrasonic waves, Pulse and beam shapes, Ultrasonic transducers, Distance and Area calibration, Weld inspection by UT; Acoustic emission testing: Sources of acoustic emission, Source parameters, Kaiser-Felicity theory, Equipment and Data analysis;

Radiography methods: X-rays and their properties, X-ray generation, X-ray absorption and atomic scattering; Image formation, Image quality, Digital Radiography, Image interpretation, Radiation Shielding; ASTM standard test method for NTD tests, like Radiographic, Ultrasonic, Electromagnetic (eddycurrent), X-ray, Acoustic and Tomographic techniques; and Comparison and selection of NDT methods.

Text Book(s) and References:

1. Nondestructive Testing, Louis Cartz, ASM International
2. Nondestructive Evaluation and Quality Control, ASM Handbook, Vol. 17.
3. Non-Destructive Test and Evaluation of Materials By J Prasad, McGraw Hill, 2017
4. Welding Inspection, American Welding Society,3rdEd.,2000
5. The Mechanical Testing of Metals and Alloys By foster, P. Field, Cousens Press, 2007
6. Metals Handbook: Mechanical testing, American Society for Metals, 1978
7. ASTM standards for mechanical test, such as: ASTM E8/E8M (Tension test for metals)
8. ASTM D6110-10 (Charpy impact test), ASTM E9-09 (Compression test), ASTM E139-11 (Creep test)
9. ASTM standards for various non-destructive tests

Course Title	Course Code	Structure (I-P-C)		
Lasers in Manufacturing	ME523	**3**	**0**	**3**

Pre-requisite, if any: Basic concepts of manufacturing processes

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

CO1	Understand essential characteristics of lasing materials and principles of lasers.
CO2	Find the importance and able to critically discuss the properties of lasers
CO3	Extend and identify their suitability for various applications.
CO4	Determine the requirement of laser components in different configurations.
CO5	Evaluate and differentiate the lasers required for various material processes and manufacturing
CO6	Demonstrate a laser method with theoretical modeling of the laser material processing extended to the design, manufacturability and economics of a component.

Syllabus:

Introduction to Lasers: Basic principle of laser generation, Stimulated Emission; Properties of laser beam, Industrial, medical and scientific applications of Laser.

Basic concept of the Laser System: Gain Medium, Optical Resonator, Pump Source, Laser beam delivery systems; Introduction and basic fundamentals and characteristics of different industrial lasers: He-Ne, CO2, Nd:YAG, Excimer, Fiber, Diode and Ultra-short pulse lasers.

Laser processing fundamentals: Laser beam interaction with metal, semiconductor and insulator; Ultra-short laser pulse interaction; heat flow theory.

Laser Material Processing Applications: process characteristics, mode of material removal: Laser Cutting and Drilling; Laser Welding; Laser Surface Modifications; Laser Additive Manufacturing; Laser Metal Forming; Laser shock peening; Laser Etching and Paint Striping; LCVD and LPVD; Laser hybrid machining; Liquid assisted laser machining: applications and advantages;

Overview of Industrial & Scientific Applications of laser: Metrological applications, Holography (Non-destructive Testing), Laser Isotope Separation, Laser fusion ; Theoretical modeling of laser material processing; and Economics of Laser Applications in Manufacturing, Laser safety standards and safety procedures.

Text Book(s) and References:

1. Laser Fundamentals By William T. Silfvast, Cambridge University Press, New Delhi, 2nd South Asian Edition, 2004.
2. Principles of Lasers By SveltoOrazio, Springer, 5th Ed. 2010
3. Laser Material Processing By W. M. Steen and J. Mazumder, Springer, 4th Ed. 2010.
4. Laser Materials Processing By Elijah Kannatey–Asibu, Jr, Wiley, 2009
5. Laser Fabrication and Machining of Materials By Narendra B. Dahotre&Sandip P. Harimkar, Springer, 2007.

Course Title	Course Code	Structure (I-P-C)		
Digital Manufacturing	ME524	**3**	**0**	**3**

Pre-requisite, if any: Basic concepts of manufacturing processes

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

CO1	Understand essential concepts of digital design
CO2	Find the importance and able to critically discuss additive and subtractive digital manufacturing
CO3	Extend and identify their suitability for various shape digitization and manufacturing
CO4	Determine the comprehensive understanding of the digital manufacturing technology
CO5	Evaluate the application and potential in modern manufacturing practices.
CO6	Demonstrate a digital description that is required for direct fabrication of products from raw materials

Syllabus:
Digital design: Geometrical design of curves, Surfaces and solids, Introduction to computer aided engineering analysis and optimum design. Consideration of manufacturing and assembly aspects in design.

Shape digitization: 3D object scanning, Solid reconstruction from point cloud and tessellated data, Downstream applications;

Digital manufacturing: Subtractive manufacturing: Basic architecture, Control hardware and software details, Tooling, Sculptured surface machining.

Additive Manufacturing: Basics, Hardware details and capabilities of commercial systems, Planning of material addition, Rapid tooling solutions;

Computer Aided Process Planning: CAPP and route sheet development, CAPP system, Computer aided plant layout, Computer Aided Production Planning and Control, Algorithms for CAPP.

Product Database Management Systems: Types, Management Information System, Manufacturing data preparation, Shop-floor control, automatic identification systems (sensors, trackers), Product life cycle management; and Introduction of Industry 4.0.

Text Book(s) and References:
1. Fundamentals of Digital Manufacturing Science, by Z. Zhou, S. Xie, D. Chen, Springer, 2012.
2. Rapid Prototyping: Principles and Applications By C.K. Chua, K.F. Leong, C.S. Lim, John Wiley, 2010.
3. Mastering CAD CAM By Ibrahim Zeid, McGraw Hill, 2005.
4. Automation, production systems, and computer-aided manufacturing By M P Groover, Pearson, 2016.

Course Title	Course Code	Structure (I-P-C)		
Smart Materials and Structures	ME525	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Analyze the behaviour and properties of various smart materials and structures and assess their suitability for different applications.
CO2	Design and develop smart sensors and actuators using appropriate principles of operation and integration techniques with smart materials and structures.
CO3	Apply modeling and simulation techniques to analyze and optimize the performance of smart materials and structures in complex and dynamic environments.
CO4	Develop control strategies for smart materials and structures, including feedback and feedforward control, and optimize their performance using advanced techniques.
CO5	Evaluate emerging trends and developments in smart materials and structures and assess their impact on engineering and other fields.
CO6	Critically evaluate the ethical and societal implications of smart materials and structures and propose solutions to address potential risks and challenges associated with their development and use.

Syllabus:

Fundamentals of Smart Materials and Structures: Introduction to smart materials and structures**;** Materials and structures exhibiting smart behavior**;** Characterization techniques for smart materials and structures**;** Properties and performance of smart materials and structures**;** Applications of smart materials and structures in engineering and other fields

Smart Sensors and Actuators: Introduction to sensors and actuators**;** Types of sensors and actuators**;** Principles of operation and design of sensors and actuators**;** Applications of smart sensors and actuators**;** Integration of sensors and actuators with smart materials and structures

Modeling and Simulation of Smart Materials and Structures: Introduction to modeling and simulation; Constitutive models for smart materials and structures; Finite element analysis of smart materials and structures; Multiphysics modeling of smart materials and structures; Validation and verification of modeling and simulation results

Control and Optimization of Smart Materials and Structures: Introduction to control and optimization; Control strategies for smart materials and structures; Optimization techniques for smart materials and structures; Feedback and feedforward control of smart materials and structures; Applications of control and optimization in smart materials and structures

Advanced Topics in Smart Materials and Structures: Emerging trends and developments in smart materials and structures**;** Bio-inspired and bio-integrated smart materials and structures**;** Soft robotics and wearable technologies**;** Advanced fabrication and manufacturing techniques for smart materials and structures**;** Ethics and societal implications of smart materials and structures

Text Book(s) and References:

1. Frecker, M., Inman, D., & Kota, S. (2007). Smart materials and structures. Cambridge University Press.
2. Cheng, F. Y. (2005). Smart structures: Analysis and design. Cambridge University Press.
3. Fagan, M. J. (2008). Introduction to smart materials. CRC Press.
4. Ramaswamy, S., & Raghavan, S. (2017). Multiphysics modeling: Numerical methods and engineering applications. John Wiley & Sons.
5. Chattopadhyay, A., & Ganguli, R. (2011). Control of smart structures: An introduction. John Wiley & Sons.
6. Laschi, C., & Mazzolai, B. (Eds.). (2016). Soft robotics: From theory to applications. Academic Press.

Course Title	Course Code	Structure (I-P-C)		
Design for Manufacturing and Assembly	ME526	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	In-depth understanding on the concepts of Design for Manufacturing
CO2	Find the importance of appropriate design for economical production and selection of the materials
CO3	Extend and emphasise on assemblies using powered and non – powered machine shop equipment in conjunction with mechanical documentation.
CO4	Determine the need/problem identification, competitive benchmarking, and aspects of human factors in DFMA
CO5	Evaluate the application and potential of design in modern manufacturing practices.
CO6	Demonstrate and integrate the knowledge of compliance analysis and interference analysis for assembly and also availing visco-elastic and creep in plastics

Syllabus:

Design methodology and philosophy: Types of designs, design models, concurrent engineering, and product life cycle.
Design Teams – Organizations & product Planning: Need Analysis & Scope- mission statement, customer study, Kano diagram-Establishing Product Function- functional decomposition, FAST and SOP, function structure.
Product Teardown- reverse engineering: Product Specifications- product design tools, QFD, Computer Aided Design, Robust design, DFX, DFM, DFA, DFMA, DFSS.
Design guidelines: For metallic and non-metallic products to be manufactured by various processes.
Generation and evaluation of concepts: TRIZ, Decision matrix etc.
Industrial Design: Aesthetics and ergonomic aspects of product design. Value Engineering. Failure mode and effects analysis.

Text Book(s) and References:

1. Ashby M.F., Materials Selection in Mechanical Design, Butterworth-Heinemann, (2016).
2. Swift K.G., Booker J.D., Process Selection: From Design to Manufacture, Butterworth-Heinemann , (2003)
3. Dieter G.E., Schmidt L.C., Engineering Design, McGraw-Hill higher education, (1991).
4. Bralla J.G., Handbook for Product Design for Manufacture: A practical guide to low cost production, McGraw-Hill, (1986).
5. Ashby M.F., Johnson K., Materials and Design – the art and science of materials selection in product design, Butterworth-Heinemann, (2014).
6. Courtney T.H., Mechanical Behaviour of Materials, McGraw Hill, (2000).

Course Title	Course Code	Structure (I-P-C)		
Additive Manufacturing	ME527	**3**	**0**	**3**

Pre-requisite, if any: Basic concepts of manufacturing processes

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

CO1	In-depth understanding on the concepts of AM, various AM technologies
CO2	Find the importance of appropriate selection of materials for AM, modeling of AM processes
CO3	Extend and emphasise on applications of AM in disparate fields of modern manufactured components.
CO4	Determine the need/problem identification, competitive aspects for which conventional subtractive manufacturing can be replaced with AM techniques.
CO5	Evaluate the application and potential of AM in ability to manufacture 3D objects availing hybrid methods
CO6	Demonstrate and integrate the knowledge of compliance of AM involving planned strategies for post processing methods

Syllabus:

Introduction to Additive Manufacturing (AM): General overview, Introduction to reverse engineering Traditional manufacturing vis AM, Computer aided design (CAD) and manufacturing (CAM) and AM, Different AM processes and relevant process physics, AM process chain Application level: Direct processes–Rapid Prototyping, Rapid Tooling. Rapid Manufacturing; Indirect Processes - Indirect Prototyping. Indirect Tooling, Indirect Manufacturing.

Materials science for AM: Discussion on different materials used, Use of multiple materials, multifunctional and graded materials in AM, Role of solidification rate, Evolution of non-equilibrium structure, Structure property relationship, Grain structure and microstructure.

AM technologies: Powder-based AM processes involving sintering and melting (selective laser sintering, shaping, and electron beam melting. involvement), Printing processes (droplet based 3DSolid-based AM processes - extrusion based fused deposition modeling object Stereo lithography Micro- and Nano-additive

Process selection, planning, control for AM: Selection of AM technologies using decision methods, Additive manufacturing process plan: strategies and post processing. Monitoring and control of defects.

Text Book(s) and References:

1. Ian Gibson, David W. Rosen, Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing Springer, 2010.
2. Andreas Gebhardt, Understanding additive manufacturing: rapid prototyping, rapid tooling, rapid manufacturing, Hanser Publishers, 2011.
3. L. Lu, J. Fuh and Y.-S. Wong, Laser-induced materials and processes for rapid prototyping, Kluwer Academic Press, 200I.
4. C.K. Chua, K.F. Leong and C.S. Lim, Rapid prototyping: principles and applications, 3rd Edition, World Scientific, 2010.

Course Title	Course Code	Structure (I-P-C)		
Materials Fabrication and Characterization	ME528	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand basic principles of the synthesis techniques and fabrication techniques
CO2	Find the importance of appropriate physical, morphological and chemical properties of materials
CO3	Extend and interpret various materials characterization techniques.
CO4	Determine the principle and operation of characterization equipment's and the adjustment of operation variables to obtain good images / results
CO5	Evaluate and compare principle; operation of different characterization tools such as optical microscope, scanning electron microscopes and transmission electron microscope
CO6	Demonstrate and integrate the knowledge of materials by comprehend analysis availing characterization techniques

Syllabus:

Nanopowder synthesis: Synthesis of nanomaterials: Gold, Silver, different types of Nano oxides, TiO2, ZnO by using sol-gel method, Co-precipitation, Hydrothermal, Microwave, Solvothermal and bio synthesis methods, Nanotubes and Nanowires, Carbon nanotubes, Graphene preparation, powder syntheses, crystal growth techniques, zone refining, properties and applications.

Alloying methods: Top down and bottom up synthesis- mechanical alloying, Mechanical ball-milling, Ion implantation, Inert gas condensation, Arc discharge, RF-plasma arc technique, Laser ablation, Template assisted synthesis, Clusters, Colloids, Zeolites, Porous silicon.

Deposition Techniques: Chemical vapour deposition (CVD), Metal Organic chemical vapour deposition (MOCVD), Epitaxial growth techniques: Molecular beam epitaxy, Atomic layer deposition, Pulsed laser deposition, Pulsed electrochemical deposition, Magnetron sputtering, Spin coating, Introduction to Lithography techniques.

Material characterization: Principle, Theory, Working and Application; X-Ray Diffraction, Field Emission Scanning Electron Microscopy, High Resolution-Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy.

Advanced characterization: Photoluminescence Spectroscopy, Raman Spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Thermal analysis – Differential Scanning Calorimetry (DSC) – Thermogravimetric Analysis (TGA) – Differential Thermal Analysis (DTA) – Dynamic Mechanical Analysis (DMA), Mechanical Testing- Nano Indentation -Vibrating Sample Magnetometer, Zeta Potential and Particle size measurement.

Text Book(s) and References:

1. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
2. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate (Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.
3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
4. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004.
5. J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York.2005.
6. B. D. Cullity, "Elements of X-ray Diffraction", 4th Edition, Addison Wiley,1978.
7. M. H. Loretto, "Electron Beam Analysis of Materials", Chapman and Hall,1984
8. ASM Handbook: Materials Characterization, ASM International, 2008.
9. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd., 2008.
10. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
11. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.

Course Title	Course Code	Structure (I-P-C)		
Introduction to Smart Manufacturing	ME529	**3**	**0**	**3**

Pre-requisite, if any: Basics of computer and manufacturing operations

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

CO1	Develop a comprehensive understanding of the fundamental principles of smart manufacturing, including cyber-physical systems, data analytics, machine learning, artificial intelligence, and the Internet of Things.
CO2	Gain hands-on experience with programming languages and tools commonly used in smart manufacturing, including Python, R, and MATLAB.
CO3	Develop the ability to apply data mining and machine learning techniques to analyze large-scale data sets in order to improve manufacturing processes.
CO4	Understand the importance of integrating data analytics and machine learning techniques with traditional engineering principles in order to design and optimize manufacturing processes.
CO5	Develop the ability to use simulation and modeling tools to design and test manufacturing processes, and to analyze the impact of different variables on process performance.
CO6	Gain a deeper understanding of the ethical and societal implications of smart manufacturing, including issues related to privacy, security, and automation.

Syllabus:
Introduction to Smart Manufacturing: Overview of smart manufacturing and its benefits; Cyber-physical systems and their role in smart manufacturing; Applications of smart manufacturing in different industries

Industrial IoT and Smart Sensors: Introduction to the Internet of Things (IoT) and its role in smart manufacturing; Smart sensors and their importance in collecting data for smart manufacturing; Case studies of IoT and smart sensors in manufacturing.

Big Data Analytics and Machine Learning: Introduction to big data analytics and its role in smart manufacturing; Machine learning algorithms and their applications in smart manufacturing; Case studies of big data analytics and machine learning in manufacturing

Artificial Intelligence and Smart Manufacturing: Introduction to artificial intelligence and its role in smart manufacturing; AI techniques and their applications in smart manufacturing; Case studies of artificial intelligence in manufacturing

Digital Twin and Virtual Commissioning: Introduction to digital twin technology and its role in smart manufacturing; Virtual commissioning and its importance in reducing manufacturing costs and time-to-market; Case studies of digital twin and virtual commissioning in manufacturing.

Smart Factory and Industry 4.0: Introduction to Industry 4.0 and its role in smart manufacturing; Smart factory concepts and their applications in Industry 4.0; Case studies of smart factories and Industry 4.0 in different industries
Cybersecurity and Smart Manufacturing: Introduction to cybersecurity risks in smart manufacturing; Best practices for securing smart manufacturing systems and data; Case studies of cybersecurity incidents in smart manufacturing.
Future of Smart Manufacturing: Emerging trends and technologies in smart manufacturing; Implications of

smart manufacturing for the workforce and society; Opportunities and challenges for companies adopting smart manufacturing

Text Book(s) and References:

1. Smart Manufacturing: Concepts and Methods by J. Paulo Davim
2. Cyber-Physical Systems: Integrated Computing and Engineering Design by Fei Hu
3. Modern Manufacturing Engineering: by J. Paulo Davim
4. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems by Aurélien Géron
5. Python for Data Analysis by Wes McKinney
6. Applied Artificial Intelligence: A Handbook For Business Leaders by Mariya Yao, Adelyn Zhou, Marlene Jia
7. Kumar, K., Zindani, D., & Davim, J. P. (2019). Industry 4.0: Developments towards the fourth industrial revolution. Cham, Switzerland: Springer.
8. Cioffi, R., Travaglioni, M., Piscitelli, G., Petrillo, A., & Parmentola, A. (2020). Smart manufacturing systems and applied industrial technologies for a sustainable industry: A systematic literature review. Applied Sciences, 10(8), 2897.
9. Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2019). Smart manufacturing: Characteristics, technologies and enabling factors. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 233(5), 1342-1361.

Course Title	Course Code	Structure (I-P-C)		
Processing of Alloys and Composites	ME530	**3**	**0**	**3**

Pre-requisite, if any: Material science and metallurgy

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

CO1	Identify and classify different types of composites and soft materials, including their structures and properties.
CO2	Analyze and explain the mechanisms behind different types of phase transformations and their impact on material properties.
CO3	Evaluate and apply various surface engineering techniques to improve the properties and durability of different types of materials.
CO4	Assess and compare the design, structure, and properties of conventional and high entropy materials, including single and multiphase HEAs.
CO5	Analyze and predict the mechanical behavior of materials under different conditions, including stress-strain relationships, fracture, fatigue, and wear.
CO6	Demonstrate proficiency in using different tools and techniques in failure analysis, such as metallographic techniques, fractography, and non-destructive testing.

Syllabus:

Composites: Introduction, classification of composites, strengthening mechanism in composite, types of reinforcements, production methods for reinforcements, metal matrix composites, carbon-carbon composites, ceramic matrix composites, polymer matrix composites, interfaces and interphases, properties.

Soft Materials: Introduction to ‘soft’ materials in terms of structure, property- Colloids, foams, gels, liquid crystals, soft biological materials such as DNA, and polymers (synthetic and natural) Structure (states and configuration) of polymers, synthesis, effect of temperature (glass transition and melting), branching, cross-linking on properties, crystallization in polymers (types and mechanism), mechanical behaviour – viscoelasticity -spring dash pod models – relaxation behaviour (time and temperature effect) Self-assembly and Supramolecular organization with reference to cellulose, silk, collagen and biological macromolecules

Phase Transformations: Phase stability and free energy of mixing; free energy-composition diagrams and phase diagrams; defects and diffusion; nucleation and growth; liquid-solid, precipitation, disorder-order, spinodal and martensitic phase transformations

Surface Engineering: Surface dependent engineering properties, common surface-initiated engineering failures, mechanism of surface degradation, classification and scope of surface engineering in metals, ceramics, polymers and composites, Surface protection and surface modification techniques.

High Entropy Material: Conventional vs high entropy alloy (HEA) design, thermodynamic aspects, structure and properties of single and multiphase HEAs, special subclasses of HEAs, high entropy related materials including oxides, carbides, nitrides and borides and their properties.

Functional and Structural polymers: Structural polymers, crystallisation in polymers (types and mechanism), mechanical behaviour - viscoelasticity -spring dash pod models - relaxation behaviour (time and temperature effect), functional polymers (conducting polymers, liquid crystalline polymers, polymeric photonic crystals), characterization- scattering by polymers, flow in polymers- rheology, polymer blends and composites, blending (solubility and compatibility)

Mechanical Behaviour and Testing: Mechanical behaviour of composites, stress-strain relations, elastic properties, thermal stresses, strength, fracture, toughness, fatigue, creep and wear
Tools and techniques in failure analysis: General Practices, Photography, X-rays techniques, Mechanical property evaluations, Metallographic techniques, Fractography, Non-destructive testing technique

Text Book(s) and References:

1. Young, R.J., and Peter A. Lovell, Introduction to Polymers, 3rd revised edition, CRC Press, 2011.
2. Rudin, A., The Elements of Polymer Science and Engineering, 3rd edition, Academic Press, 2012.
3. Barbero, E.J., Introduction to Composite Materials Design, Second Edition, CRC Press, 2011.
4. Kar, K. K., Composite Materials: Processing, Applications, Characterizations, Springer, 2017.
5. Practical engineering failure analysis, H.M. Tawancy, A. Ul-Hamid and N.M. Abbas, Marcel Dekker, New York, 2004.
6. Introduction to Dislocations, D. Hull and D.J. Bacon, Pergamon Press, Oxford, 1984.
7. Introduction to Microfabrication by Sami Fransilla (Wiley)
8. Koo, J.H., Polymer Nanocomposites: Processing, Characterization, and Applications, McGraw-Hill, 2010.
9. A.J. McEvily, Metal Failures: Mechanisms, Analysis, Prevention, John Wiley and Sons, 2002.
10. Failure analysis and prevention, Volume 11, ASM Handbook, The Materials Information Society, 2002.
11. Failure analysis of engineering structures: Methodology and case histories, V. Ramachandran, A.C. Raghuram, R.V. Krishnan and S.K. Bhaumik, ASM International, 2005.
12. Failure analysis of Engineering Materials, Charles R. Brooks and Ashok Choudhury

Course Title	Course Code	Structure (I-P-C)		
Computer Integrated Manufacturing Systems	ME531	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Analyze and evaluate the key components and architecture of CIM systems, including the role of computers and communication protocols in system integration.
CO2	Design and integrate CIM systems using database and software engineering principles, with a focus on achieving optimal communication and interoperability between different manufacturing systems.
CO3	Demonstrate proficiency in using CIM technologies such as CAD, CAM, FMS, AMHS, robotics, and automated assembly systems to design and implement automated manufacturing processes.
CO4	Apply manufacturing planning and control (MPC) systems to manage and optimize CIM processes, including quality control and inspection techniques.
CO5	Evaluate and assess the impact of human factors on CIM systems, and identify strategies for managing the human-machine interface in automated manufacturing environments.
CO6	Analyze and critique advanced topics in CIM, such as real-time control and monitoring, simulation and optimization, and concurrent engineering, and apply these concepts to design and optimize CIM systems.

Syllabus:

Introduction to CIM Systems: Definition and evolution of CIM; Advantages of CIM systems; CIM system components and architecture; Role of computers in CIM

CIM System Design and Integration: Designing and integrating CIM systems; Role of databases and software engineering in CIM; Communication protocols and standards for CIM integration; Integration of different manufacturing systems

CIM Technologies: Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM); Flexible Manufacturing Systems (FMS); Automated Material Handling Systems (AMHS); Robotics and automated assembly systems

CIM System Management: Manufacturing Planning and Control (MPC) systems; Quality Control and Inspection in CIM; Maintenance of CIM systems; Human factors in CIM

Advanced Topics in CIM: Real-time control and monitoring in CIM; Simulation and optimization of CIM systems; Concurrent engineering and product design in CIM; Integration of CIM with other enterprise systems (ERP, CRM, etc.)

Text Book(s) and References:

1. Rehg, J. A., & Kraebber, H. W. (2005). Computer integrated manufacturing. Pearson Education.
2. Groover, M. P. (2014). Automation, production systems, and computer-integrated manufacturing. Pearson Education.
3. Jacobs, F. R., & Berry, W. L. (2011). Manufacturing planning and control for supply chain management. McGraw-Hill.

4. Chang, T. C., & Wysk, R. A. (2017). Computer-Aided Manufacturing. CRC Press.
5. Gilchrist, A. (2016). Industry 4.0: The Industrial Internet of Things. Wiley.
6. Brown, S. G. B., & Stavely, P. (2019). Manufacturing Systems Engineering. CRC Pres

Course Title	Course Code	Structure (I-P-C)		
Industrial Instrumentation & Metrology	ME532	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Demonstrate an understanding of the fundamental principles of instrumentation and metrology, including measurement uncertainty, accuracy, precision, and repeatability.
CO2	Analyze and select appropriate measurement tools and techniques for a given application, taking into account factors such as sensor resolution, sensitivity, and noise.
CO3	Design and implement measurement systems, including data acquisition and signal processing components, that meet specific performance criteria and requirements.
CO4	Evaluate the performance of measurement systems through statistical analysis of data, identification and control of error sources, and estimation of uncertainty.
CO5	Apply knowledge of instrumentation and metrology to solve real-world problems in a range of industrial settings, such as manufacturing, process control, and quality assurance.
CO6	Communicate technical information effectively through written and oral presentations, including formal technical reports and presentations to non-technical audiences.

Syllabus:

Introduction to Industrial Instrumentation: Definition and scope of industrial instrumentation; Types of instruments and their classification; Elements of measuring systems: sensor, transducer, signal conditioning, data acquisition; Performance criteria and accuracy of measuring instruments; Calibration techniques and standards; Trends and recent developments in industrial instrumentation

Sensors and Transducers: Introduction to sensors and transducers; Mechanical sensors: force, torque, pressure, and displacement sensors; Optical sensors: fiber optic sensors, photodiodes, and phototransistors; Thermal sensors: thermocouples, RTDs, and thermistors; Chemical sensors: pH sensors, gas sensors, and biosensors; Signal conditioning and amplification of sensor signals

Signal Processing and Data Acquisition: Introduction to signal processing and data acquisition
Analog signal processing techniques: filtering, amplification, and modulation; Digital signal processing techniques: sampling, quantization, and coding; Data acquisition systems: sensors, signal conditioning, and signal digitization; Real-time systems and control applications; Trends and recent developments in signal processing and data acquisition

Metrology and Quality Control: Introduction to metrology and quality control; Measurement standards and traceability; Measurement uncertainty and error analysis; Statistical process control and quality assurance; Calibration systems and procedures; Trends and recent developments in metrology and quality control

Advanced Topics in Industrial Instrumentation: Introduction to advanced topics in industrial instrumentation; Smart sensors and wireless sensor networks; Industrial automation and control systems; Robotics and mechatronics; Machine vision and image processing; Trends and recent developments in advanced topics in industrial instrumentation

Text Book(s) and References:

1. Beckwith, T. G., Marangoni, R. D., & Lienhard V, J. H. (2013). Mechanical measurements. Pearson Education.
2. Doebelin, E. O., & Manik, D. N. (2014). Measurement systems: Application and design. McGraw-Hill Education.
3. Helfrick, A. D., & Cooper, W. D. (2016). Modern electronic instrumentation and measurement techniques. Pearson Education.
4. Jones, D. A., & Hawkins, G. A. (2014). Engineering metrology. John Wiley & Sons.
5. Bar-Cohen, Y. (Ed.). (2018). Measurement, instrumentation, and sensors handbook: Electromagnetic, optical, radiation, chemical, and biomedical measurement. CRC Press.
6. Jayaraman, K., & Brown, R. G. (Eds.). (2015). Handbook of dimensional measurement. John Wiley & Sons.

Course Title	Course Code	Structure (I-P-C)		
MEMS/NEMS and Sensors	ME533	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand the fundamental principles and technologies of MEMS/NEMS and sensors, including their design, fabrication, and characterization.
CO2	Analyze the various types of MEMS/NEMS and sensors, including their advantages, limitations, and applications.
CO3	Design and optimize MEMS/NEMS and sensors for specific applications, using analytical and simulation tools.
CO4	Evaluate the performance of MEMS/NEMS and sensors through experimental testing and measurement techniques and interpret the results.
CO5	Apply knowledge of MEMS/NEMS and sensors to real-world problems and propose innovative solutions.
CO6	Communicate effectively, both orally and in writing, about MEMS/NEMS and sensors concepts, designs, and results, to both technical and non-technical audiences.

Syllabus:

Introduction to MEMS/NEMS and Sensors; Fundamentals of MEMS/NEMS and sensors**;** History and evolution of MEMS/NEMS and sensors**;** Applications of MEMS/NEMS and sensors**;** Market trends and future directions

Fabrication and Packaging Techniques: Silicon-based fabrication techniques; Non-silicon based fabrication techniques; Thin film deposition techniques**;** Surface and bulk micromachining**;** Packaging techniques for MEMS/NEMS and sensors

MEMS/NEMS and Sensor Design: Design considerations for MEMS/NEMS and sensors**;** Mechanical design of MEMS/NEMS devices**;** Electrical design of MEMS/NEMS and sensors**;** Sensing mechanisms and transduction principles; Design of microfluidic systems for sensors

Characterization and Testing of MEMS/NEMS and Sensors: Static and dynamic characterization of MEMS/NEMS devices**;** Electrical testing and calibration of sensors**;** Optical and thermal characterization techniques**;** Reliability testing and failure analysis of MEMS/NEMS and sensors

Emerging Trends in MEMS/NEMS and Sensors: MEMS/NEMS for biomedical applications**;** MEMS/NEMS for energy harvesting and storage; MEMS/NEMS for environmental monitoring**;** NEMS and beyond: Carbon nanotubes and graphene-based devices**;** Sensor fusion and integrated systems for IoT and smart applications.

Text Book(s) and References:

1. Madou, M. J. (2011). Fundamentals of microfabrication and nanotechnology (3rd ed.). CRC Press.
2. Maluf, N. I., Williams, K. R., & Muller, R. S. (2004). An introduction to microelectromechanical systems engineering (2nd ed.). Artech House.

3. Sze, S. M., & Lee, M. (2017). Nanoelectronics and nanosystems: From transistors to molecular and quantum devices. Wiley.
4. Hsu, W. H., & Tai, Y. C. (2011). MEMS and microsystems: Design, manufacture, and nanoscale engineering. Wiley.
5. Gardner, J. W., & Varadan, V. K. (Eds.). (2001). Microsensors, MEMS, and smart devices. Wiley.
6. Bhushan, B. (Ed.). (2018). Handbook of nanomaterials properties. Springer.

Course Title	Course Code	Structure (I-P-C)		
Metal Forming	ME534	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand the fundamental principles of metal forming, including deformation mechanisms, flow stress, and material behavior.
CO2	Analyze and design various metal forming processes, such as rolling, forging, extrusion, and sheet metal forming, based on material properties and process parameters.
CO3	Apply numerical modeling techniques, such as finite element analysis, to predict and optimize the behavior of metal forming processes.
CO4	Develop expertise in the use of metal forming equipment and tools, including presses, dies, and tooling.
CO5	Understand the principles of process monitoring and control in metal forming, including sensors, actuators, and feedback systems.
CO6	Apply the principles of metal forming to specific applications, such as the automotive industry, aerospace, and medical devices, and evaluate the advantages and limitations of different metal forming techniques for these applications.

Syllabus:

Fundamentals of Metal Forming: Introduction to metal forming processes**;** Classification of metal forming processes**;** Characteristics of metals and alloys for forming**;** Deformation mechanisms in metal forming**;** Friction and lubrication in metal forming
Bulk Forming Processes: Rolling processes and applications**;** Forging processes and applications**;** Extrusion processes and applications**;** Drawing processes and applications**;** Stretch forming processes and applications
Sheet Metal Forming Processes: Introduction to sheet metal forming**;** Bending and forming of sheet metal**;** Deep drawing of sheet metal**;** Hydroforming of sheet metal**;** Superplastic forming of sheet metal
Special Metal Forming Processes: Introduction to special metal forming processes**;** Explosive forming**;** Electromagnetic forming**;** Incremental forming**;** Powder metallurgy processes**;** Joining processes in metal forming
Modeling, Simulation, and Optimization of Metal Forming Processes: Introduction to modeling, simulation, and optimization**;** Finite element analysis of metal forming processes**;** Process modeling and design optimization**;** Process monitoring and control**;** Emerging trends and developments in metal forming

Text Book(s) and References:

1. Hosford, W. F., & Caddell, R. M. (2011). Metal forming: Mechanics and metallurgy. Cambridge University Press.
2. Sahai, Y. (2016). Fundamentals of metal forming technology. CRC Press.
3. Boljanovic, V., & Singh, J. (2010). Sheet metal forming processes and die design. Industrial Press Inc.
4. Altan, T., & Tekkaya, A. E. (2012). Metal forming analysis. Butterworth-Heinemann.
5. Trent, E. M. (2010). Precision metal forming. CRC Press.
6. Müller, U., & Schubert, A. (2015). Joining processes in the automotive industry: Development, modeling, and optimization. Springer.

Course Title	Course Code	Structure (I-P-C)		
Total Quality Management	ME535	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand the principles and practices of Total Quality Management, including the historical development of TQM and its impact on organizations.
CO2	Develop skills in statistical process control and quality measurement techniques, including the use of tools such as Pareto charts, histograms, and control charts.
CO3	Analyze the impact of quality management on organizational performance, including the relationship between TQM and customer satisfaction, employee engagement, and financial outcomes.
CO4	Identify strategies for implementing TQM in a variety of organizational settings, including manufacturing, service, and healthcare industries.
CO5	Evaluate the role of leadership and organizational culture in successful TQM implementation, including the importance of effective communication, training, and continuous improvement.
CO6	Apply TQM principles and practices in a real-world setting through case studies, simulations, and/or research projects, demonstrating the ability to identify problems, analyze data, and develop and implement solutions to improve organizational performance.

Syllabus:
Introduction to TQM: Historical perspective of TQM; Definition and principles of TQM; Quality gurus and their contributions; Importance of TQM in today's business environment

Mathematical details: Statistical quality control techniques such as control charts, process capability indices, and acceptance sampling plans will be covered. Students will learn to use statistical software packages for analyzing quality data.

TQM Tools and Techniques: Process mapping and analysis; Statistical process control; Failure mode and effects analysis; Quality function deployment; Root cause analysis

Mathematical details: Students will learn to apply statistical process control techniques such as control charts, process capability indices, and statistical hypothesis testing to monitor and improve processes. They will also learn to use quality function deployment tools to identify customer requirements and translate them into design specifications.

TQM Implementation: Creating a quality culture**;** Employee involvement and empowerment**;** Leadership and management commitment**;** Continuous improvement and problem-solving**;** Benchmarking and best practices

Mathematical details: Students will learn to use statistical techniques to identify and prioritize quality improvement opportunities. They will also learn to use process improvement tools such as process flow charts, cause-and-effect diagrams, and Pareto charts.
TQM and Business Strategy: Strategic planning and deployment**;** Customer focus and satisfaction**;** Supplier management and partnerships**;** Performance measurement and metrics**;** Alignment with organizational goals

and objectives

Mathematical details: Students will learn to use statistical methods to analyze customer satisfaction data and to develop performance metrics that align with organizational goals and objectives.

TQM and Organizational Change: Change management principles and practices**;** Resistance to change and how to overcome it**;** Developing a change management plan**;** Communication strategies for change**;** Sustaining TQM initiatives over time

Mathematical details: Students will learn to use statistical process control techniques to monitor the effectiveness of change management initiatives and to identify opportunities for improvement.

Text Book(s) and References:

1. Goetsch, D. L., & Davis, S. B. (2021). Quality management for organizational excellence: Introduction to total quality (9th ed.). Pearson.
2. Liker, J. K. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. McGraw-Hill.
3. Juran, J. M., & De Feo, J. A. (2010). Juran's quality handbook: The complete guide to performance excellence (6th ed.). McGraw-Hill.
4. Dale, B. (2015). Total quality management. John Wiley & Sons, Ltd.
5. Oakland G. F. Total Quality Management, Oxford, 2003.
6. S. S. Singh, Total quality control essentials by McGraw Hill Inc.93 Singapore.

Course Title	Course Code	Structure (I-P-C)		
Nano Finishing Science and Technology	ME536	**3**	**0**	**3**

Pre-requisite, if any: Material science and metallurgy

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

CO1	Understand the principles and concepts of nano finishing, including surface metrology, tribology, and surface integrity at nanoscale.
CO2	Demonstrate knowledge of advanced finishing processes, such as abrasive flow machining, electrochemical polishing, magnetic abrasive finishing, and superfinishing.
CO3	Develop an understanding of nanomaterials and their applications in nano finishing, including surface modification and nanoparticle-assisted finishing.
CO4	Apply surface characterization techniques, such as atomic force microscopy and X-ray photoelectron spectroscopy, to measure surface roughness, energy, and adhesion at nanoscale.
CO5	Analyze the economic and environmental aspects of nano finishing, and evaluate its industrial applications in sectors such as aerospace, automotive, biomedical, and electronics.
CO6	Demonstrate proficiency in writing technical reports, presenting research findings, and working collaboratively in a team environment.

Syllabus:

Fundamentals of Nano Finishing: Introduction to nano finishing science and technology; Principles of surface metrology and characterization; Surface roughness and its measurement at nanoscale; Fundamentals of surface integrity and tribology; Overview of conventional and non-conventional finishing processes

Advanced Finishing Processes: Principles and applications of advanced finishing processes, such as abrasive flow machining, electrochemical polishing, and magnetic abrasive finishing; Surface nanocrystallization and its applications; Chemical mechanical polishing and planarization; Magnetorheological finishing and polishing; Superfinishing and ultraprecision machining

Nanomaterials and Nanofinishing: Introduction to nanomaterials and their properties; Role of nanomaterials in nano finishing; Surface modification of nanomaterials; Nanoparticle assisted finishing; Surface functionalization using nanomaterials

Surface Metrology and Characterization Techniques: Advanced surface metrology techniques, such as atomic force microscopy, scanning electron microscopy, and X-ray photoelectron spectroscopy; Surface energy and wettability measurements; Contact mechanics and surface adhesion; In situ characterization techniques for nano finishing; Surface texture analysis and machine vision

Applications of Nano Finishing: Industrial applications of nano finishing in sectors such as aerospace, automotive, biomedical, and electronics; Advancements in nano finishing for additive manufacturing; Nano finishing for micro/nano-electromechanical systems; Nano finishing for surface patterning and functionalization; Economic and environmental aspects of nano finishing

Text Book(s) and References:

1. Bhushan, B. (Ed.). (2008). Springer Handbook of Nanotechnology (3rd ed.). Springer.
2. Luo, X., & Liang, Y. (Eds.). (2018). Nanofinishing Science and Technology: Basic and Advanced Finishing and Polishing Processes. CRC Press.

3. Pettersson, M., & Zhou, J. (Eds.). (2018). Handbook of Surface Metrology. Springer.
4. Zhang, X., & Wang, J. (Eds.). (2016). Nanomaterials in Advanced Manufacturing and Engineering Applications. Springer.
5. Jain, V. K. (2013). Advanced Machining Processes. Allied Publishers Pvt. Ltd.

Hu, Z. (2014). Micro and Nano Fabrication Technology. McGraw Hill Education.

Course Title	Course Code	Structure (I-P-C)		
Processing of Composites	ME537	**3**	**0**	**3**

Pre-requisite, if any: Material science and metallurgy

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

CO1	Understand the principles and concepts of composite materials, including their types, constituents, properties, and applications.
CO2	Demonstrate knowledge of processing techniques for polymer, metal, and ceramic matrix composites, and design considerations for each.
CO3	Analyze the properties and performance of composites and evaluate their suitability for different applications.
CO4	Develop expertise in advanced manufacturing techniques for composites, including additive manufacturing, automation, and process optimization.
CO5	Apply computational tools and simulation techniques to model and analyze the manufacturing process and properties of composites.
CO6	Evaluate the environmental impact of composites manufacturing and identify opportunities to improve sustainability.

Syllabus:

Introduction to Composites: Overview of composites and their types**;** Constituents of composites**;** Manufacturing processes for composites; Properties and applications of composites

Polymer Matrix Composites: Types of polymer matrix composites**;** Processing techniques for polymer matrix composites**;** Properties and performance of polymer matrix composites**;** Design considerations for polymer matrix composites

Metal Matrix Composites: Types of metal matrix composites**;** Processing techniques for metal matrix composites**;** Properties and performance of metal matrix composites**;** Design considerations for metal matrix composites

Ceramic Matrix Composites: Types of ceramic matrix composites**;** Processing techniques for ceramic matrix composites**;** Properties and performance of ceramic matrix composites**;** Design considerations for ceramic matrix composites

Advanced Manufacturing Techniques for Composites: Additive manufacturing for composites**;** Automation and robotics for composites manufacturing**;** Process optimization and control for composites**;** Sustainability and environmental impacts of composites manufacturing

Text Book(s) and References:

1. Agarwal, B. D., & Broutman, L. J. (2018). Composite Materials: Science and Engineering (3rd ed.). Springer.
2. Kuo, W. S., & Chern, T. L. (2019). Processing of Polymer Matrix Composites (2nd ed.). Woodhead Publishing.
3. Srivatsan, T. S., & Kumar, R. (2015). Metal Matrix Composites (2nd ed.). CRC Press.
4. Bansal, N. P. (2018). Ceramic Matrix Composites: Materials, Modeling and Technology. John Wiley &

Sons.
5. Gibson, R. F. (2012). Principles of Composite Material Mechanics (4th ed.). CRC Press.
6. Kim, N. J. (Ed.). (2019). Additive Manufacturing of Metals: From Fundamental Technology to Rocket Nozzles, Medical Implants, and Custom Jewellery. Springer.

Course Title	Course Code	Structure (I-P-C)		
Surface Engineering	ME538	**3**	**0**	**3**

Pre-requisite, if any: Material science and metallurgy

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

CO1	Understand the principles and concepts of surface engineering, including surface characterization and modification techniques.
CO2	Demonstrate knowledge of various surface analysis techniques and their applications in characterizing surfaces.
CO3	Analyze the properties and performance of surfaces, and evaluate their impact on material behavior and application.
CO4	Develop expertise in surface modification techniques, and design surfaces with specific properties and functionalities.
CO5	Apply computational tools and simulation techniques to model and analyze the behavior of engineered surfaces.
CO6	Evaluate the performance of surface-engineered materials for various applications and assess their potential for real-world applications.

Syllabus:

Introduction to Surface Engineering: Surface engineering concepts and applications; Types of surfaces and their characteristics; Surface properties and measurement techniques; Surface modification techniques and their applications

Surface Characterization Techniques: Surface analysis techniques (e.g., XPS, AFM, SEM, TEM)**;** Microstructural characterization of surfaces**;** Surface texture measurement and analysis**;** Surface energy and wettability analysis

Surface Modification Techniques: Coating and thin film deposition techniques; Surface treatment techniques (e.g., plasma, laser, ion implantation); Surface functionalization techniques (e.g., grafting, self-assembled monolayers); Surface patterning and microfabrication techniques

Surface Properties and Performance: Surface properties and their impact on material performance; Surface degradation and failure mechanisms; Surface engineering for improved tribological performance; Surface engineering for enhanced corrosion resistance

Applications of Surface Engineering: Surface engineering for biomedical applications; Surface engineering for energy conversion and storage; Surface engineering for electronics and optoelectronics; Surface engineering for environmental protection

Text Book(s) and References:

1. Rickerby, D. G. (2018). Surface Engineering (2nd ed.). Woodhead Publishing.
2. Roy, D. (Ed.). (2018). Handbook of Surface Engineering and Nanotechnology (3rd ed.). CRC Press.
3. Wang, Q., & Liang, Y. (2019). Surface Modification Technologies XXVIII: Proceedings of the 28th International Conference on Surface Modification Technologies. ASM International.
4. Dowling, D. P. (2018). Surface Science: An Introduction (2nd ed.). John Wiley & Sons.

5. Li, X. (2019). Advances in Surface Engineering. Springer.
6. Khang, G., Lee, H., & Kim, B. S. (Eds.). (2017). Surface Modification Technologies XV: Proceedings of the 15th International Conference on Surface Modification Technologies. ASM International.

Course Title	Course Code	Structure (I-P-C)		
Modern Manufacturing Technologies	ME539	**3**	**0**	**3**

Pre-requisite, if any: Basic concepts of Manufacturing

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

CO1	Understand the fundamental principles of modern manufacturing technologies, including their advantages and limitations, and how to select the appropriate process for a given application.
CO2	Develop expertise in advanced machining processes, additive manufacturing, smart manufacturing, and materials processing and forming, including the ability to design, analyze, and optimize manufacturing processes and systems.
CO3	Gain practical experience in using modern manufacturing tools and techniques, such as computer-aided design (CAD), computer-aided manufacturing (CAM), and numerical simulation software.
CO4	Analyze and evaluate the impact of modern manufacturing technologies on society, including their economic, environmental, and ethical implications.
CO5	Communicate effectively about modern manufacturing technologies, including the ability to write technical reports and give oral presentations.
CO6	Develop the skills needed to continue learning about modern manufacturing technologies and keep up with advancements in the field throughout their careers.

Syllabus:

Fundamentals of Metal Forming: Introduction to metal forming processes**;** Classification of metal forming processes**;** Characteristics of metals and alloys for forming**;** Deformation mechanisms in metal forming**;** Friction and lubrication in metal forming

Introduction to Modern Manufacturing Technologies: Overview of modern manufacturing technologies and their applications**;** Trends and challenges in modern manufacturing**;** Classification and selection of modern manufacturing processes**;** Process planning and control in modern manufacturing**;** Safety and environmental considerations in modern manufacturing

Advanced Machining Processes: Principles and applications of advanced machining processes, such as ultrasonic machining, electrical discharge machining, and laser machining**;** Non-traditional machining processes and their advantages and limitations**;** Micro/nano-scale machining techniques and their applications**;** Advanced tool materials and coatings for machining**;** Machining of difficult-to-machine materials and complex shapes

Additive Manufacturing and 3D Printing: Principles and applications of additive manufacturing and 3D printing; Types of additive manufacturing technologies and their advantages and limitations; Materials and processes for additive manufacturing; Design for additive manufacturing and topology optimization; Post-processing and finishing of additively manufactured parts

Smart Manufacturing and Industry 4.0: Principles and applications of smart manufacturing and Industry 4.0**;** Cyber-physical systems and the Internet of Things in manufacturing**;** Advanced sensors and data analytics in manufacturing**;** Digital twins and virtual manufacturing**;** Applications of smart manufacturing and Industry 4.0 in various industries

Materials Processing and Forming: Principles and applications of materials processing and forming Advanced metal forming processes and techniques, such as high-speed forming and hydroforming Polymer processing techniques, such as injection molding and extrusion; Composite materials processing and manufacturing; Process monitoring and control in materials processing and forming

Text Book(s) and References:

1. Kalpakjian, S., & Schmid, S. R. (2014). Manufacturing Engineering and Technology (7th ed.). Prentice Hall.
2. El-Wardany, T. I. (2018). Modern Manufacturing Processes (1st ed.). CRC Press.
3. Gibson, I., Rosen, D. W., & Stucker, B. (2015). Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing (2nd ed.). Springer.
4. Lienig, J., & Tolksdorf, R. (2017). Smart Production: Wertschöpfung durch Geschäftsmodelle (1st ed.). Springer.
5. Dieter, G. E., & Schmidt, L. C. (2017). Engineering Design (5th ed.). McGraw-Hill.
6. Ashby, M. F., Shercliff, H., & Cebon, D. (2019). Materials: Engineering, Science, Processing and Design (3rd ed.). Butterworth-Heinemann.

Course Title	Course Code	Structure (I-P-C)		
Mechanical Vibrations and Condition Monitoring	ME541	**3**	**0**	**3**

Pre-requisite(s): Dynamics of Machines.

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

CO1	Understand and apply the maintenance scheme to various industry problems.
CO2	Perform fault analysis, machine condition monitoring and faults diagnostics.
CO3	Use modern testing equipment to identify the faults in machines.
CO4	Understand application of vibration analysis to the condition monitoring of machines.
CO5	Learn techniques in the field of signal processing, thermography, ultrasonics apart from the traditional noise- and vibration-based monitoring.

Syllabus:

Types of maintenance, preventive and corrective maintenance, preventive maintenance – time based & condition-based condition monitoring, cost effectiveness & performance monitoring, different condition monitoring techniques - on-line and off-line techniques.

Various techniques for fault detection, visual inspection, crack detection techniques: magnetic crack detection and radiography, oil analysis, wear particle analysis, ferrography, ultrasonic crack detection, thermography.

Non-destructive techniques – important features, types of defects detected by NDT – visual, dye penetration, acoustic emission and its applications, X-ray, radiographic, magnetic flux test etc, application of NDT techniques.

Vibration data collection, techniques, instruments, vibration analysis of rotating machines and mechanical systems, faults diagnosed by vibration analysis, noise monitoring, temperature monitoring, pressure monitoring.

Signal analysis and computer aided data acquisition, time domain signal analysis, frequency domain signal analysis, spectrum analysis, fault detection transducers and instrumentation.

Applications of condition monitoring in mechanical systems, cutting tools and machine tools condition monitoring, IC engine condition monitoring, power plant condition monitoring, 3D printing condition monitoring, rotating machines condition monitoring.

Textbook(s) and Reference(s):

1. R. Collacott, “Mechanical Fault Diagnosis and Condition Monitoring,” Springer.
2. R. Barron, “Engineering Condition Monitoring Practice, Methods and Applications,” Addison, Weslay Longman.
3. P. Girdhar, “Machinery vibration analysis and predictive maintenance,” Elsevier.
4. R. Isermann, “Fault-Diagnosis Applications,” Springer.
5. A. Ghosh and A. K. Mallik, “Theory of Mechanism and Machines,” Affiliated East –West Press Private Ltd., 2009.

Course Title	Course Code	Structure (I-P-C)		
Mechanical Vibrations	ME542	**3**	**0**	**3**

Pre-requisite(s): Dynamics of Machines.

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

CO1	Understand the free and forced vibration of single and multi-degree-of-freedom systems.
CO2	Understand the working principle of vibration measuring instruments.
CO3	Mathematically model vibration problems and to mitigate vibration effects.
CO4	Design and develop vibration absorbers, dampers and vibration isolators.
CO5	Analyze the vibration of continuous systems such as shaft, rod and beams.

Syllabus:

Single degree-of-freedom systems: formulation, energy method, Newton-Euler method, free vibration, undamped and damped free vibration, forced vibration, harmonic excitation, solution of differential equation of motion, vector approach, complex frequency response, magnification factor, resonance, force transmissibility, displacement transmissibility, vehicular suspension, vibration measuring instruments.

Multi degree-of-freedom systems: the eigenvalue problem and its solution, natural frequencies and mode shapes, orthogonality, generalized coordinates, response to initial conditions and typical excitation forms, proportional and modal damping.

Continuous systems: MDOF systems as a limiting case of continuous systems, lumped parameter analysis and discretization, mass and stiffness operators for continuous systems as analogues to matrices for MDOF systems.

Classic examples of one-dimensional continuous systems: strings, rods, beams, derivation and solution of equations of motion, response to typical boundary conditions and excitation forms.

Two-dimensional continuous systems such as plates and membranes.

Textbook(s) and Reference(s):

1. L. Meirovitch, “Fundamentals of Vibrations,” McGraw-Hill, 2002.
2. J.P. Den Hartog, “Mechanical Vibrations,” Dover, 1985.
3. S.S. Rao, “Mechanical Vibrations,” Pearson, 2003.
4. A. Leissa, “Vibrations of Continuous Systems,” McGraw-Hill, 2011.
5. W.T. Thomson, “Theory of Vibration with Applications,” Pearson, 2008.

Course Title	Course Code	Structure (I-P-C)		
Advanced Solid Mechanics	ME543	**3**	**0**	**3**

Pre-requisite, if any: Mechanics of Materials

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

CO1	Apply the stress-strain relations for linearly elastic members using normal stress, shear stress and distortion energy theories.
CO2	Analyse the mechanical structures using energy methods.
CO3	Design straight beams, curved and asymmetrical bending of beams
CO4	Analyse the beams under unsymmetrical loading.
CO5	Apply shear centre of thin wall beams, torsion & axisymmetric problems

Syllabus:

Analysis of Stress – Traction vector, stress tensor, Principle stresses, Hydrostatic and deviatoric stresses

Analysis of Strain – displacement field, deformation tensor, strain tensor, principle strain

Stress-Strain Relations for Linearly Elastic Solids-Anisotropic, isotropic behaviour

Theories of Failure: Significance of the theories of failure, Factor of safety in design.

Energy Methods: Hooke's law and the principle of superposition, Work done by forces and elastic strain energy stored, Reciprocal theorem, First theorem of Castigliano, Theorem of virtual work.

Bending of Beams: Straight beams and asymmetrical bending, Bending of curved beams.

Torsion & Axisymmetric Problems: Torsional of general prismatic bars-solid sections, Stresses in composite tubes, Thermal Stresses.

Text Book(s) and References:

1. Irving H. Shames, "Mechanics of Deformable Solids", Krieger Pub Co, 2008.
2. L.S. Srinath, "Advanced Mechanics of Solids", 3rd Edition,TMH, 2009.

Course Title	Course Code	Structure (I-P-C)		
IC Engines and Gas Turbines	ME545	**3**	**0**	**3**

Pre-requisite, if any: Thermodynamics

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

CO1	Solve problems on engine performance parameters.
CO2	Identify different types of dynamometers.
CO3	Understand the combustion process, carburetion of engines.
CO4	Understand the working of gas turbines and its performance.
CO5	Understand the working of jet propulsion and its parameters.

Syllabus:

I.C. Engines : Energy conversion, basic engine components, Working principle of engines - two stroke and four stroke engines, SI and CI engines, Classification of I.C. Engines, Valve and port timing diagrams, comparison of two stoke and four stroke engines, comparison of SI and CI engines, application of I.C engines. Engine Performance Parameters: The First law analysis of engine cycle, Brake power, indicated power, friction power, mean effective pressure, engine efficiencies, performance calculations, Heat balance.
Measurements and Testing: Measurement of Brake power – Rope brake, hydraulic, Eddy current and swinging field DC dynamometers; Friction power – Willian‟s line method, Morse test, motoring test and retardation test.
Combustion in S.I Engines: Homogeneous and heterogeneous mixtures, principle of carburetion, stages of combustion in S.I Engines, knocking. Combustion in C.I Engines: Disintegration of fuel jet, stages of combustion, knocking. Super Charging: types of superchargers, advantages and limitations of super charging.
Reciprocating air Compressors: Introduction and classification of compressors, mechanical details and working principle of a single stage reciprocating compressor, equation for work, effect of clearance volume, isothermal, adiabatic, and volumetric efficiencies, two-stage compression, Condition for minimum work. Centrifugal& Axial flow Compressors: introduction, essential parts of a centrifugal compressor, principle of operation. – Introduction to axial flow compressor, geometry and working principle.
Gas Turbines: Simple Gas Turbine, ideal cycle, essential components, open and closed cycle arrangements, requirements of working medium, applications of Gas Turbines, comparison of Gas Turbines with reciprocating engines, work output and efficiency of a simple Gas Turbine cycle, optimum pressure ratio for maximum specific output, Gas Turbines with regeneration, reheating and intercooling.
Jet Propulsion: Introduction to Propeller engines and Gas Turbine engines, working principle of Ramjet engine, Pulse jet engine, Turboprop engine and Turbojet engine, Thrust and thrust equation, specific thrust, parameters affecting flight performance, introduction to Rocket propulsion, classification of Rockets and principle of Rocket propulsion.

Text Book(s) and References

1. V.Ganeshan, Internal Combustion Engines, TMH Publishers, 4th Edition, 2017.
2. V.Ganeshan, Gas Turbines, TMH Publishers, 3rd Edition, 2017.
3. Heywood John, , IC Engines Fundamentals, TMH Publishers, 2nd Edition, 2018.
4. Ferguson, Internal Combustion Engines, John Wiley Publisher, 2nd Edition, 2009.
5. Herb Saravana muttoo, Gas Turbine Theory, Prentice Hall Publisher, 6th Edition, 2008.

Course Title	Course Code	Structure (I-P-C)		
Computational Fluid Dynamics	ME546	**3**	**0**	**3**

Pre-requisite, if any: Fluid Mechanics, Heat Transfer

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

CO1	Formulate the basic fluid dynamics problem mathematically
CO2	Analyze the mathematical behavior of partial differential equations
CO3	Understand various solution methodologies.
CO4	Apply the FDM and FVM techniques to solve heat transfer problems.
CO5	Solve the elementary incompressible fluid problems using the CFD techniques

Syllabus:

Basics of Computational fluid dynamics, Governing equations of fluid mechanics and heat transfer, Physical boundary conditions - elliptic, parabolic, and hyperbolic equations, Finite different formulation, stability analysis.

Finite difference and finite volume formulation of steady/transient one-dimensional conduction equation, grid generation.

Finite volume formulation of steady one-dimensional convection and diffusion problems, central, upwind, hybrid and power-law schemes; Discretization equations for two-dimensional convection and diffusion.

Solution methodologies: Direct and iterative methods, Thomas algorithm, relaxation method, alternating direction implicit method.

Numerical methods for Navier-Stokes equation - Turbulence models: mixing length model, Two equation (k-epsilon) model.

Text Book(s) and References:

1. Patankar. S. V, "Numerical Heat Transfer and Fluid Flow", CRC Press, 1980.
2. H. Versteeg, W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", 2nd Edition, PHI, 2007
3. J. D. Anderson, "Computational Fluid Dynamics - Basics with Applications", Mc Graw Hill, 1995.
4. K. Muralidhar, T. Sundararajan, "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, 1995.
5. T. K. Sengupta, "Fundamentals of Computational Fluid Dynamics", University Press, 2004.

Course Title	Course Code	Structure (I-P-C)		
Optimization techniques for Mechanical Engineers	ME547	**3**	**0**	**3**

Pre-requisite, if any: Calculus, Differential Equations

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

CO1	Familiarize with the curve fitting techniques.
CO2	Understand the concepts and need for optimisation.
CO3	Familiarize with the various calculus and search techniques of optimisation problems.
CO4	Familiarize with the Non-traditional optimisation techniques.

Syllabus:

Introduction: Introduction to system design, Morphology of design with a flow chart, Concept of workable design, practical example on workable system and optimal design.

System Simulation: Successive substitution method, Newton Raphson method: One and Multiple unknowns, Gauss Siedel method, Rudiments of finite difference method for partial differential equations, with examples.

Regression and Curve Fitting: Need for regression in simulation and optimization; Concept of best fit and exact fit; Concept of least square regression fit; Gauss Newton method for nonlinear least squares regression

Optimization: Basic ideas, Need for optimisation, formulation, graphical method, linear programming problems, simplex method, Types of optimisation problems: Calculus methods; Lagrange multipliers, search techniques, local and global optimum.

Non-traditional optimization techniques: Genetic Algorithms, Simulated Annealing, Particle swam optimisation algorithm, Artificial Neural networks.

Text Book(s) and References:

1. C. Balaji, "Essentials of Thermal System Design and Optimization", 2nd Edition, Ane Books, 2019.
2. Kalyanmoy Deb, "Optimization for Engineering Design: Algorithms and Examples", 2nd edition, Prentice Hall India, 2012.
3. S. S. Rao, " Engineering Optimization: Theory and Practice”, 4th edition, John Wiley & Sons, 2009
4. Yogesh Jaluria, "Design and Optimization of Thermal Systems", McGraw Hill, 1998.

Course Title	Course Code	Structure (I-P-C)		
Product Design and Development	ME548	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand overall awareness of the product design process
CO2	Find the importance of tools and principles applied in industries for the design and development of the product.
CO3	Extend and emphasise on methodologies for various steps of product design such as user study
CO4	Determine the need/problem identification, competitive benchmarking, and aspects of human factors in product design
CO5	Evaluate the application and potential of design in modern manufacturing practices.
CO6	Demonstrate a creative concept, generation of suitable design and prototyping/modelling for modern manufacturing practices

Syllabus:
Design methodology and philosophy: Types of designs, design models, concurrent engineering, and product life cycle.

Design Teams – Organizations & product Planning: Need Analysis & Scope- mission statement, customer study, Kano diagram-Establishing Product Function- functional decomposition, FAST and SOP, function structure.

Product Tear down- reverse engineering: Product Specifications- product design tools, QFD, Computer Aided Design, Robust design, DFX, DFM, DFA, DFMA, DFSS.

Design guidelines: For metallic and non-metallic products to be manufactured by various processes. **Generation and evaluation of concepts**: TRIZ, Decision matrix etc.

Industrial Design: Aesthetics and ergonomic aspects of product design. Value Engineering. Failure mode and effects analysis.

Text Book(s) and References:

1. Eppinger, S, Ulrich, K, Product design and development, McGraw-Hill, (2000).
2. Kevin Otto, Kristin Wood, Product design, Pearson, (2004).
3. George E. Dieter, Engineering Design, McGraw Hill, (2000).
4. David G Ullman, The Mechanical Design Process, McGraw Hill, (2003).

Course Title	Course Code	Structure (I-P-C)		
Computational Tools for Engineers	ME549	**3**	**0**	**3**

Pre-requisite, if any: Basic concepts of computers

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

CO1	Determine numerical methods used in linear algebra for optimizing manufacturing processes.
CO2	Analyze behavior of manufacturing processes under different conditions using numerical methods for solving nonlinear algebraic equations.
CO3	Effectively develop accurate models of manufacturing processes using interpolation methods.
CO4	Evaluate manufacturing process performance using numerical differentiation and integration methods.
CO5	Demonstrate the use of numerical methods for solving ordinary differential equations in optimizing manufacturing processes.
CO6	Develop numerical methods for solving partial differential equations to optimize manufacturing processes in complex systems.

Syllabus:

Linear Algebraic Equations: Direct and iterative solution techniques for simultaneous linear algebraic equations; Gauss elimination, Gauss-Jordon, LU Decomposition, QR Method; Eigenvalues and Eigenvectors; Power and inverse power method, householder transformation; Physical interpretation of eigenvalues and eigenvectors

Nonlinear Algebraic Equations: Bisection method, fixed-point iteration method**;** Newton-Raphson, Secant method**;** Solution of system of nonlinear algebraic equations

Interpolation and Numerical Differentiation/Integration: Polynomial interpolation, Lagrange interpolating polynomial, Hermite interpolation**;** Interpolation in 2 and 3 dimensions**;** Finite difference formula using Taylor series**;** Differentiation of Lagrange polynomials**;** Simpson's rule, Gauss-quadrature rule, Romberg method**;** Multiple integrals

Ordinary Differential Equations: Euler, Heun's method, and stability criterion**;** Second order and fourth order Runge-Kutta methods**;** Adams-Bashforth-Moulton method**;** System of ODEs and nonlinear ODEs

Partial Differential Equations: Classification of PDEs**;** Elliptic equations**;** Parabolic equations (Transient diffusion equation)**;** Hyperbolic equations (Wave equation)

Text Book(s) and References:

1. S. P. Venkateshan, Prasanna Swaminathan, Computational Methods in Engineering, Ane Books
2. Steven C. Chapra, Numerical Methods for Engineering, Mc-Graw Hill Education
3. Joe D Hoffman, Numerical Methods for Engineers and Scientists, Second Edition, Marcel Dekker (2001)
4. Gilbert Strang, Computational Science and Engineering, Wellesley-Cambridge Press

Course Title	Course Code	Structure (I-P-C)		
Soft Computing Techniques	ME550	**3**	**0**	**3**

Pre-requisite, if any: MATLAB

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

CO1	Determine numerical methods used in linear algebra for optimizing manufacturing processes.
CO2	Analyze behavior of manufacturing processes under different conditions using numerical methods for solving nonlinear algebraic equations.
CO3	Effectively develop accurate models of manufacturing processes using interpolation methods.
CO4	Evaluate manufacturing process performance using numerical differentiation and integration methods.
CO5	Demonstrate the use of numerical methods for solving ordinary differential equations in optimizing manufacturing processes.
CO6	Develop numerical methods for solving partial differential equations to optimize manufacturing processes in complex systems.

Syllabus:

Problem Solving Methods and Tools: Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison, A*, AO*, Branch and Bound search techniques, p type, Np complete and Np Hard problems.

Evolutionary Computing Methods: Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming.

Genetic Algorithm and Genetic Programming: Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications.

Swarm Optimization: Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms.

Advances in Soft Computing Tools: Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems.

Artificial Neural Networks: Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting back propagation training, applications.

Text Book(s) and References:

1. Tettamanzi Andrea, Tomassini and Marco, Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Springer, 2001.
2. Elaine Rich, Artificial Intelligence, McGraw Hill, 2/e, 1990.
3. Kalyanmoy Deb, Multi-objective Optimization using Evolutionary Algorithms, John Wiley and Sons, 2001.

Course Title	Course Code	Structure (I-P-C)		
Big Data Analytics	ME551	**3**	**0**	**3**

Pre-requisite, if any: Basic Statistics

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

CO1	Understand the principles of Big Data Analytics and its applications in Smart Manufacturing.
CO2	Acquire skills to collect, store, process, and analyze large volumes of data generated in the manufacturing process using various tools and technologies.
CO3	Learn how to extract insights from Big Data to optimize production processes, increase efficiency, and reduce costs in Smart Manufacturing.
CO4	Gain knowledge of the best practices in data management, data quality, and data governance in the context of Smart Manufacturing.
CO5	Explore the role of Artificial Intelligence, Machine Learning, and Deep Learning in Big Data Analytics for Smart Manufacturing.
CO6	Develop the ability to communicate the results of Big Data Analytics to non-technical stakeholders and make data-driven decisions in Smart Manufacturing.

Syllabus:

Introduction to Big Data Analytics: Introduction to Industry 4.0 and the role of Big Data Analytics; Overview of Big Data Analytics and its challenges and opportunities**;** Big Data Processing and Architecture for large-scale data analysis

Data Acquisition and Pre-processing: Data acquisition and integration from multiple sources**;** Data pre-processing techniques for large-scale data**;** Data transformation and cleaning for data quality

Big Data Analytics Techniques: Data mining concepts and techniques for pattern discovery**;** Association rule mining, classification, and clustering for data analysis**;** Anomaly detection and outlier analysis for quality control**;** Time series analysis for forecasting

Big Data Analytics Tools and Technologies: Apache Hadoop and Spark for distributed processing**;** NoSQL databases for scalable data storage**;** Cloud computing platforms for flexible and cost-effective infrastructure**;** Stream processing frameworks for real-time data analysis**;** Visualization tools for data presentation

Applications of Big Data Analytics: Predictive maintenance for equipment performance and reliability**;** Quality control and yield optimization for production efficiency**;** Production planning and scheduling for resource allocation**;** Supply chain management for logistics and inventory control**;** Customer relationship management for customer satisfaction and loyalty**;** Product design and innovation for market insights and trend analysis

Practice:

Initial few exercises using R on association rule mining, classification, clustering wherein various existing algorithms are tested over benchmark datasets – This shall expose students to the basics of AI perspective over databases. Mapreduce abstraction using the IDE framework, Hadoop, Architecture, Data deduplication storage systems, Venti and DDFS, Shingles and minhashing, locality sensitive hashing, Latent Semantic Indexing, case study for dimensionality reduction, Support for distributed / parallel computing in R, case studies of Clustering in high dimensional space, Web link analysis, Pagerank algorithm, survey / simulation.

Text Book(s) and References:

1. A. Rajaraman, J. Leskovec, J. Ullmann, Mining of Massive Data sets, Cambridge University Press, 2011, ISBN: 1107015359.
2. Maheshwari, A. (2018). Data analytics made accessible. Apress.
3. Ammari, H. M. (2016). Big data analytics for sensor-network collected intelligence. CRC Press.
4. Hahn, G. J., & Meeker, W. Q. (2017). Statistical process control and quality improvement. John Wiley & Sons.

Course Title	Course Code	Structure (I-P-C)		
Applied Operations Research	ME552	**3**	**0**	**3**

Pre-requisite, if any: Linear Algebra

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

CO1	In-depth understanding on the concepts of AM, various AM technologies
CO2	Find the importance of appropriate selection of materials for AM, modeling of AM processes
CO3	Extend and emphasise on applications of AM in disparate fields of modern manufactured components.
CO4	Determine the need/problem identification, competitive aspects for which conventional subtractive manufacturing can be replaced with AM techniques.
CO5	Evaluate the application and potential of AM in ability to manufacture 3D objects availing hybrid methods
CO6	Demonstrate and integrate the knowledge of compliance of AM involving planned strategies for post processing methods

Syllabus:

Introduction to Operations Research: Overview of Operations Research and its applications; Modeling and problem formulation; Linear Programming: formulation and graphical solution

Linear Programming and Optimization: Linear Programming: Simplex method; Linear Programming: Duality and Sensitivity Analysis; Network Models: Shortest path, minimum spanning tree, maximal flow; Integer Programming: Formulation and solution methods

Nonlinear Optimization: Unconstrained optimization: Gradient and Newton's methods; Constrained optimization: Kuhn-Tucker conditions; Nonlinear Programming: Formulation and solution methods; Convex optimization

Stochastic Processes: Probability theory and stochastic processes; Markov Chains: Definition and properties; Markov Chains: Stationary distribution and limiting probabilities; Queuing theory: Birth-death process, M/M/1, M/M/S, M/G/1 queues

Simulation and Decision Analysis: Monte Carlo Simulation: Sampling techniques, variance reduction, and applications; Decision Analysis: Decision Trees, Payoff Tables, and Expected Value of Perfect Information; Game Theory: Strategic games and Nash Equilibrium; Multi-criteria decision-making methods: Analytical Hierarchy Process (AHP), TOPSIS, GREY, MOORA, ELECTRE,…

Text Book(s) and References:

1. Anderson,Sweeny,andWilliams,An Introduction to Management Science: Quantitative Approaches to Decision Making,11th Edition.
2. Ackoff, R.L. and Sasini, M. W., Fundamentals of Operations Research, Wiley & Sons, New York.
3. Wagner, H.M., Principle of Operations Research, Prentice Hall, New Jersey.
4. Vohra N.D., Quantitative Techniques in Management, Tata McGraw Hill.

Churchman, C.W.: Introduction to Operations Research John Wiley& Sons New York.

Course Title	Course Code	Structure (I-P-C)		
Digital Control for Automation	ME553	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Students will understand principles of digital control such as Z-transform, sampling, quantization, and linear difference equations and how to apply them to systems.
CO2	Students will be able to analyze the performance and stability of digital control systems.
CO3	Students will be able to design digital control systems to meet desired specifications and demonstrate their implementation with appropriate hardware or software as per the project requirement.
CO4	Students will be able to understand the steps involved in the design of Digital Control for industrial automation.

Syllabus:

Module 1:
- Introduction to Digital Control for Automation, need for discrete-time control, comparison between Analog and Digital Control, sampling, quantization, data reconstruction and filtering of sampled signals, Review of Z-transforms, z-transform and its properties.

Module 2:
- Controllability, observability, control law design, decoupling by state variable feedback, effect of sampling period. Estimator/ Observer Design: full order observers, reduced order observers, regulator design.
- Mathematical modelling of sampling process. Simulation examples- effect of sampling rate. Analysis of filters in discrete domain.

Module 3:
- Z-transform analysis of closed loop and open loop systems, multirate Z-transform. Nyquist stability criterion; Stability analysis of closed loop systems in the z-plane: root loci, frequency domain analysis, Stability tests. Discrete equivalents.
- Discrete time Fourier Transform, the relationship between the Fourier Transform and the z-transform.

Module 4:
- Digital controller design for SISO systems: design based on root locus method in the z-plane, design based on frequency response method, design of lag compensator, lead compensator, lag lead compensator, design of PID Controller based on frequency response method, direct design, method of Ragazzini.
- 2DOF discrete PID controller- software approach. State space representation in discrete system.

Module 5:
- Data loggers, Data Acquisition Systems (DAS), Direct Digital Control (DDC). Supervisory Control and Data Acquisition Systems (SCADA), sampling considerations.
- Functional block diagram of computer control systems, alarms, interrupts. Characteristics of digital data, controller software, linearization. Digital controller modes: Error, proportional, derivative and composite controller modes. PLC: Evolution, Components, advantages over relay logic, Architecture, Programming devices, Discrete and Analog I/O modules.

Module 6:
Discrete LQR design. Introduction to event triggered systems: examples using state flow technique. Real-Time Applications of Computer Aided Design.

Course Title	Course Code	Structure (I-P-C)		
Non-linear Dynamics	ME554	**3**	**0**	**3**

Pre-requisite, if any: Linear Algebra

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

CO1	Interpret the nonlinear dynamical equation geometrically
CO2	Understand the system qualitatively without solving the nonlinear system.
CO3	Understand the deep simplicity in the chaotic system.

Syllabus:
Introduction to nonlinear dynamics; Flows on the line – geometrical way of thinking, Linear stability analysis, existence and uniqueness.

Bifurcations – saddle node, trans-critical, pitch fork; Flow on the curve – uniform and non-uniform oscillator

Linear two-dimensional systems – classification; Phase plane – phase portrait, fixed points and linearization, conservative systems.

Limit cycles – Ruling out closed orbits, Poincare – Bendixson theorem, Lienard systems, Relaxation Oscillators, Weakly nonlinear oscillators; Hopf bifurcation, Global bifurcation of cycles, Poincare map

Lorenz equation, chaos on a strange attractor, Lorenz map; 1D maps – Fixed points and cobwebs, Logistic maps, periodic window; Fractals, strange attractors.

Text Book(s) and References:

1. Steven H Strogatz, "Nonlinear Dynamics and Chaos", Perseus books, 1994.
2. J D Murray, "Mathematical Biology – an introduction", Springer.

Course Title	Course Code	Structure (I-P-C)		
Operations and Supply Chain Management	ME555	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand the importance of Operations and Supply Chain Management.
CO2	Apply forecasting techniques in estimating the number of products.
CO3	Use inventory management techniques to determine the optimum quantity of material.
CO4	Design the factory and plant layout using qualitative and quantitative models.
CO5	Decide the dispatch procedure required for production processes and other activities.
CO6	Understand the applications of information technology in the supply chain.

Syllabus:

Introduction: Introduction to Operations Management – Challenges, Methodologies
Forecasting: Need for forecasting, Qualitative and Quantitative Methods, Time series models – Simple Exponential smoothing, Linear Models, Regression, Holt's, seasonality, Winter's model, causal models, Goodness of the forecast.
Facility layout and location: Qualitative aspects, Quantitative models for layout decisions, Product, process, position, group layout, Location decisions-quantitative models. Capacity and aggregate planning, Capacity measurement, Long-term and short-term strategies, Aggregate planning.
Inventory management: Various costs in inventory management and need, Deterministic models and discounts, Probabilistic inventory management.
Scheduling models and applications: Scheduling in MRP system, Sequencing rules and applications, Batch production sequencing and scheduling.
Introduction to the supply chain: Definition, complexity, key issues, Centralized vs. decentralized systems.
Value of information and supply chain integration: Bullwhip effect, Push-based, pull-based systems. Outsourcing: Make or buy decisions. Transportation decision: Drivers of the decision, Network design decisions, Cross-docking, trans-shipment.
Distribution and logistics in supply chains: Direct shipment/intermediate storage policies, Vehicle routing models, Third-party logistics.
Information technology in the supply chain: Enabling the supply chain through IT, ERP vendor platforms, Service-oriented architecture (SOA), RFID

Text Book(s), References and Web Resources:

1. R. Panneerselvam, Production/Operations Management, Prentice Hall of India Pvt Ltd, 2007.
1. S. N. Chary, Production and Operations Management, TMH, 4th Edition 2010
2. Joseph.G.Monks, Operations Management, McGraw-Hill Inc., 3rd Revised edition
3. P.Rama Murthy, Production and Operations Management, New Age International, 2nd Edition, 2005.
4. Operations and Supply Chain Management by Prof. G. Srinivasan, IIT Madras (https://nptel.ac.in/courses/110106045).
5. Operations Management by Prof. Inderdeep Singh, IIT Roorkee (https://onlinecourses.nptel.ac.in/noc20_me30/preview).

Course Title	Course Code	Structure (I-P-C)		
Industry 4.0	ME556	**3**	**0**	**3**

Pre-requisite, if any: **Nil**

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

CO1	Understand what is Industry 4.0 and distinguish various components in Industry 4.0 Environment
CO2	Identify the Challenges of Industry 4.0
CO3	Analyze the Importance and role of Big Data and Analytics
CO4	Importance of Connected Systems and Sensors
CO5	Understand necessary details of IoT, IIoT, 'Cyber Physical Systems (CPS)', Advanced Robotics, Image Processing Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL).

Syllabus:
Introduction to Industry Revolutions, Details of Industry 4.0

Sensors, Machine Vision and Connected Systems Analyzing Data and Modeling to Make Sense of Data

Data Analysis, the role of Big Data and Analytics, Control of Manufacturing Systems and Processes

Digital Twin, its importance in Industry 4.0

Impact of Industry 4.0 on various industries

Applications of Collaborative Robots, Image Processing Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL), Augmented Reality and Virtual Reality, in Manufacturing Environment
Towards Manufacturing as an Autonomous System

Text Book(s) and References:

1. Luo, ZongWei, Smart Manufacturing Innovation and Transformation: Interconnection and Intelligence: Interconnection and Intelligence, IGI Global, 2014.
2. Fei Tao, Meng Zhang, A.Y.C. Nee, Digital Twin Driven Smart Manufacturing, Academic Press, 2019.
3. Alp Ustundag and Emre Cevikcan, “Industry 4.0: Managing the Digital Transformation”.
4. Bartodziej, Christoph Jan, “The Concept Industry 4.0”.
5. Klaus Schwab, “The Fourth Industrial Revolution”.
6. Christian Schröder , “The Challenges of Industry 4.0 for Small and Medium-sized Enterprises”

Course Title	Course Code	Structure (I-P-C)		
Design and Analysis of Experiments	ME557	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Students will be able to understand the importance of testing and inspections.
CO2	Students will be able to draw the suitability and purpose of different testing methods.

Syllabus:

Introduction to Designed Experiments: Strategy of experimentation, Typical applications, Basic principles and guidelines for designing experiments.

Basic statistical concepts: Descriptive Statistics, Sampling and Sampling Distributions, Tests of Hypotheses.

Single factor experiments with Fixed Effects: ANOVA, Model Adequacy Tests, and Orthogonal Contrasts.

Experiments with Blocking Factors: Randomised Complete and Incomplete Block Designs, Latin Squares Design.

Factorial Experiments: 2^2, 3^2, and 2^k Designs, Blocking and Confounding, and Fractional Factorial Designs.

Linear Regression Models: Estimation of Parameters, Tests of Hypothesis, Regression Model Diagnostics.

Response Surface Design: Method of Steepest Ascent, Second-Order Response Surface, Experimental Designs, Computer Models, Mixture Experiments, Evolutionary Operations

Advanced Design of Experiments: Random Effects Models, Analysis of Covariance, Non-Normal Response, and Taguchi Methods.

Text Book(s):

1. Design and Analysis of Experiments, D. C. Montgomery, John Wiley & Sons, Wiley Student Edition, International Student Version, 7th Edition, 2009.
2. Design of Experiments: An Introduction Based on Linear Models, M. Morris, Chapman& Hall/CRC Texts in Statistical Science, First Edition, 2010.
3. Practical Guide to Designed Experiments: A Unified Approach, P. D. Funkenbusch, CRC Press, 2004.
4. The Theory of the Design of Experiments, D. R. Cox and N. Reid, Chapman and Hall/CRC, 200.
5. Design and Analysis of Experiments A. M. Dean and D. Voss, Springer Texts in Statistics, Second Edition, 2001.