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# M.Tech Manufacturing Engineering

# Curriculum and Syllabus

# (2021 Admission Onwards)

# M.TECH –MANUFACTURING ENGINEERING

## Department of Mechanical Engineering

Manufacturing Sector is the engine of growth for our country and it provides a stable economy. According to the technology road map 2035, the manufacturing sector in India needs to grow through adoption of technology platforms which include nano engineering, additive manufacturing, adaptive automation, precision manufacturing and sustainable manufacturing. The industry needs the skill and creativity to manufacture complex, high specialization products. This program provides an in depth understanding of wide range of domains like advanced manufacturing processes, micro and nano manufacturing, additive manufacturing, lean manufacturing, Internet of things, machine learning and smart factory concepts and is an important link for industrial competitiveness.

The syllabus for various courses has been designed in general to introduce the application of analytical and quantitative methods in manufacturing and to train the students to develop skills in the utilization of the modern tools such as simulation, optimization, statistical data analysis, and finite element analysis. During the course of study, the students will acquire knowledge and skills to solve practical problems encountered in manufacturing.

# M Tech Manufacturing Engineering

## 1.0 Mission of the Department

| | |
|---|---|
| M1 | To develop in each student, a profound understanding of fundamentals, motivation for continuous learning, and practical problem-solving skills for building a successful career. |
| M2 | To create and share technical knowledge and collaborate with Industry and Institutions for the betterment of Society. |
| M3 | To imbibe ethical values, leadership skills and entrepreneurial skills in students. |
| M4 | To sustain a conducive environment to involve students and faculty in research and development. |

## 2.0 Program Educational Outcomes (PEOs)

| | |
|---|---|
| PEO1 | Develop and implement innovative methods and models for improving performance of manufacturing systems |
| PEO2 | Apply smart manufacturing concepts for enhancing manufacturing and supply chain operations |
| PEO3 | Conduct research by following ethical practices with intellectual integrity to provide cost-effective and sustainable solutions for the industrial and societal problems |
| PEO4 | Collaborate and function effectively as an individual and team member in a professional career and/or entrepreneurship |

## 3.0 Program Outcomes (POs)

| | |
|---|---|
| PO1 | Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program |
| PO2 | An ability to write and present a substantial technical report/document. |
| PO3 | An ability to independently carry out research/investigation and development work to solve practical problems |
| PO4 | Develop and analyse the manufacturing processes and systems, to improve their performances using modern tools and approaches. |
| PO5 | Apply the knowledge of Science and Engineering to develop materials and processes for the strategic needs of Industry and Society |
| PO6 | Implement automation and IoT concepts for process improvement and control |

## Curriculum

### First Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 21MA611 | FC | Random Processes and Partial Differential Equations | 3 0 3 | 4 |
| 21ME601 | FC | Advanced Manufacturing Processes | 3 0 0 | 3 |
| 21ME602 | FC | Advances in Material Science and Characterisation | 3 0 0 | 3 |
| 21ME603 | FC | Machining Dynamics | 2 0 3 | 3 |
| 21ME604 | SC | Manufacturing Automation | 2 0 3 | 3 |
| 21ME682 | SC | Machine Learning with Python | 0 0 3 | 1 |
| 21ME681 | SC | Manufacturing Process Lab | 0 0 3 | 1 |
| 21HU601 | HU | Amrita Values Programme* | | P/F |
| 21HU602 | HU | Career Competency I* | | P/F |
| | | | Credits | 18 |

*** Non-credit course**

### Second Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 21ME605 | SC | Micro and Nano Manufacturing | 2 0 3 | 3 |
| 21ME606 | SC | Lean Manufacturing | 3 0 0 | 3 |
| 21ME607 | SC | Smart Manufacturing | 3 0 0 | 3 |
| | E | Elective I | 3 0 0 | 3 |
| | E | Elective II | 3 0 0 | 3 |
| 21RM617 | SC | Research Methodology & IPR | 2 0 0 | 2 |
| 21ME684 | SC | Computer Aided Manufacturing Lab | 0 0 3 | 1 |
| 21ME683 | SC | Manufacturing System Simulation Lab | 0 0 3 | 1 |
| 21HU603 | HU | Career Competency II | 0 0 2 | 1 |
| | | | Credits | 20 |

### Third Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 21ME608 | SC | Additive Manufacturing | 2 0 3 | 3 |
| | E | Elective III* | 3 0 0 | 3 |
| 21ME798 | | Dissertation Phase I | | 10 |
| | | | Credits | 16 |

***Can opt for NPTEL/Swayam courses with the prior approval from the Department**

### Fourth Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 21ME799 | | Dissertation Phase II | | 16 |
| | | | Credits | 16 |

Total credits: 70

## List of Courses

### Foundation Core

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 21MA611 | Random Processes and Partial Differential Equations | 3 0 3 | 4 |
| 21ME601 | Advanced Manufacturing Processes | 3 0 0 | 3 |
| 21ME602 | Advances in Materials Science and Characterization | 3 0 0 | 3 |
| 21ME603 | Machining Dynamics | 2 0 3 | 3 |

### Subject Core

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 21ME604 | Manufacturing Automation | 2 0 3 | 3 |
| 21ME605 | Micro and Nano Manufacturing | 2 0 3 | 3 |
| 21ME606 | Lean Manufacturing | 3 0 0 | 3 |
| 21ME607 | Smart Manufacturing | 3 0 0 | 3 |
| 21ME608 | Additive Manufacturing | 2 0 3 | 3 |
| 21RM617 | Research Methodology & IPR | 2 0 0 | 2 |
| 21ME682 | Machine Learning with Python | 0 0 3 | 1 |
| 21ME681 | Manufacturing Process Lab | 0 0 3 | 1 |
| 21ME684 | Computer Aided Manufacturing Lab | 0 0 3 | 1 |
| 21ME683 | Manufacturing System Simulation Lab | 0 0 3 | 1 |

### Electives

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 21ME701 | Design for Manufacturing and Assembly | 3 0 0 | 3 |
| 21ME702 | Theory of Elasticity and Metal Forming | 3 0 0 | 3 |
| 21ME703 | Optimization Techniques in Engineering | 2 0 3 | 3 |
| 21ME704 | Product Lifecycle Management | 3 0 0 | 3 |
| 21ME705 | Sustainable Manufacturing | 3 0 0 | 3 |
| 21ME706 | Surface Engineering | 3 0 0 | 3 |
| 21ME707 | Finite Element Analysis | 2 0 3 | 3 |
| 21ME708 | Robust Design | 3 0 0 | 3 |
| 21ME709 | Production and Operations Management | 3 0 0 | 3 |
| 21ME710 | Logistics and Supply Chain Management | 3 0 0 | 3 |
| 21ME711 | Reliability Engineering | 3 0 0 | 3 |
| 21ME712 | Quality Engineering | 3 0 0 | 3 |
| 21ME713 | Non-Destructive Testing and Evaluation | 3 0 0 | 3 |
| 21ME714 | Composite Materials and Processing | 3 0 0 | 3 |
| 21ME715 | Tool Engineering and Design | 3 0 0 | 3 |
| 21ME716 | Advanced Materials for Aerospace and Nuclear Applications | 3 0 0 | 3 |
| 21ME717 | Multi Objective Optimization | 2 0 3 | 3 |

**21MA611 RANDOM PROCESSES AND PARTIAL DIFFERENTIAL EQUATIONS 3-0-3-4**

**Course Objectives:**

1. Expose the student to random experiments, probability and counting methods.
2. Elucidate random variables, their functions, and random processes
3. Familiarize hypotheses testing, regression and ANOVA.
4. Develop skills in employing numerical methods for solving differential equations

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Understand concepts of probability, random variables and their properties |
| CO02 | Formulate fundamental probability distribution and density functions, as well as functions of random variables, random process. |
| CO03 | Demonstrate skill of performing hypotheses testing, analysis of variance and linear regression. |
| CO04 | Apply finite difference and finite element methods to obtain solution of partial differential equation. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 1 | - | - | 1 | - | - |
| CO02 | 1 | - | 1 | 1 | - | - |
| CO03 | 2 | 1 | 2 | 2 | - | - |
| CO04 | 2 | 1 | 2 | 2 | - | - |

**Skills Acquired:**

Solve problems involving random variables, distributions and random process. Build regression models, test hypotheses, perform ANOVA. Solve partial differential equations using numerical methods.

**Syllabus:**

Review of Probability Concepts

Random Variables: Single and multiple variables (discrete, continuous, and mixed), important distributions, functions of random variables, joint distributions, sum of random variables, moment-generating functions, random vectors, and inequalities; law of large numbers and the central limit theorem.

Introduction to Random Processes: Poisson processes, discrete-time Markov chains, continuous-time Markov chains, and Brownian motion.

Statistical Inference: Point and interval estimation, Estimation Methods, Hypothesis testing, Goodness of fit, Bayesian statistics, Nonparametric methods. Linear models - Sample inference, one way ANOVA, Multiple comparisons, Linear Regression.

Partial Differential Equations: Basic definitions- Elliptic, Parabolic and Hyperbolic Equations. Numerical simulations using Finite Difference and Finite Element Methods.

MATLAB applications: Generate random variables, Simulate probabilistic systems, ANOVA and solving PDE using FDM and FEM.

**Text Books / References:**


1. A. Papoulis and Unnikrishna Pillai, *“Probability, Random Variables and Stochastic Processes”*, Fourth Edition, McGraw Hill, 2002.
2. Montgomery, D.C. and Runger, G.C., *"Applied statistics and probability for engineers"*, John Wiley & Sons, 2018.
3. Ravichandran, J. *“Probability and Statistics for Engineers”*, First Edition, Wiley India, 2012.
4. Montgomery, D.C., Peck, E.A. and Vining, G.G., *"Introduction to linear regression analysis"*, John Wiley & Sons, 2021.
5. Li, J. and Chen, Y.T., *“Computational partial differential equations using MATLAB”*. CRC press, 2019.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 15 | - |
| Continuous Assessment (Lab)* | 30 | - |
| End Semester | - | 35 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME601 ADVANCED MANUFACTURING PROCESSES 3-0-0-3**

**Course Objectives:**

1. To familiarize the fundamentals of advanced casing processes and to understand the basic concepts of solidification.
2. To give exposure to various advanced welding techniques and to be familiarize with welding standards, weldability of different materials.
3. To select and apply various advanced machining processes for specific applications and to understand the optimization of parameters to obtain the desired machining quality.
4. To understand the concepts of severe plastic deformation and High energy rate forming and to be familiarize with basics of stress strain relations and the deformation mechanisms.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Select and apply suitable advanced casting techniques to obtain the desired quality and to understand the concepts of solidification. |
| CO02 | Perform suitable advanced welding techniques to obtain the desired weld joint and to understand the effect of welding parameters on weld quality. |
| CO03 | Select and apply suitable advanced machining processes and optimize its parameters to achieve the desired machining characteristics. |
| CO04 | Examine the stress strain relations and the deformation mechanisms and select appropriate severe plastic deformation and High energy rate forming processes to get the near net shape of the product. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 1 | 1 | 1 | 0 | 1 |
| CO02 | 2 | 1 | 1 | 1 | 0 | 1 |
| CO03 | 2 | 1 | 1 | 1 | 1 | 1 |
| CO04 | 2 | 1 | 1 | 1 | 1 | 1 |

**Skills Acquired:**

Ability to select the appropriate casting, welding processes, advanced machining processes, severe plastic deformation and high energy rate forming processes & to optimize its process parameters to obtain the desired quality.

**Syllabus:**

Advanced Casting: Recap of conventional casting processes and casting metallurgy. Advanced casting processes: Continuous casting, Investment casting, Vacuum casting, Squeeze casting and Stir Casting, Directional solidification process. Rapid solidification processes - Foil strip and thin/micro casting, metallic glasses. Analysis of casting processes using software tools - Case studies.

Advanced Welding: Recap of conventional welding processes and welding metallurgy. Introduction to welding standards. Weldability of stainless steels, Cu, Al, Ti, Ni alloys, dissimilar materials, non-metallic materials. Advanced welding processes: Plasma Arc welding, Laser beam welding, Electron beam welding and solid-state welding processes. Micro welding, Analysis of welding processes using software tools - Case studies.

Advanced machining processes: Electric Discharge Machining - Abrasive Jet Machining - Abrasive Water Jet Machining. Laser Beam machining and drilling. Laser cutting, Plasma Arc machining and Electron Beam Machining. Metal removal mechanisms, applications and case studies.

Advanced forming processes: Stress strain relations in elastic and plastic deformation - concept of flow stress determination - deformation mechanisms. Severe plastic deformation and High energy rate forming-Electro-magnetic forming, explosive forming, Hydro forming, Electro-hydraulic forming, Stretch forming, Contour roll forming and roll bonding. Applications and case studies.

**Text Books/ References:**


1. Yu, K.O., *"Modelling for Casting and Solidification Processing"*, Marcel Dekker, 2002.
2. Sindo Kou, *"Welding Metallurgy"*, Second Edition, John Wiley Publications, New York, 2003.
3. Jain V.K., "Advanced Machining Processes", Allied Publishers Pvt. Ltd., NewDelhi, 2007.
4. Hassan Abdel-Gawad El-Hofy *"Advanced Machining Processes / Non Traditional and Hybrid Machining Processes"*, McGraw-Hill Education, First Edition, 2005.
5. G.F. Benedict, Marcel Dekker, *"Non-traditional Manufacturing Processes"*, Marcel Dekker, 1987.
6. E. P. DeGarmo, J. T Black, R. A. Kohser, *"Materials and Processes in Manufacturing"*, 10th Edition, John Wiley & Sons, 2008.
7. Henry S.Valberg., *"Applied Metal Forming"*, Cambridge University Press, 2012.
8. Wagoner, R. H. and Chenot, J. L., *"Metal Forming Analysis"*, Cambridge University Press, 2005.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME602 ADVANCES IN MATERIALS SCIENCE AND CHARACTERISATION 3-0-0-3**

**Course Objectives:**

1. To familiarize the fundamentals of thermodynamics of nucleation and kinetics of growth.
2. To select appropriate materials and manufacturing techniques to meet end applications.
3. To understand the benefits of high-performance energy materials and its fabrication route.
4. To provide materials' structure and its properties with the aid of advanced characterization techniques.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Gain knowledge about thermodynamics of nucleation and strengthening mechanisms |
| CO02 | Analyse (and select) suitable materials and methods to meet high end and light weight application |
| CO03 | Acquire knowledge in high performance materials and techniques |
| CO04 | Analyse interrelationships and interdependence between processing, structure, properties, and performance using advanced material characterization techniques |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 0 | 2 | 2 | 0 | 0 | 0 |
| CO02 | 2 | 2 | 2 | 0 | 3 | 0 |
| CO03 | 2 | 2 | 2 | 0 | 3 | 0 |
| CO04 | 2 | 2 | 2 | 1 | 1 | 0 |

**Skills Acquired:**

Concept of advanced materials science and its characterization up to the atomic level, Difference between conventional and advanced materials, Thermodynamics and equipment details for advanced materials.

**Syllabus:**

Introduction to advanced materials science, thermodynamics of homogeneous and heterogeneous nucleation and kinetics of growth, non-equilibrium freezing, segregation, nucleation in the solid state, diffusion in solids, strengthening mechanism and principles. Material science and processing of light materials- aluminium, titanium, high strength steel, magnesium alloys, super alloys, high temperature materials, ceramic and carbon composites, cellular solids, metal foams.

Processing of nano, bio and composite materials and their manufacturing science, high performance polymers, recent advances in material development- functionally gradient materials and characterization, carbon nanostructures, graphenes, fullerenes, next generation battery and fuel cell materials. Introduction to special processes- High energy ball milling, thin films and vapour depositions, laser and other high intensity beam processes, sol-gel technique, synthesis and additive manufacturing.

Introduction to advanced materials characterization techniques-Scanning electron microscopy, transmission electron microscopy and energy dispersive analyses, X-ray diffraction, atomic force microscopy, Fourier-transform infrared spectroscopy, Field array NDT techniques for futuristic materials.

Challenges and scope for new and advanced materials, case studies related to design-materials selection – manufacturing models.

**Text Books/ References:**


1. Bhushan Bharat, *"Springer Handbook of Nanotechnology"*, Springer, 2017
2. Rowe Jason, *"Advanced Materials in Automotive Engineering"*, Woodhead Publishing, 2016.
3. Cao Guozhong, *"Nanostructures & Nanomaterials: Synthesis, Properties & Applications"*, Imperial College Press, 2004.
4. Michio Inagaki Feiyu Kang Masahiro Toyoda Hidetaka Konno, *"Advanced Materials Science and Engineering of Carbon"*, 1st Edition, Butterworth-Heinemann, 2013, ISBN: 9780124077898
5. Gaskell, David R., *"Introduction to Metallurgical Thermodynamics"*, McGraw Hill, 1973
6. W. D. Callister, *"Materials Science and Engineering: An Introduction"*, John Wiley & Sons, 2007.
7. C. Kittel, *"Introduction to Solid State Physics"* , Wiley Eastern Ltd, 2005.
8. Sam Zhang, Lin Li and Ashok Kumar, *"Materials Characterization Techniques"*, CRC Press, (2008)


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME603** **MACHINING DYNAMICS** **2-0-3-3**

**Course Objectives:**

- Introduce basics of the metal cutting mechanism of metal cutting operations
- Review fundamental concepts of free and forced vibrations
- Introduce basics of modal analysis - analytical and experimental
- Inculcate chatter stability analysis of machine tools by introducing self-excited machine tool vibrations
- Introduce advanced topics of high-performance machining / high-speed machining

**Course Outcomes:**

| Cos | CO Description |
|---|---|
| CO01 | Understand the basics of modeling metal cutting operations and identify various parameters affecting metal cutting processes |
| CO02 | Formulate a mathematical model of a system to study its dynamic characteristics considering natural frequency, damping factors, and mode shapes |
| CO03 | Perform stability analysis using Frequency Response Functions (FRF) and Plots, and Stability Lobe Diagrams (SLD) for turning and milling processes |
| CO04 | Familiarize with various sensors and signal processing methods to monitor and control the machining processes |
| CO05 | Conduct experimental investigations to study the dynamic behavior of metal cutting processes and improve their stability |

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 2 | 2 | 1 | - |
| CO02 | 3 | 2 | 2 | 2 | - | - |
| CO03 | 3 | 2 | 2 | 2 | - | 2 |
| CO04 | 3 | 2 | 2 | 2 | - | 2 |
| CO05 | 3 | 2 | 2 | 2 | - | 2 |

**Skills Acquired:**

Cutting Force measurement using cutting tool dynamometers; Gain user-level familiarity with machine tool dynamics testing equipment and machining process monitoring equipment; Conduct Modal Analysis; Predict Chatter using Frequency Response Functions; Familiarise with software tools for sensor signature processing.

**Syllabus:**

Machining forces: Systems of cutting tool geometry - ASA, ORS and NRS systems - Cutting force components in turning, milling, and drilling - Construction of Merchant Circle Diagram - Cutting power consumption and specific energy requirement - Analytical models for estimation of cutting forces in orthogonal and oblique cutting – Measurement of cutting forces.

Cutting temperature: Analytical estimation of cutting temperature - Experimental methods - Effect of machining parameters on cutting temperature – Control of cutting temperature and cutting fluid application - Concept of machinability – Failure of cutting tool and tool life - Cutting tool materials – Modelling and Simulation of metal cutting processes.

Modal Analysis: Introduction – Frequency Response Functions (FRF) – FRF measurement techniques – Modal parameter extraction - Modal models- Experimental methods.
Machine tool vibration - Vibration analysis methods - Chatter prediction in machining - Vibration control - Frequency response functions and stability lobe plots for turning / milling processes – Sensor-based monitoring of machining processes using Vibration, Acoustic Emission, and Cutting force sensors.

Machining issues in Advanced machining processes: High-Speed Machining, Thin-wall machining, and High-performance machining - Machining economics and optimization.

Lab Component: Cutting Force / Cutting temperature Measurement, Chip Morphological studies, Tool wear and Tool life studies, Modeling and Simulation of metal cutting processes, Modal analysis, and Modal parameter extraction, optimize machining parameters using stability lobe plots, Process monitoring and control using sensors and signal processing.

**Text Books/ References:**

1. Stephenson, David A., and John S. Agapiou., *“Metal cutting theory and practice”*, CRC press, 2016.
2. Schmitz, Tony L., and K. Scott Smith., *“Machining dynamics”*, Birkhauser, Springer, 2014.
3. Grzesik, Wit. *“Advanced machining processes of metallic materials: theory, modelling and applications*”. Elsevier, 2008.
4. Fu, Zhi-Fang, and Jimin He., *“Modal analysis”*, Elsevier, 2001.
5. Yusuf, Altintas., *"Manufacturing automation: Metal cutting mechanics, machine tool vibrations, and CNC design."* Cambridge UP, Cambridge, UK (2000).
6. Juneja BL., *“Fundamentals of metal cutting and machine tools”,* New Age International; 2003.

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME604 MANUFACTURING AUTOMATION 2- 0-3-3**

**Course Objectives:**

1. To provide the interdisciplinary knowledge in mechanical, electric, and control subsystems for developing automated manufacturing systems
2. To introduce various sensing, actuating and control elements of an automated system
3. To provide hands on experience on automated system design using Hydraulics, Pneumatics, PLC, Microcontrollers and Robotics.

**Course Outcomes:**

| | |
|---|---|
| CO01 | Design and simulate fluid power circuits to automate manufacturing processes/systems |
| CO02 | Select and integrate various components of automation like sensors, actuators, PLC and robots for a given application |
| CO03 | Develop microcontroller programs to monitor and control the manufacturing systems |
| CO04 | Design and develop an automated system for a given industrial application |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 2 | 3 | 0 | 1 |
| CO02 | 2 | 1 | 2 | 3 | 0 | 2 |
| CO03 | 3 | 1 | 2 | 2 | 0 | 2 |
| CO04 | 3 | 3 | 3 | 3 | 0 | 2 |

**Skills Acquired:**

Design of fluid power circuits for automation, Programing PLC & Robots and Programming Micro controllers for interfacing sensors.

**Syllabus:**

Introduction to automation – Basic Elements-Levels of automation. Hardware Components of automation-sensors and actuators for automation- A/D and D/A Converters- Input and Output devices for discrete data. Application of fluid power in automation- Pneumatic, Hydraulic and Electro- Pneumatic system components-circuit design for manufacturing automation. Mechanization of parts handling- Parts feeding- Parts sensing, Automated Guided Vehicle.

Discrete Process Control- Logic and Sequence Control, Programmable Logic controllers (PLC)- components-Ladder logic diagrams- I/O addresses- Timer and counters- PLC Programming applications. Robotics in Automation: Robot anatomy; Work volume - Drive systems - Sensors for industrial robots. Forward and reverse kinematics, Robot Drives, End effectors, application of robots in industrial environment, robot programming, autonomous robots- learning, adaptation, sensing and navigation.

Introduction to IoT and IIoT Concepts, Data Monitoring using Arduino/Raspberry Pi: Basic structure - Input / Output processing - Programming -Mnemonics Timers, Internal relays and counters – A/D, D/A Conversion - Analog input / output, Programming and interfacing with Sensors in manufacturing applications. Supervisory Control and Data Acquisition (SCADA)-Data Acquisition- Remote Telemetry Units- Human Machine Interface (HMI) and)-Communications Network- implementation examples in manufacturing.

**Lab Practice**:

Fluid Power Circuits: Design and Simulation of fluid power circuits for a given automated system requirement.
PLC Programming: PLC control of electro-pneumatic and electro-hydraulic systems, Interfacing digital input and output field devices with PLC hardware. Exercises on sensor integration using Arduino/Raspberry Pi.
Robot Programming: Industrial robot programming for material handling and processing applications

**Text Books/ References:**


1. Mikell P. Groover, *"Automation, Production Systems and Computer Integrated Manufacturing"*, Fifth Edition, Pearson Education, 2019.
2. Robert J. Schilling, *"Fundamentals of Robotics, Analysis & Control",* Prentice Hall, 2009.
3. Chang,T.C., Wysk, R.A., and Wang,H.P., *"Computer-Aided Manufacturing"*, Prentice Hall, 2008.
4. Antony Espossito, *"Fluid power with Applications "*, Pearson, Seventh Edition., 2009.
5. Nanua Singh, Tatla Dar Singh., *"Systems Approach to Computer-Integrated Design and Manufacturing"*, John Wiley & Sons, 1995.
6. Gaston C. Hillar, "Internet of Things with Python", Packt Publishing Limited, 2016


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects, presentations, etc.,

**21ME682** **MACHINE LEARNING WITH PYTHON** **0-0-3-1**

**Course Objectives:**

1. Introduce basic python programming and concepts
2. Enable python programming skills for scientific computing
3. Provide hands on programming for practical prediction-based applications

**Course Outcomes:**

| | |
|---|---|
| CO01 | Understand the given programming language constructs. |
| CO02 | Develop simple programs with scripts and control statements. |
| CO03 | Illustrate problems machine learning methods |
| CO04 | Apply data analytics using python scientific packages. |

**CO- PO Mapping:**

| | PO1 | PO2 | PO3 | P04 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | 0 | 3 | 0 |
| **CO2** | 2 | 3 | 3 | 0 | 3 | 0 |
| **CO3** | 2 | 3 | 3 | 0 | 3 | 0 |
| **CO4** | 2 | 3 | 3 | 0 | 3 | 0 |

**Skills Acquired:**

Problem solving of the physical systems/mathematical models using Python programming

**Syllabus:**

Introduction to Python: motivation for learning Python in various engineering applications. The concept of data types: variables, assignments; immutable variables; numerical types; arithmetic operators and expressions; comments in the program; understanding error messages; Conditions, boolean logic, logical operators: ranges;

Control statements: if-else, loops (for, while); Continue; pass; break; short-circuit (lazy) evaluation. Reading/writing text and numbers from/to a file; creating and reading a formatted file. Lists, tuples, Set and dictionaries: basic list operators, replacing, inserting, removing an element; searching and sorting lists; adding and removing keys, accessing and replacing values; traversing dictionaries.

Python packages for scientific computing: Numpy, SciPy, Pandas, Scikit-learn. Data analysis with python; Concepts of data preparation; Time series data analysis. Introduction to machine learning; Extraction of features for machine learning methods; Linear regression, logistic regression, decision tree, random forest algorithm. Data visualization.

Machine learning methods for predictive maintenance, condition monitoring, autonomous vehicles: Multivariate time series prediction; Support vector machines; Recurrent neural networks: convolution neural networks. An introduction on few python machine learning packages: Tensor flow; Keras and PyTorch.

**Text Books/ References:**


1. Guttag, John., *"Introduction to Computation and Programming Using Python: With Application to Understanding Data"*, Second Edition. MIT Press, 2016. ISBN:9780262529624.

2. William McKinney, "*Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython*", Second edition (27 October 2017), Shroff/O'Reilly, ISBN-10: 9789352136414, ISBN-13: 978-9352136414.

3. Hans Fangohr, *"Introduction to Python for Computational Science and Engineering (A beginner's guide)"*, Faculty of Engineering and the Environment University of Southampton,September 7, 2015.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Continuous Assessment (Lab)* | 70 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME681 MANUFACTURING PROCESS LAB 0-0-3-1**

**Course Objectives:**

1. To practise the fabrication of a Metal Matrix Composite (MMC) sample using a stir casting process.
2. To familiarize the fabrication of samples using casing processes and analyze its microstructure.
3. To give exposure to the fabrication of metal welded joint using various materials by GTA / GMA welding processes and analyze the welded joint quality.
4. To practise the machining of various metals using EDM by varying its process parameters to obtain the desired machining quality.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Fabricate a MMC casting sample to obtain the desired quality and inspect its microstructure concerning various process parameters. |
| CO02 | Perform fabrication of sand mould casting sample and understand the effect of cooling rate on the microstructure of casted sample. |
| CO03 | Fabricate a welded joint of different materials using the GTA and GMA process and analyze the microstructure of welded joint by varying the process parameters. |
| CO04 | Machining various metal samples using the EDM process and analyze the sample for MRR or surface roughness concerning various process parameters. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 2 | 1 | 1 | 1 | - |
| CO02 | 2 | 2 | 1 | 1 | 1 | - |
| CO03 | 2 | 2 | 1 | 1 | 1 | - |
| CO04 | 2 | 2 | 1 | 1 | 1 | - |

**Skills Acquired:**

Prepare a casting / welding samples and analyze the variation in microstructure by varying the process parameters. Machining of different materials using advanced machining processes and optimize its parameters to get desired MRR or surface finish.

**List of Exercises:**

1. Preparation of Metal Matrix Composite (MMC) sample using various metallic and ceramic reinforcements by varying process parameters using the stir casting process.
2. Analyze the microstructure of MMC samples and mechanical properties such as hardness and tensile strength.
3. Preparation of a conventional sand mould casting and analyze the variation in the microstructure of the casting sample by varying the cooling rate of the casting.
4. GTA welding of various metal samples and analyzing its microstructure after cutting the cross-section of weld bead.

5. Analyze the effect of weld quality due to GTAW process parameters such as welding current, travel speed and stand-off distance.
6. GMA welding of various metal samples and analyzing their microstructure after cutting the weld bead cross-section and interpreting it.
7. Analyze the effect of weld quality due to GMAW process parameters such as welding current, travel speed and stand-off distance.
8. Measurement of weld bead geometry elements using macrostructure analysis.
9. Machining various metal samples using an EDM machine with various process parameters.
10. Analyze EDM machined sample surface finish with respect to MRR and machining parameters.
11. Measure the tool wear experimentally in the EDM process and develop correlation between process parameters and tool wear.

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Continuous Assessment (Lab)* | 80 | - |
| End Semester | - | 20 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME605 MICRO AND NANO MANUFACTURING 2-0-3-3**

**Course Objectives:**

1. Understanding the various types of advanced micromachining processes used to manufacture miniature devices
2. Introduce Conventional and Non-conventional micromachining, forming, and finishing processes.
3. Inculcate the concepts of precision and ultraprecision machining techniques to produce components with high dimensional and form accuracy
4. Impart knowledge on manufacturing of MEMS devices
5. Machinability studies using precision milling machines, ultra-precision high-speed machining center, and wire EDM processes
6. Demonstrate the photolithographic process to fabricate miniature devices

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Recognize the need and identify suitable applications for traditional and advanced micromachining, forming joining, and deposition processes. |
| CO02 | Understand the metal removal mechanisms in ultra-precision machining and appreciate the use of diamond turning, diamond grinding, and polishing process to make devices with good dimensional and form accuracy |
| CO03 | Design the fabrication process using Photolithography / LIGA to make MEMS devices |
| CO04 | Select a suitable Metrology for measurement of dimensional, form, and surface integrity of components manufacturing using micro and nano Manufacturing |
| CO05 | Conduct experimental studies in micro/precision milling machines, precision high-speed machining centers, and EDM to analyze the process capability. |

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 2 | 1 | 1 | 0 |
| CO02 | 3 | 2 | 2 | 1 | 1 | 0 |
| CO03 | 3 | 2 | 2 | 1 | 1 | 0 |
| CO04 | 3 | 2 | 2 | 1 | 1 | 0 |
| CO05 | 3 | 2 | 2 | 1 | 1 | 0 |

**Skills Acquired:**

Conduct machinability studies in precision and micro machining machines; Design of MEMS devices; Dimensional and form Measurement of micro and nano features.

**Syllabus:**

Introduction to macro, meso, micro, and nanomanufacturing - Classification – Mechanical type micromachining processes - Abrasive based nano finishing process – Thermo-Electric type micromachining processes - Chemical and Electro-Chemical type Advanced Machining Processes - Traditional Mechanical Micromachining Process: Micro Turning, Micro Drilling, Micro Grinding, High-Speed Machining – Micro tools, ultra-fast laser micro/nano machining, Electron beam nano machining.

Micro forming techniques: laser micro-bending, micro-deep drawing, and micro-extrusion. Micro welding and joining techniques. Micro-fabrication using deposition techniques: epitaxial, sputtering, chemical vapor deposition (CVD) techniques.

Precision and Ultra-Precision machining technologies: Machining accuracies - Deformation and failure factors – Ductile regime machining - Single Point Diamond Turning (SPDT) – Ultra-Precision Grinding Technology – ELID process - Ultra-precision Polishing processes.

Micro-Electro-Mechanical Systems (MEMS) – Photolithography – Bulk Micro Machining – Surface Micro Machining – High aspect ratio Micro Machining: LIGA process – MEMS transducers – Micro Fluidic Devices - Metrology for micro and nano Manufacturing

**Lab Practice:**

- Micromachining using the precision milling machine
- Machining studies using Precision and Ultra-precision machining process.
- Study of Advanced machining process: EDM
- Design and Fabrication of MEMS devices
- Surface Modification using PVD/CVD Techniques
- Metrology: Microscopy, AFM, non-contact probes, CMM

**Textbooks/ References:**


1. Jain, Vijay Kumar, ed. "*Micromanufacturing processes*". CRC Press, 2016.
2. Kumar, K., Zindani, D., Kumari, N. and Davim, J.P., "*Micro and Nano Machining of Engineering Materials*". Springer International Publishing. 2019
3. Jackson, M. J., *"Micro and nano machining."* Springer, London, 2008. 271-297.
4. Hsu, Tai-Ran., "*MEMS and microsystems: design, manufacture, and nanoscale engineering*". John Wiley & Sons, 2008.
5. Kibria, Golam, B. Bhattacharyya, and J. Paulo Davim., "*Non-traditional micromachining processes*". Springer, 2017.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME606 LEAN MANUFACTURING 3-0-0-3**

**Course Objectives:**

1. To impart knowledge on basic concepts of lean manufacturing to continuously improve the productivity
2. To familiarize lean tools for improvement and integrate them with the organization's strategies to personalize the lean process.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Identify key requirements and concepts in lean manufacturing. |
| CO02 | Initiate a continuous improvement change program in a manufacturing organization. |
| CO03 | Analyze and improve a manufacturing system by applying lean manufacturing tools |
| CO04 | To achieve lean six sigma quality and sustainability in a manufacturing system |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 2 | 2 | 0 | 0 | 0 |
| CO02 | 2 | 0 | 0 | 0 | 2 | 0 |
| CO03 | 0 | 0 | 3 | 3 | 0 | 2 |
| CO04 | 0 | 0 | 2 | 3 | 0 | 0 |

**Skills Acquired:**

Capability to understand the value stream and non-value addition of a manufacturing/business system, To apply the concepts of TAKT TIME, To practice KAIZEN concept in manufacturing systems. Students can get a lean certification and do work independently as consultants.

**Syllabus:**

Lean Manufacturing - Introduction - History of Lean – Toyota Production System- comparison to other methods - The 7 Wastes, their causes and the effects – An overview of Lean Principles / concepts / tools - Toyota Production System, Tools of Lean Manufacturing- Continuous Flow - Continuous Flow Manufacturing and Standard Work Flow - 5S and Pull Systems (Kanban and ConWIP systems) - Error Proofing and Set-up Reduction – Total Productive Maintenance (TPM) - Kaizen Event examples. - Ford Production Systems, Value Stream Mapping – Current state and Future State. Building a Current State Map, Key issues in building the Future State Map - Process tips in building the map and analysis of the customer loop, supplier loop, manufacturing loop and information loop - Example of completed Future State Maps, Sustainable value stream mapping, Assessment of economical, environmental and social dimentions of sustainability –VSM 4.0 and information logistics, determine the wastes in information flow- Implementation of lean practices - Best Practices in Lean Manufacturing. Six Sigma Fundamentals -Selecting Projects – Six Sigma Statistics - DMAIC – Define, Measure, Analyze, Improve, Control. Lean Six Sigma – Four Keys to Lean Six Sigma - Delight Your Customers with Speed and Quality Improve Your Processes, Work Together for Maximum Gain, Base Decisions on Data and Facts - Five Laws of Lean Six Sigma - Case Studies.

Ergonomics-as enabler of lean manufacturing, Ergonomic consideration at work, Principles related to: the use of human body, the arrangement of workplace, the design of tools and equipment

The impact of Industry 4.0 on soft lean practices, The facilitating effects of lean manufacturing on Industry 4.0 implementation, Effect of environmental factors on the integration of Industry 4.0 and lean manufacturing, Study on the performance implications of Industry 4.0 and lean manufacturing integration.

**Text Books/ References:**


1. James P. Womack, Daniel T. Jones, and Daniel Roos, *"The Machine that Changed the World: the Story of Lean Production"*, Simon & Schuster, 1996.
2. Jeffrey K. Liker, *"Becoming Lean"*, Industrial Engineering and Management Press, 1997.
3. James P. Womack and Daniel T. Jones, *"Lean Thinking"*, Free Press-Business and Economics, 2003.
4. Rother M. and Shook J., *"Learning to See", The Lean Enterprise Institute, Brookline, 2003. 5. George, Michael. L. "Lean six sigma: combining six sigma quality with lean speed"*, Tata McGraw Hill Education, New Delhi, 2002.
6. Larson, Alan, *"Demystifying six sigma : a company-wide approach to continuous improvement"*, Jaico, Mumbai, 2007.
7. Barnes, R, *"Motion and Time Study"* - Design and Measurement of Work. NY: John Wiley and Sons, 8th Edition, 1985.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME607** **SMART MANUFACTURING** **3-0-0-3**

**Course Objectives:**

1. To impart knowledge on the fundamentals of manufacturing and Industry 4.0
2. To give the exposure on machine learning algorithms and data analytics.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Gain the knowledge on various aspects of manufacturing systems and Industry 4.0 |
| CO02 | Apply the smart factory concepts in manufacturing industries |
| CO03 | Apply the various machine learning algorithms to predict the performance |
| CO04 | Evaluate the performance on the factory through data analytics and machine learning algorithms |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | | 2 | 3 | 2 | 3 |
| CO02 | 3 | 2 | 3 | 3 | 2 | 3 |
| CO03 | 3 | 2 | 3 | 3 | 2 | 3 |
| CO04 | 3 | 2 | 3 | 3 | 2 | 3 |

**Skills Acquired:**

Smart Factory Concepts, Data Management, Data Analytics, Machine Learning Algorithms

**Syllabus:**

Industry 4.0: Basic principles and technologies of a Smart Factory, Digitalization and the Networked Economy, Globalization and Emerging Issues. Cyber-Physical Systems and Cyber-Physical Production Systems, smart workpiece, Digital Twins in Production, Assistance systems for production. Blockchain.

Artificial Intelligence & Augmented reality in Manufacturing. Human-Robot Collaboration, Interoperability: Communication systems and standards for Industry 4.0 and cloud applications, Cloud Manufacturing and the connected factory, cyber security, Artificial Intelligence in Production: Machine Learning Application.

Data Analytics: Introduction, Importance and characteristics of Big Data, Size of Big Data, Types of analytics, Model Complexity, Over and Under-fitting, Data Processing prior to Machine Learning, Data Visualization, Machine Learning Library, analytics method and modelling. Data Management with Python. Security.

Application Domains: Factories and Assembly Line, Food Industry, Healthcare, Power Plants, Inventory Management & Quality.

**Text Books/References:**


1. Gilchrist, A., "*Industry 4.0: the industrial internet of things*", Apress, 2016
2. Rawat, D. B., Brecher, C., Song, H., & Jeschke, S. (2017)., "*Industrial Internet of Things: Cybermanufacturing Systems*", Springer, 2017.
3. Shalev-Shwartz, S., & Ben-David, S., "*Understanding machine learning: From theory to algorithms*", Cambridge university press, 2014.
4. Masoud Soroush, McKetta Michael Baldea, & Thomas Edgar (2020). "*Smart Manufacturing: Concepts and Methods*", Elsevier, 2020.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21RM617** **RESEARCH METHODOLOGY & IPR** **2-0-0-2**

**Course Objectives**

1. To develop an understanding of the basic framework of research process
2. To identify various sources of information for literature review and data collection
3. To develop an understanding of the ethical dimensions of conducting applied research

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Understand research problem formulation |
| CO02 | Analyse research related information |
| CO03 | Follow research ethics |
| CO04 | Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity. |
| CO05 | Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular |
| CO06 | Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits |

**CO-PO Mapping:**

| | **PO1** | **PO2** | **PO3** | **P04** | **PO5** | **PO6** |
|---|---|---|---|---|---|---|
| CO01 | 1 | 1 | 2 | | | |
| CO02 | 1 | 1 | 3 | | | |
| CO03 | 1 | 1 | 2 | | | |
| CO04 | 1 | 0 | 3 | | | |
| CO05 | 1 | 1 | 2 | | | |
| CO06 | 1 | 1 | 2 | | | |

**Skills Acquired:**

Research problem identification, solution strategies, research ethics, report writing, IPR

**Syllabus:**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Effective literature studies approaches, analysis Plagiarism, Research ethics.

Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

**Text Books/References:**


1. Stuart Melville and Wayne Goddard, *"Research methodology: an introduction for science & engineering students"*, Juta & Co. Ltd., 1996.
2. Wayne Goddard and Stuart Melville, *"Research Methodology: An Introduction"*, Juta & Co. Ltd., 2004.
3. Ranjit Kumar, 3rd Edition, *"Research Methodology: A Step-by-Step Guide for beginners"*,SAGE Publications, 2010.
4. Halbert, *"Resisting Intellectual Property"*, Taylor & Francis Ltd ,2007.
5. Mayall, *"Industrial Design"*, McGraw Hill, 1992.
6. Niebel, *"Product Design"*, McGraw Hill, 1974.
7. Asimov, *"Introduction to Design"*, Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, *"Intellectual Property in New Technological Age"*, 2016.
9. T. Ramappa, *"Intellectual Property Rights Under WTO"*, S. Chand, 2008


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Continuous Assessment | 70 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME684 COMPUTER AIDED MANUFACTURING LAB 0-0-3-1**

**Course Objectives:**

1. Introduce fundamental understanding of the principles of CAD/CAM, including engineering drawing, geometric and surface, and feature-based design
2. Familiarize with CNC machine tools and their construction, and tooling for performing a variety of metal cutting operations
3. Inculcate the programming skills to write CNC programs using Computer-Aided Manufacturing (CAM) software and integrate with CNC machine and perform machining operation in a CNC machine tool

**Course Outcomes:**

| Cos | CO Description |
|---|---|
| CO01 | Understand the construction of CNC machine tool and select suitable tooling for manufacturing |
| CO02 | Read the blueprints and develop process plans for manufacturing the components in CNC turning and machining centers |
| CO03 | Create 3D models using CAD tools and generate CNC programs using CAM software, integrate the program with the CNC turning/machining center |
| CO04 | Familiarize with the High-Speed Machining process and its tooling and generate CNC programs for the precision components |
| CO05 | Perform machining operations in CNC machines, measurements using advanced metrology and sensors, following safety standards, and effectively communicate the outcomes of the experimental work |

**CO-PO Mapping**

| Cos | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 3 | 2 | - | 1 | - |
| CO02 | 2 | 3 | 2 | - | 1 | 2 |
| CO03 | 2 | 3 | 2 | 3 | 0 | 2 |
| CO04 | 2 | 3 | 2 | 3 | 0 | 2 |
| CO05 | 2 | 3 | 2 | 3 | 0 | 2 |

**Skills Acquired:**

Develop Process Plans; Manual Part programming for turning and milling operations; CNC Code generation using CAM software

**Syllabus:**

Introduction to CAM - Types, construction, tooling of CNC machines - Blueprint reading and process planning - CNC Manual Part Programming - Programming using CAM software for CNC turning and machining center -Machining practices – High-Speed Machining Centre: tooling, programming – Inspection of machined components using advanced metrology and sensors.

**Test Books/References :**

1. Bi, Zhuming, and Xiaoqin Wang. Computer-aided design and manufacturing. John Wiley & Sons, 2020.
2. Machine tool manuals
3. Lab manual

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Continuous Assessment (Lab)* | 80 | - |
| End Semester | - | 20 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME683 MANUFACTURING SYSTEM SIMULATION LAB 0-0-3-1**

**Course Objectives:**

1. The primary objective of the courses is to make the students proficient in the use of discrete event simulation software for modeling and simulation of the manufacturing system.
2. The students are expected to model real-world manufacturing systems and to analyze the system for improvement using a discrete event simulation package.

**Course Outcomes**:

| COs | CO Description |
|---|---|
| CO01 | Appreciate the role of discrete-event simulation and modeling and their application in the manufacturing environment. |
| CO02 | Analysis of simulation input data using statistical tools and fit the input data into a suitable probability distribution for developing simulation models of manufacturing systems. |
| CO02 | Simulation modeling of complex manufacturing systems using discrete event simulation software package. |
| CO04 | Interpret and analyze the simulation results of a real-world problem, identify bottlenecks, and provide suggestions for performance improvement. |

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | - | 2 | - | - | - |
| CO02 | 2 | 3 | 2 | 3 | - | 1 |
| CO03 | 2 | 3 | 2 | 3 | - | 1 |
| CO04 | 2 | 3 | 2 | 3 | - | 1 |

**Skills Acquired:**
Performance Modelling of Manufacturing Systems using Discrete Event Simulation Software; Bottleneck analysis

**Syllabus:**

Introduction to Simulation Modelling and Analysis – Review of probability distributions and basic statistics – Performance measures of a manufacturing system - Input data modelling - Modelling basic and detailed operations: part arrivals, sequencing, and scheduling, resources/processes, transporters, material handling, inventory management, inspection, etc. - Simulation output analysis – Bottleneck analysis – Sensitivity Analysis - Simulation Optimization – Exercise / Case problems: Modelling and analysis of Flow shops, Job shops, Flexible Manufacturing Systems, Push / Pull manufacturing systems, Supply Chains using discrete event simulation package.

**Text Books/References:**


1. Kelton, W. David. *Simulation with ARENA*. McGraw-Hill, 2015.
2. Altiok, Tayfur, and Benjamin Melamed. *Simulation modeling and analysis with Arena*. Elsevier, 2010.
3. Rossetti, Manuel D. *Simulation modeling and Arena*. John Wiley & Sons, 2015.
4. Lab Manual

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Continuous Assessment (Lab)* | 70 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME608 ADDITIVE MANUFACTURING 2-0-3-3**

**Course Objectives:**

1. To make students understand the wide range of additive manufacturing processes, capabilities and materials
2. To provide comprehensive knowledge on the various software tools and techniques that enable additive manufacturing.
3. To make the students learn to create physical objects that satisfies product development/prototyping requirements, using /additive manufacturing processes.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Demonstrate appropriate levels of understanding on the principles of additive manufacturing processes |
| CO02 | Demonstrate competency in the use of materials for additive manufacturing processes |
| CO03 | Demonstrate the methodology of CAD tools and CAD interface with additive manufacturing systems |
| CO04 | Identify suitable additive manufacturing process, define optimum process parameters and develop physical prototypes using suitable additive manufacturing systems. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 0 | 2 | 2 | 2 | 0 |
| CO02 | 2 | 0 | 2 | 2 | 2 | 0 |
| CO03 | 2 | 0 | 2 | 2 | 2 | 0 |
| CO04 | 2 | 0 | 2 | 2 | 2 | 0 |

**Skills Acquired:**

Selection of suitable additive manufacturing technique for a given application, finishing of additive manufactured part, CAD data transfer to additive manufacturing, technology for metal additive manufacturing

**Syllabus:**

Introduction: Methods and Systems: Introduction to layered manufacturing, Importance of Additive Manufacturing, Additive Manufacturing in Product Development
Classification of additive manufacturing processes, Common additive manufacturing technologies; Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereo Lithography (SLA), Selection Laser Melting (SLM), Digital Laser Processing (DLP), Jetting, 3D Printing, Laser Engineering Net Shaping (LENS), Laminated Object Manufacturing (LOM), Electron Beam Melting (EBM), Wire Arc Additive Manufacturing (WAAM), Electro Chemical AM, 4D Printing. Capabilities, materials, costs, advantages and limitations of different systems.

Material and Process Evaluation: Material science for additive manufacturing-Mechanisms of material consolidation-FDM, SLS, SLM, 3D printing and jetting technologies. Polymers coalescence and sintering, photopolymerization, solidification rates, Meso and macro structures, Additive Manufacturing of composite materials. Process evaluation: process-structure relationships, structure property relationships, Post processing:

Heat treatment, shot peening, HIPS, Micro finishing of AM parts, Applications: Prototyping, Industrial tooling, Aerospace, Automobile, Medical etc., Quality control and reliability: Defects in FDM, SLS and SLM, Critical process parameters: geometry, temperature, composition, phase transformation, Numerical and experimental evaluation: roles of process parameter combination, process optimization.

CAD in Additive Manufacturing: CAD Modelling for 3D printing: 3D Scanning and digitization, data handling &reduction Methods, AM Software: data formats and standardization, Slicing algorithms: -uniform flat layer slicing, adaptive slicing, Process-path generation: Process-path algorithms, rasterisation, part Orientation and support generation.

Design for Additive Manufacturing: Design for minimum material usage, Topology design optimization, Mass customization, Generative Design, Part consolidation, Design guidelines for extrusion, liquid and powder-based AM.

**Laboratory:**
CAD Modeling: Introduction to CAD environment, Sketching, Modeling and Editing features, Different file formats, Export/Import geometries, Part orientation, Slicing, Support generation-FDM/SLA, Process path selection, Printing-FDM/SLA,

**Text Books/References:**


1. Gibson, I., Rosen, D.W. and Stucker, B., *"Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing"*, Springer, 2010.
2. Chua, C.K., Leong K.F. and Lim C.S., *"Rapid prototyping: Principles and applications"*, second edition, World Scientific Publishers, 2010.
3. Liou, L.W. and Liou, F.W., *"Rapid Prototyping and Engineering applications : A tool box for prototype development"*, CRC Press, 2011.
4. Kamrani, A.K. and Nasr, E.A., *"Rapid Prototyping: Theory and practice"*, Springer, 2006.
5. Hilton, P.D. and Jacobs, P.F., *"Rapid Tooling: Technologies and Industrial Applications"*, CRC press, 2005.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME701 DESIGN FOR MANUFACTURE AND ASSEMBLY 3-0-0-3**

**Course Objectives:**

1. Understand the concept and application for Design for manufacturing and assembly and its impact on product cost and quality.
2. Be able to optimize tolerances to enhance manufacturability.
3. Be able to optimize various manufacturing processes to enhance manufacturability.
4. Be able to discuss various fundamentals of assembly and design recommendations for product development.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Understand the Design fundamentals, material selection process and compare the cost implications of the Design and manufacturability of various products. |
| CO02 | Apply design guidelines for manufacturing processes like casting, welding, forming machining and powder metallurgy. |
| CO03 | To Understand and Evaluate the Environmental impacts due to the DFMA process. |
| CO04 | Analyze any product and Improve upon the existing ones using the DFMA guidelines and principles. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 0 | 3 | 3 | 0 | 0 |
| CO02 | 3 | 0 | 3 | 3 | 0 | 0 |
| CO03 | 2 | 0 | 3 | 2 | 0 | 0 |
| CO04 | 3 | 2 | 3 | 3 | 0 | 0 |

**Skills Acquired:**

Develop designs by considering manufacturability, material selection for product design, tolerance analysis

**Syllabus:**

Group technology, Value engineering, development and evaluation of alternative solutions, Tolerance analysis Introduction to materials and material selection: Classification of engineering materials, Material selection for product design. Classification of the manufacturing process, Basic manufacturing processes, Mechanical properties of the material.

Design for Casting- Introduction to casting - Sand casting, Die-casting, Injection moulding - Design recommendation, suitable materials

Design for powder metal processing: Introduction to powder metal processing, Design recommendations.
Design for machining: Introduction to machining - Design for tuning operation, Design for machining round holes, Design for milling Process, Design for broached parts – Process description, Suitable materials, Design recommendations, Recommended tolerances

Metal Extrusion: Introduction to Metal Extrusion Process – Metal stamping, Rolled formed section, Design for extrusion, Design for Forging - Suitable Material, Design Recommendations

Design for welding: Design for the recommendation for welding process, Design for solder and brazed assembly, Design for adhesively bonded constructions - Suitable materials, Design recommendations
Design for Assembly: Introduction, Design consideration, Design for Fasteners: Introduction, Design recommendation for fasteners.

Case studies on product design for manufacturing and assembly.

**Text Books/ References:**


1. J. Lesko, *"Industrial Design, Materials and Manufacture Guide"*, John Willy and Sons, Inc, 2008.
2. George E. Dieter and Linda C. Schmidt (2009), *"Engineering Design"*, Fourth edition, McGraw-Hill companies, New York, USA
3. Geoffrey Boothroyd, Peter Dewhurst and Winston Knight ,*"Product Design for Manufacture and Assembly"*, Second Edition, CRC press, Taylor & Francis, Florida, USA, 2010.
4. O. Molloy, S. Tilley and E.A. Warman, *"Design for Manufacturing and assembly"*, First Edition, Chapman &Hall, London, UK, 1998.
5. D.E. Whitney, *"Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development"*, Oxford University Press, New York, 2005.
6. A.K. Chitale and R.C. Gupta, *"Product design and Manufacturing"*, Prentice Hall of India, New Delhi, 2013.
7. James G.Bralla, *"Design for Manufacturability Handbook"*, Second Edition, McGraw-Hill companies, New York, USA, 2020.
8. Geoffrey Boothroyd, *"Assembly Automation and Product Design"*, Second Edition, CRC press, Taylor & Francis, Florida, USA, 2005.
9. G. Q. Huang, *"Design for X, Concurrent Engineering Imperatives"*, First Edition, Chapman &Hall, London, UK,1996.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME702 THEORY OF ELASTICITY AND METAL FORMING 3-0-0-3**

**Course Objectives:**

1. To familiarize the metallurgical aspects of metal forming and its classification.
2. To give exposure to stress-strain effect and microstructural differences due to various forming processes.
3. To understand the various forces and geometrical relationship during rolling of metals.
4. To select and apply various sheet metal forming processes such as shearing, blanking, bending, stretch forming, deep drawing, drawing and extrusion.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Understand the stress strain relations in elastic and plastic deformation, concept of flow stresses, deformation mechanisms and the metal forming effects on mechanical properties. |
| CO02 | Analyze mechanics of metal working, flow stress determination, temperature in metal working and microstructural differences of various hot and cold working processes. |
| CO03 | Perform suitable rolling processes and to analyze the rolling load, rolling variables, problems and defects in rolled products. |
| CO04 | Examine the forming limit criteria, analysis of extrusion process and defects in formed parts and to understand the various sheet metal forming operations. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 2 | 2 | 3 | 1 | 0 |
| CO02 | 2 | 2 | 2 | 3 | 0 | 0 |
| CO03 | 0 | 0 | 2 | 0 | 1 | 0 |
| CO04 | 0 | 0 | 2 | 0 | 1 | 0 |

**Skills Acquired:**

Deformation mechanisms, identification of metallurgical changes during forming, select suitable technique to form the material into suitable shape and size, able to identify the reasons for defects during forming.

**Syllabus:**

Metallurgical aspects of metal forming-slip, twinning mechanics of plastic deformation-effects of temperature, strain rate, microstructure and friction in metal forming - yield criteria and their significance-classification of metal forming processes-advantages and limitations-stress strain relations in elastic and plastic deformation-concept of flow stresses-deformation mechanisms- hot and cold working processes and its effect on mechanical Properties.

Fundamentals of metal working: Classification of forming processes, mechanics of metal working, flow stress determination, temperature in metal working, strain-rate effects, metallurgical structure, friction and lubrication. Forging: Classification, forging in plane strain, calculation of forging loads, forging defects: incomplete die filling, die misalignment, laps, incomplete forging penetration, microstructural differences, hot shortness, pitted surface, surface cracking, micro cracking due to residual stresses

Rolling of metals: Classification, hot and cold rolling, forces and geometrical relationships, simplified analysis of rolling load, rolling variables, problems and defects in rolled products: centreline cracking, warping, edge wrinkling, edge cracking, centre splitting, centreline wrinkling- torque and power.

Extrusion: Classification, deformation, lubrication, defects, analysis of extrusion process.
Drawing of rods, wires and tubes: Introduction, analysis of wire and tube drawing, residual stresses.
Sheet metal forming: Introduction, forming methods, shearing, blanking, bending, stretch forming, deep drawing, forming limit criteria, defects in formed parts. Codes and Standards

**Text Books/References:**


1. Timoshenko, S. P. and Goodier, J. N., "*Theory of Elasticity*", Third Edition, McGraw Hill, 3rd edition, 2017.
2. Chakrabarthy, J., "*Theory of Plasticity*", Third Edition, McGraw Hill, 2006.
3. Dieter, G. E., "*Mechanical Metallurgy*", Third Edition, McGraw Hill, 2017.
4. Waboner, R. H. and Chenot, J. L., "*Metal Forming Analysis*", Cambridge University Press, 2005.
5. Henry S.Valberg., *"Applied Metal Forming"*, Cambridge University Press, 2010.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME703 OPTIMIZATION TECHNIQUES IN ENGINEERING 2-0-3-3**

**Course Objectives:**

1. Introduce the traditional and modern methods of optimization techniques used for solving non-linear unconstraint and constraint engineering optimization problems.
2. Considering the computational aspects, the course will involve a significant number of computational assignments using software tools and a term project in the area of engineering optimization.

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Formulate the engineering problems as an optimization problem |
| CO02 | Apply necessary and sufficient conditions for a given optimization problem for optimality |
| CO03 | Select appropriate solution methods and strategies and solve optimization problems |
| CO04 | Justify and apply the use of modern heuristic methods for solving complex optimization problems to obtain optimal / near-optimal solution |
| CO05 | Interpret and analyze the solution obtained by optimization algorithms and improve their convergence and solution quality |
| CO06 | Solve Engineering Design and Manufacturing related optimization problems using software tools. |

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 2 | - | - | - |
| CO02 | 3 | 2 | 2 | 3 | - | - |
| CO03 | 3 | 2 | 2 | - | - | - |
| CO04 | 3 | 2 | 2 | 3 | - | - |
| CO05 | 3 | 2 | 2 | 3 | - | - |
| CO06 | 3 | 2 | 2 | 3 | - | - |

**Skills Acquired:**

Formulate the engineering problems as an optimization problem; Select appropriate solution methods and strategies and solve optimization problems; Solving complex optimization problems using heuristic/ meta heuristic approach; Solve Engineering Design and Manufacturing related optimization problems using software tools.

**Syllabus:**

Introduction to Optimization - Engineering applications - Statement of an optimization problem - Classification - Optimal problem formulation: Problems in design and manufacturing fields - Optimality criteria - Classical optimization techniques - Kuhn-Tucker (KT) optimality conditions.

Non-linear programming algorithms: One-dimensional problem, Unconstrained optimization problem, Constrained optimization problem - Transformation methods - Interior and exterior penalty function method - Convergence and divergence of optimization algorithms - Complexity of algorithms.

Modern Methods in Optimization: Genetic Algorithm - Simulated Annealing - Particle Swarm Optimization - Neural Network-based optimization - Optimization of Fuzzy systems - Multi-Objective optimization – Optimization in the probabilistic domain - Shape and Topology optimization - Data Analytics and optimization using Machine learning approach.

**Lab Practice :**
Implementing optimization algorithm using software tools / Programming for solving Engineering Design / Manufacturing related problems

- Checking the optimality of unconstraint and constraint optimization problems using the Hessian matrix.
- Solving Linear, Mixed Integer, Quadratic, Non-Linear Unconstrained, and Constrained optimization problems using direct and gradient-based algorithms.
- Implementing Modern methods of optimization namely GA, SA, and PSO for solving large scale linear and complex non-linear optimization problems
- Statistical modeling and Parameter optimization
- Multi-objective optimization using Evolutionary Multi-Objective Optimization algorithms
- Case studies / Project / Presentation / Report writing: Optimal design of real-world engineering problems

**Text Books / References:**


1. Rao, Singiresu S. "*Engineering optimization: theory and practice*". John Wiley & Sons, 2019.
2. Deb, Kalyanmoy. "*Optimization for engineering design: Algorithms and examples*". PHI Learning Pvt. Ltd., 2012.
3. Arora, J.S., "*Introduction to Optimum Design*", Academic Press, 4th Edition, 2017.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME704 PRODUCT LIFECYCLE MANAGEMENT 3-0-0-3**

**Course Objectives:**

- To expose the components of product life cycle management.
- To develop structure and effectiveness of configuration management.
- To describe various types of project flows and role assignments.
- To understand the issues related to change management.
- To understand configuration of product and data management.

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Identify components of PLM/PDM |
| CO02 | Evaluate the structure of configuration management. |
| CO03 | Create project work flows and assign roles. |
| CO04 | Analyze issues in change management. |
| CO05 | Develop product configurations and manage the data. |

**CO-PO mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO1 | 1 | | | | | |
| CO2 | 1 | 2 | | | | |
| CO3 | 1 | 2 | | 2 | | |
| CO4 | 1 | | 2 | 2 | | |
| CO5 | 1 | 2 | 2 | | | |

**Skills Acquired:**

Know about digitally connected enterprise and operational complexity, business process optimization

**Syllabus:**

Introduction to Product life cycle - PLM- PDM concepts -present market constraints - need for collaboration – Object oriented programming concepts - internet and developments in server - client computing. Components of a typical PLM / PDM setup - hardware and software - document management - creation and viewing of parts and documents- version control -case studies. Configuration management: Base lines - product structure - configuration management – Effectivity - case studies.

Creation of projects and roles - life cycle of a product- life cycle management - automating information flow-workflows - creation of work flow templates -life cycle - work flow integration - case studies. Change management: Change issue- change request- change investigation- change proposal - change activity - case studies. Generic products and variants: Data Management Systems for FEA data - Product configuration - comparison between sales configuration and product configuration -generic product modeling in configuration model - use of order generator for variant creation-registering of variants in product register-case studies. Implementation issues and best practices.

**Text Books/ References:**


1. Kevin Otto and Kristin Wood, *“Product Design”*, Pearson, 2001.
2. Daniel Amor, *“The E-Business Revolution”*, Prentice Hall, 2000.
3. David Bed Worth, Mark Henderson, and Phillip Wolfe, *“Computer Integrated Design and Manufacturing”*, McGraw Hill, 1991.
4. Terry Quatrain., *“Visual Modeling with Rational Rose and UML”*, Addison Wesley, 1998.
5. Antti Saaksvuori and Anselmi Immonen, *“Product Life Cycle Management”*, Second Edition, Springer, 2005.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME705 SUSTAINABLE MANUFACTURING 3 -0- 0 – 3**

**Course Objectives:**

1. To develop a new product addressing sustainability issues;
2. To conduct a life cycle assessment on a product;
3. To compare and evaluate alternative manufacturing processes

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Knowledge with the ability to contemplate and address impact from decisions on industrial economics, ecology and societal aspects on a universal level |
| CO02 | Apply and utilize the knowledge within new areas and analyse previous unknown problems, challenges, and plan and organize implementations of actions |
| CO03 | Elaborate their knowledge in areas, like management, manufacturing technologies and methods, engineering, energy, and communication |
| CO04 | Effective communication and influence on colleagues, suppliers and customers and contribute to shape the basic values for future manufacturing |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | 2 | 3 | 1 | 1 | 2 |
| CO02 | 2 | 2 | 3 | 1 | 1 | 2 |
| CO03 | 2 | 2 | 3 | 1 | 1 | 2 |
| CO04 | 2 | 2 | 3 | 1 | 1 | 2 |

**Skills Acquired:**

Assess and design the life cycle of products, analyze processes for achieving sustainability in manufacturing

**Syllabus:**

Introduction to the environmental issues pertaining to the manufacturing sector – pressure to reduce costs – processes that minimize negative environmental impacts – environmental legislation and energy costs – acceptable practice in society – adoption of low carbon technologies – need to reduce the carbon footprint of manufacturing operations.

Cost and income based approaches, demand estimation methods – expressed and revealed preference, choice modeling – Multi-criteria analysis- Stakeholder analysis – Environmental accounting at sector and national levels

Frameworks and techniques – environmental management systems – life cycle assessment –
strategic and environmental impact assessments – carbon and water foot-printing

Concepts of Competitive Strategy and Manufacturing Strategies and development of a strategic improvement programme – Manufacturing strategy in business - success Strategy formation and formulation – Structured strategy formulation – Sustainable manufacturing system design options – Approaches to strategy formulation – Realization of new strategies/system designs

Challenges in logistics and supply chain – developing the right supply chain strategy for the products – need to align the supply network around the strategy – Tools that can be used systematically to identify areas for improvement in supply chains – Specific challenges and new thinking in the plan, source and delivering of sub-processes

Life cycle assessment Manufacturing and service activities –Influence of product design on operations – Process analysis – Capacity management – Quality management –Inventory management – Just-In-Time systems – Resource efficient design – Consumerism and sustainable well-being.

Case Studies on sustainable manufacturing

**Text Books / References:**


1. Seliger, G, *"Sustainable Manufacturing: Shaping Global Value Creation"*, Springer ,2012
2. Dornfeld, David., *"Green Manufacturing"*, Springer-Verlag, New York,2012
3. Davim, J.P.(2010), *"Sustainable Manufacturing"*, John Wiley & Sons,2010
4. Gupta, S.M. and Lambert, A.J.D., *"Environment Conscious Manufacturing"*, CRC Press,2008.
5. Douglas C.Montgomery, *"Design and Analysis of Experiments"*, 5th Edition, John Wiley & Sons, 2012.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME706 SURFACE ENGINEERING 3-0-0-3**

**Course Objectives:**

1. To impart knowledge on the fundamentals of surface treatment and diffusion techniques.
2. To understand the working principle of Physical/chemical vapor deposition; plasma spray coating; plasma assisted ion implantation.
3. To illustrate various methods of surface modification like Micro Arc Oxidation/Plasma Electrolytic Oxidation process
4. To understand the effects of phase transformation, post irradiation characterization and testing/evaluation of surface-properties.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | To select suitable surface coating technique for a given requirement. |
| CO02 | Select appropriate thermal process to alter the material surface |
| CO03 | Apply the knowledge of tribology to improve wear resistance |
| CO04 | To characterize the modified surface |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 2 | 2 | 3 | 0 |
| CO02 | 3 | 2 | 2 | 2 | 3 | 0 |
| CO03 | 3 | 2 | 2 | 1 | 3 | 0 |
| CO04 | 3 | 2 | 2 | 1 | 3 | 0 |

**Skills Acquired:**

Understand various surfaces and its properties and ability to protect and modify the surfaces by applying various types of surface treatment and coatings. To learn characterization, novelty of composition and microstructure with the knowledge on testing and evaluation of surface properties

**Syllabus:**

Introduction to surface engineering-Classification of surfaces and properties-Surface degradation, Wear and Corrosion - types of wear-Roles of friction and lubrication-Overview of different forms of corrosion-Surface treatment and coating: Chemical and Electrochemical polishing, Chemical conversion coatings, Phosphating, Chromating, Chemical colouring, Anodizing of aluminium alloys- Thermo chemical processes-Surface pre-treatment-Deposition of copper, zinc, nickel and chromium - principles and practices-Alloy plating, Electro composite plating, Electro less plating of copper, nickel phosphorous, nickel-boron, electro less composite plating, application areas- Physical/Chemical vapour deposition, Plasma spray coating; Plasma assisted ion implantation, Surface modification by directed energy beams like Ion, Electron and Laser beams, Energy transfer, Beam configuration and modes-Solid lubricants coating and Surface corrosion resistance-Micro arc oxidation/Plasma electrolytic oxidation process-Diffusion phenomenon and equation-Effects of phase transformation-Simulation of surface modification processes-Solutions for practical problems-Novelty of composition and microstructure-Post irradiation characterization and testing/evaluation of surface, Properties, Structure and Property Correlation-Failure mechanisms

ASTM Standards for Mechanical and Tribological Testing

**Text Books/ References:**

1. Griffiths, B., *“Manufacturing Surface Technology”*, Taylor and Francis, 2001.
2. Davis, J. R., *“Surface Engineering for Corrosion and Wear Resistance”*, Maney, 2001.
3. Halling, J., *“Principles of Tribology”*, Macmillan, 1992.
4. Ohring,M., *“The Materials Science of Thin Films”*, Academic Press Inc., 2005.
5. Pradeep L. Menezes, *“Tribology for Scientists and Engineers”*, Springer, 2013

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME707 FINITE ELEMENT ANALYSIS 2-0-3-3**

**Course Objectives:**

1. Inculcate the knowledge to develop and use finite element programs to solve and analyze 1D and Multi-D problems using different finite element procedures.
2. Inculcate the knowledge to formulate Strong, Weak, Galerkins, and Matrix forms to formulate and solve linear and non-linear multi-physics problems using the method of weighted residuals.
3. Utilize commercial finite element packages to model, solve, and analyze multi-physics problems.

**Course Outcomes:**

| | |
|---|---|
| CO1 | Classify and develop different finite element procedures to solve simple 1D and 2D static problems like bars, beams, trusses, frames, etc. |
| CO2 | Formulate basic and higher order elements with applicability to 1D and Multi-D coordinate systems |
| CO3 | Formulate and solve static and dynamic/transient problems in Solid Mechanics and Heat Transfer using the Method of Weighted Residuals |
| CO4 | Estimate finite element assembly procedure by constructing ID, IEN, LM arrays |
| CO5 | Develop finite element models to solve and analyze, static and dynamic, linear and non-linear multi-physics problems using a finite element package |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3) | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO1 | 1 | 3 | 3 | 0 | 2 | 0 |
| CO2 | 2 | 3 | 3 | 0 | 2 | 0 |
| CO3 | 3 | 3 | 3 | 3 | 2 | 0 |
| CO4 | 2 | 0 | 3 | 0 | 0 | 0 |
| CO5 | 2 | 3 | 3 | 3 | 2 | 0 |

**Skills Acquired:**

Finite Element Modeling, Element Selection, Development of Process Model, Use finite element package to solve practical problems.

**Syllabus:**

Fundamentals of governing equations in Solid Mechanics and Heat Transfer. Strong form, weak form, Variational formulation, weighted residual method - Galerkin formulation, Formulation of the finite element equations - Element types - Basic and higher order elements- Coordinate systems. Finite elements in Solid Mechanics: analysis of trusses, beams and frames, Plane stress, plane strain and axisymmetric elements, Plate and shell elements.- Isoperimetric formulation. Finite elements in Heat Transfer: Formulations and solution procedures in one-dimensional and two-dimensional problems.

Structural dynamics: Formulation - Element mass matrices - Evaluation of Eigen values and Eigen vectors - Natural frequencies and mode shapes - Numerical time integration.

Computer implementation of the Finite element method: pre-processing, element calculation, equation assembly, Solving, Post processing – primary and secondary variables. Introduction to computational packages.

Lab: Exercises covering structural analysis, dynamic analysis using and thermo mechanical coupled analysis FEA packages– Finite element modelling of metal forming and metal cutting operation

**Text Books/References:**


1. Rao, S. S., "*The Finite Element Method in Engineering*", Sixth Edition, Elsevier, 2018.
2. Jacob Fish and Ted Belytschko, "*A First Course in Finite Elements*", Wiley Inter Science, 2007.
3. David V. Hutton, "*Fundamentals of Finite Element Analysis*", McGraw Hill, 2005.
4. Daryl L. Logan, "*A First Course in the Finite Element Method*", Fifth Edition, Cengage Learning, 2012.
5. Zienkiewicz, O.C., Taylor, R.L., and Zhu, J.Z., "*The Finite Element Methods, Vol.1-The basic formulation and linear problems*", Butterworth Heineman, Sixth Edition, 2005.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,

**21ME708** **ROBUST DESIGN** **3 0 0 3**

**Course Objectives:**

1. The course presents the theory of modeling with a variation using physical models and methods for practical applications on designs more insensitive to variation.
2. Provides a comprehensive understanding of optimization and robustness for probabilistic design

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Familiarize with the statistical theories required for implementing robust design concepts in product development |
| CO02 | Create designs that have minimal sensitivity to input variation |
| CO03 | Perform sensitivity analysis and determine design parameters that have the largest impact on variation |
| CO04 | Optimize design with multiple outputs |
| CO05 | Create Empirical models to estimate system outputs |

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 3 | 2 | - | - |
| CO02 | 3 | 2 | 3 | 2 | - | - |
| CO03 | 3 | 2 | 3 | 2 | - | - |
| CO04 | 3 | 2 | 3 | 2 | - | - |
| CO05 | 3 | 2 | 3 | 2 | - | - |

**Skills Acquired:**

Perform sensitivity analysis and determine design parameters that have the largest impact on variation; Conduct Tolerance Analysis; Develop Empirical models to estimate system outputs.

**Syllabus:**

New product development process: Phases, Patterns, Design for Six Sigma – Statistical background for new product design: Statistical distributions, Probability plotting – Process capability – Robustness Concept

Introduction to variation in Engineering Design: Propagation of error, protecting design against variations, Estimation of statistical parameters, statistical bias, robustness, determining the variation of inputs using simulation approach - Modelling variation of complex systems – Desirability: Requirements and scorecards, determining desirability.

Optimization and sensitivity: Optimization procedure, Statistical outliers, Process capability, Sensitivity, and cost reduction – Modelling system cost and multiple outputs - Case studies and problem-solving - Tolerance analysis: Tolerance analysis methods, Tolerance allocation, Drift, Shift and Sorting – Case Studies and problem-solving

Empirical Modelling: Screening, Response Surfaces, Central Composite Design, Taguchi approach – Logistic regression and customer loss function – Case studies - Engineering model verification and validation:

Introduction, Design verification methods, and tools, Process validation procedure, Case study and Problem-solving using software tools.

**Text Books/ References:**


1. Dodson, Bryan, Patrick C. Hammett, and Rene Klerx. *"Probabilistic design for optimization and robustness for engineers"*. Hoboken, NJ: Wiley, 2014.
2. Arner, Magnus., *"Statistical robust design"*,Wiley, 2014.
3. Roy, Ranjit K., "*Design of experiments using the Taguchi approach: 16 steps to product and process improvement"*., John Wiley & Sons, 2001.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME709 PRODUCTION AND OPERATIONS MANGEMENT 3-0-0-3**

**Course Objectives:**

1. To develop an understanding of how the operations, have strategic importance and can provide a competitive advantage in the workplace
2. To anticipate issues in production and operations processes, practitioners may face during their careers
3. To apply operations management concepts and their influence on business decisions.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | To understand the principles and applications relevant to the planning, design and operations of manufacturing/service firms. |
| CO02 | To identify production planning and control strategies for a balanced system capacity and inventory. |
| CO03 | To apply qualitative methods and analytical tools to assist in decision making on operational issues. |
| CO04 | To analyze and create forecasting and operation scheduling systems. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | - | 2 | 2 | - | - |
| CO02 | - | - | - | - | - | - |
| CO03 | - | - | 2 | 3 | - | - |
| CO04 | 2 | - | - | - | - | - |

**Skills Acquired:**

Understand various concepts and issues in production and operations. Better application of production planning strategies. Ability to select suitable inventory models. To select suitable production scheduling technique.

**Syllabus:**

Role of Production.- Production Control Information Flow - CAD/CAM and Production Control. Forecasting Demand forecasting – techniques – Moving average – Exponential smoothing . Techniques for causal analysis such as simple linear regression analysis and multiple regression analysis. Aggregate planning - Aggregate production planning – use of LPP formulation – Master production schedule –techniques – Bill of materials – MPS. Techniques for MRP – lot sizing-capacity planning and control – Scheduling capacity and materials. Lots Sizing Concepts Inventory management – continuous review and periodical review policies – models for determining economic order quantity with holding and shortage costs- backlogging-constrained inventory optimization models. Sequence Scheduling - Scheduling on single and multiple machines – Scheduling with multiple constraints – Project Planning and Resource Constrained Scheduling. JIT and Lean systems Just-in-time and lean manufacturing systems. Integration of Industry 4.0 technologies into operational performance improvement

**Text Books/ References:**

1. David D. Bedworth and James E. Bailey, "*Integrated Production, Control Systems: Management, Analysis and Design"*, Second Edition, Management Science, 1993.
2. Thomas E. Vollmann, *"Manufacturing Planning and Control for Supply Chain Management"*, Fifth Edition, McGraw Hill, 2005.
3. Evans, J. R., *"Production and Operations Management"*, Fifth Edition, West Publishing, 1998. 4. William J. Stevenson, Mehran Hojati, *"Production/Operations/Management"*, McGraw-Hill Ryerson, Limited, 2001.
5. Chary,S.N., *"Production and Operations Management*", Fourth Edition, Tata McGraw Hill,2009.

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME710 LOGISTICS AND SUPPLYCHAIN MANAGEMENT 3-0-0-3**

**Course Objectives:**

- To expose the complexities and key issues in supply chain management.
- To develop location models, logistics networks, traveling salesman and vehicle routing and scheduling models.
- To analyze the inventory models, strategic alliances, role of information and integration in supply chain.
- To understand the issues related to global supply chains, procurement and outsourcing, product chain design and customer value.
- To understand advanced topics in supply chain related to Industry 4.0 and sustainability.

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Analyze the complexity and key issues in supply chain management |
| CO02 | Evaluate single and multiple facility location problems, logistics network configuration, vehicle routing and scheduling models. |
| CO03 | Analyze inventory models, dynamics of supply chain and role of information in supply chain. |
| CO04 | Develop the appropriate supply chain through strategic alliances and supply chain integration. |
| CO05 | Identify the issues in global supply chains, procurement, outsourcing, product chain design and customer value. |
| CO06 | Develop models in Logistics 4.0, digital supply chains, sustainable supply chains, urban logistics and humanitarian logistics. |

**CO-PO mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 1 | | 1 | | | |
| CO02 | 1 | 2 | 3 | 3 | | 1 |
| CO03 | 1 | 2 | 3 | 3 | 1 | 1 |
| CO04 | 1 | | 2 | | 1 | |
| CO05 | 1 | | 3 | | | |
| CO06 | 1 | 1 | 2 | 3 | | 1 |

**Skills Acquired:**

Analyze key issues in supply chain management and develop models and solutions

**Syllabus:**

Introduction: Introduction to SCM-the complexity and key issues in SCM. Location strategy – facility location decisions – single facility and multiple location models.Inventory strategy: Inventory Management and risk pooling-managing inventory in the SC.

Logistics: Logistics Network Configuration – data collection – data aggregation – Inventory Positioning and Logistics Coordination, Traveling salesman problems – exact and heuristic methods, Vehicle routing and scheduling – guidelines – problems.
The value of information - bullwhip effect -information sharing and incentives - lead time reduction. Supply chain integration: Supply chain integration-distributed strategies-push versus pull systems. Strategic alliances-third party logistics-retailer–supplier partnerships - distribution integration.

Issues in SCM: Procurement and outsourcing strategies – framework of eprocurement. International issues in SCM-regional differences in logistics. Coordinated product and supply chain design-customer value and SCM. Advances in supply chain: Logistics 4.0, Digital supply chains, Sustainable supply chains, Urban logistics, Humanitarian logistics.

**Text Books/ References:**


1. David Simchi-Levi and PhlipKamainsky, *"Designing and Managing the Supply Chain: Concepts, Strategies, and Cases*", McGraw Hill, 2002.
2. Martin Christopher, *"Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service"*, Prentice Hall, 1999.
3. Ronald Ballou, *"Business Logistics / Supply Chain Management*", Pearson Education, 2003.
4. Thomas E. Vollmann, Willan L. Bery, Robert Jacobs, F., and David Clay Bark, *"Manufacturing Planning and Control for Supply Chain Management"*, Fifth Edition, McGraw Hill, 2005.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME711** **RELIABILITY ENGINEERING** **3-0-0-3**

**Course Objective:**

Provide the importance of reliability, the basic methods to evaluate product and system reliability

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Determine the reliability of a product by applying the knowledge of probabilistic concept. |
| CO02 | Identify and select the various failure models |
| CO03 | Identify and select different reliability testing methods |
| CO04 | Predict the reliability of a product using failure data. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 1 | 2 | 2 | - | - |
| CO02 | 3 | 1 | 2 | 2 | - | - |
| CO03 | 3 | 1 | 2 | 2 | - | - |
| CO04 | 3 | 1 | 2 | 2 | - | - |

**Skills Acquired:**

Ability to determine reliability of a system and to identify suitable testing methods for industrial applications

**Syllabus:**

Concept and Definition of reliability (reliability mathematics)-Failure distributions, hazard models – exponential, Rayleigh, Weibull, Normal and Lognormal distributions -MTTF, MTBF. Reliability of systems – series and parallel configurations - Reliability improvement, redundancy, k-out-of-n system -Reliability of complex configurations-Reliability of three-state devices – Markov analysis-Physical reliability models – random stress and random strength-Design for reliability-Reliability allocation, derating-Maintainability-Design for maintainability-Availability-Maintenance and space provisioning. Failure data analysis-Reliability Testing-Identifying failure distributions– parameter estimation.

Approaches to intelligent control- AI approach- Concept of artificial neural network and its model, fuzzy logic and its model- Case study

**Text Books/ References:**


1. Charles Ebeling, *"An introduction to Reliability and Maintainability Engineering"*, Tata McGraw Hill, 2000.
2. Lewis E. E., *"Introduction to Reliability Engineering"*, Second Edition, John Wiley & Sons, 1995.
3. Rao S. S., *"Reliability Based Design"*, McGraw Hill, 1992.
4. Srinath L.S., *"Mechanical Reliability"*, East-West Press,2002.
5. Simon Haykins, *"Neural network : A comprehensive foundation"*, Pearson Edition, 2003
6. T. J. Ross, *"Fuzzy logic with fuzzy application"*,McGrawHill, 1997.

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME712** **QUALITY ENGINEERING** **3-0-0-3**

**Course Objectives:**

1. Exposure to modern quality philosophies and advanced quality engineering techniques
2. To manage quality in research, design and delivery of engineering works and investigation, as well as of safe work practices and systems assurance.
3. Prepare students to take positions such as lead quality engineer or engineering technologist with a possible role in management

**Course Outcomes:**

| Cos | CO Description |
|---|---|
| CO01 | Understand and apply the concepts in quality engineering to achieve organizational excellence. |
| CO02 | Process evaluation and control by various statistical methods and quality standards |
| CO03 | Implementation of different quality models for effective costs of quality systems. |
| CO04 | Learn about quality and reliability perspectives of manufacturing systems |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | - | 2 | 2 | 1 | - | - |
| CO02 | - | - | 3 | 3 | - | - |
| CO03 | 3 | - | - | - | - | - |
| CO04 | - | 2 | - | 2 | - | - |

**Skills Acquired:**

Conduct of Process Capability Studies, Interpret Data, Implementation of TQM concepts in an Industry

**Syllabus:**

Basic concepts in Quality Engineering: definitions, approaches and relevance to organizational excellence. Quality and Competitiveness. Product quality control: Acceptance sampling methods- single, multiple and sequential sampling plans; Recent developments in inspection methods. Statistical Process Control: Process evaluation and control by control charts: x-bar and R-bar charts, Moving Average and Moving Range Charts, Charts for Individuals, Median and Range Charts. Control Charts for Attributes -Non-conforming, Non-conformities (defects). Process capability studies: Various indices and approaches; use of Nomographs; Discussions on capabilities of Process. Quality costs-Quality measurement. Total Quality Management perspective, methodologies and procedures; Roadmap to TQM, ISO 9000, KAIZEN, Quality Circles, Models for organizational excellence. Quality Function Deployment, Quality Cost Systems and Quality Policy Deployment. Implementation of TQM and the management of change.

Process evaluation and control by designs of experiment: Various basic designs; Special methods such as EVOP and ROBUST design (Taguchi Methods). Six Sigma Management: Concepts, Steps and Tools; Benchmarking and Balanced Score Cards. TPM, FMECA, Fault Tree Analysis, Quality and reliability perspectives of JIT. Training for Quality. Application of Software tools and Case Studies.

**Text Book/ References:**

1. Douglas C. Montgomery, "*Design and Analysis of Experiments*", Seventh Edition, Wiley, 2010.

2. Juran J.M., *“Quality Control by Design”*, The Free Press, 1992.
3. Mitra A., *“Fundamentals of Quality Control and Improvement”*, PHI, Second Edition, 2005.
4. Evans J.R. and LindsayW.M., *“The Management and Control of Quality”*, Thomson, 2005.
5. Wadsworth H.M., Stephens K.S. and Godfrey A.B., *“Modern Methods for Quality Control and Improvement”*, John Wiley & Sons, 2004.

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME713 NON-DESTRUCTIVE TESTING AND EVALUATION 3-0-0-3**

**Course Objectives:**

1. To introduce students to a variety of case studies associated with Non-destructive testing methods and designed to provide a sound theoretical knowledge on inspection, evaluation, Testing and Documenting.

2. To provide knowledge about the conventional and advanced NDT tools by enhancing the experience for inspecting and evaluating components in accordance with industry specifications.

3.To develop a fundamental knowledge about the calibration, advanced techniques and the recent developments in non-destructive testing so as to improve the quality in manufacturing engineering components.

**Course Outcomes:**

| CO | CO Description |
|---|---|
| CO01 | Analyze the various metallurgical factors influencing the performance of materials and manufacturing processes for examine the defects for different engineering applications. |
| CO02 | Understanding on different NDE techniques and apply them for inspecting materials with industrial standards along with case studies. |
| CO03 | Select proper advanced NDE technique and compare the best technique for specific applications by applying all NDT methods by understanding the recent developments for various applications. |
| CO04 | Calibrating the instrument and the knowledge on NDT tools which enables them to perform inspection and document on component for imperfections as per standard and follow proper safety precautions. |

**CO-PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 2 | | 2 | 1 | 3 | 2 |
| CO02 | 2 | | 2 | 1 | 3 | |
| CO03 | 2 | | 2 | 1 | 3 | |
| CO04 | 2 | 2 | 2 | | 3 | 2 |

**Skills Acquired:**

Create, select, learn and apply appropriate techniques in NDT and to predict defects in various engineering components and structures

**Syllabus:**

Visual Inspection - Fundamentals of Visual Testing – Vision, lighting, material attributes, environmental factors, visual perception, direct and indirect methods – Mirrors, magnifiers, Boroscopes and Fibroscopes – Calibration - Inspection objectives, Codes, Standards and Specifications. Liquid Penetrant Testing – Types and properties – Developers – Advantages and limitations of various methods – Process of Liquid Penetrant – Types – Units– Calibration- Dye penetrant process- applicable codes and standards. Magnetic Particle Testing - Theory of magnetism – Ferromagnetic, paramagnetic materials – Characteristics of magnetic fields – magnetic hysteresis – Circular and longitudinal magnetization techniques– Advantages and limitations. Eddy Current Testing -

Generation of eddy currents – Effect of change of impedance on instrumentation – Properties of eddy currents – Eddy current sensing elements, probes, type of coil arrangement – Absolute, differential, lift off, operation, applications, advantages, limitations.

Ultrasonic testing - Fundamentals of Ultrasonic Waves - Generation of ultrasonic waves - Ultrasonic Inspection Methods and Equipment - Calibration of Testing Equipment - Testing/Evaluation/interpretation. Radiography - Basic Principles of Radiography - Film Radiography - Radiation Detectors and Safety - Radiographic Image Quality and Radiographic Techniques - Special Radiographic Techniques(Gamma rays, Digital Radiography and Computed Tomography) and safety precautions. Acoustic Emission- Principles and Theory – Operation, applications, advantages, limitations.

Material Characterization Techniques - Optical Metallographic Techniques - Surface Analysis Techniques - X Ray Diffraction Techniques - Ion Beam Techniques. Leak Testing - Introduction to leak testing– Objectives – Measurement of leakage –Types of leak – Types of flow in leaks – Leak Testing of Pressure Systems Without and with a Tracer Gas – Choosing the Optimum Leak Testing Method – Common errors in Leak testing- Applications. ThermographicTesting - Fundamentals to infrared and thermal testing – Principle – Inspection methods – Infrared radiation and infrared detectors – Applications, Case studies. Holography and Spark testing

**Text Books/References:**


1. Cartz L., *"Non-Destructive testing"* – ASM international Metals Park Ohio, US - 1995
2. Raj B, Jayakumar T., and Thavasimuthu M. *"Practical Non-Destructive Testing"* ,Narosa, New Delhi - 1997
3. ASM hand book, *"Non-Destructive Evaluation and Quality Control"*, American Society of Metals, Metals Park Ohio, USA – 1989
4. Horst Czichos, BeuthHochschule, *"Handbook of Technical Diagnostics"*, ISBN 978-3-642-25849-7 ISBN 978-3-642-25850-3 (eBook) DOI 10.1007/978-3-642-25850-3 Springer


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME714 COMPOSITE MATERIALS AND PROCESSING 3-0-0-3**

**Course Objectives:**

1. Equip students with the knowledge metallic and non-metallic (metal-alloy-composites Vs amorphous)
2. Enhance the students with knowledge of manufacturing processes
3. Equip the students to solve the new material design and process design for composite material
4. To demonstrate the design and development of futuristic and advanced composite materials and processes
5. To demonstrate composite for real time applications

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Select suitable composite materials for various conventional and advanced applications |
| CO02 | Master in selecting the appropriate manufacturing processes of the composite materials |
| CO03 | Analyse the processes behaviour and equipment design for advanced composites |
| CO04 | Evaluate and identity composite product for real time application (case study ) |
| CO05 | Create new materials, design and methods for advanced composite material |

**CO- PO Mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 1 | - | - | - | 3 | - |
| CO02 | 1 | 2 | - | - | 2 | - |
| CO03 | 1 | 2 | - | 1 | 3 | - |
| CO04 | 2 | 1 | 2 | 2 | 3 | - |
| CO05 | 3 | - | 3 | 2 | 3 | - |

**Skills Acquired:**

Composite material selection and processes composite for day to life (real life applications) Composite design (material science) and material development

**Syllabus:**

Introduction and classification of materials, necessity for composite materials, classification of composites. Types and forms of reinforcements, matrices and their properties. Pre-fabricated forms. Selection of matrices, physical and mechanical properties, bonding mechanisms. Selection of reinforcements, Types of reinforcement distributions: uniform, gradient and surface. Factors in composite design. Structure-property relationships. Models of various materials properties of composites: density, modulus, strength, specific heat, coefficient of thermal expansion, thermal conductivity and diffusivity, electrical conductivity and dielectric constant. Isotropic and anisotropic properties.

Conventional and advanced fabrication techniques for polymer, metal, ceramic and carbon composites: infiltration, moulding, pultrusion, stir casting, reaction sintering, electro-deposition, diffusion bonding, thermal and plasma spray forming, laser method, powder forming, additive processes, crystal growth and physical vapour depositions. Laminated Composites, Sample level lamination, case studies with focus on Design-Material Selection-Manufacturing model for development of new composites. Challenges and future scopes of composite and design.

Testing and inspection methods for composites: Experimental techniques, compositional Introduction to advanced instrumental characterization and introduction to advanced characterization techniques (XRD, XRF, ITFR, SEM, TEM, TGA etc). Non-Destructive Analyses of Composites. Special case study: composites from day to day life to aerospace

**Text Books/ References:**


1. Clyne, T. W. and Withers, P. J., *"An Introduction to Metal Matrix Composites"*, Cambridge University Press, 1993.
2. Matthews, F. L. and Rawlings, R. D., *"Composite Materials: Engineering and Science"*, Chapman & Hall, London, 1994.
3. Suresh, S., Martensen, A., and Needleman, A., *"Fundamentals of Metal Matrix Composites"*, Butterworth Heinemann, 1993.
4. Kainer, K.U., *"Metal Matrix Composites: custom-made materials for automotive and aerospace engineering"*, Wiley-VCH, 2006.
5. Chawla, N. and Chawla. K. K., *"Metal Matrix Composites"*, Springer, 2006.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME715 TOOL ENGINEERING AND DESIGN 3-0-0-3**

**Course Objectives:**

1. Analyze the forces involved in cutting to design cutting tools.
2. Describe the principles of location and clamping to design jigs and fixtures for a given component.
3. Describe the machines involved, force calculations to design press tools for a given component.

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Design cutting tools considering cutting forces, strength and rigidity. |
| CO02 | Design and development of jigs for a given component. |
| CO03 | Design and development of fixtures for a given component. |
| CO04 | Design and development of press tools for a given component. |

**CO-PO mapping:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 1 | - | 2 | - | 1 | - |
| CO02 | 2 | 2 | 2 | 1 | - | - |
| CO03 | 2 | 2 | 2 | 1 | - | - |
| CO04 | 2 | - | 2 | 1 | - | - |

**Skills Acquired:**

Design cutting tools, jigs, fixtures and press tools for any given component

**Syllabus:**

Cutting tools: Design of single point tool-strength and rigidity consideration, Design of twist drill, milling cutters, reamers and broaches. Jigs & Fixtures: Tolerance analysis and procedure of designing. The economic calculations, location of the work piece, degree of freedom, references surfaces, resting components, fixture elements for surface concentric and radial locations – Clamping of the workpiece, review of cutting forces, principles and methods of clamping. Quick clamping devices, standards. Guiding elements for tools, jig bushes, standards – indexing methods – standards in design of Jigs/Fixtures/Accessories for Drilling, Milling, Turning, Broaching, and Grinding. Tool design for advanced manufacturing processes-friction stir welding, EDM.,

Press tool design: Introduction terminology shearing dies- types of dies – analysis process shearing clearance –size and tolerances of die opening and punch – force, power, energy in shearing – loading center, shearing with inclined edges – strip layouts, economical stock. Design of Compound and progressive dies. Design of bending, drawing and forming dies- blank development, strain factor, calculation of force, construction of drawing and drawing dies.

**Text Books/ References:**


1. Cyril Donaldson and Donaldson Mn, *“Tool Design”*, Third Edition, Tata McGraw-Hill Education, 2001.
2. Edward G. Hoffman, *“Jig and fixture design”*, Cengage Learning, 2004.
3. Paul D. Q. Campbell, *“Basic Fixture Design”*, Industrial Press Inc., 1994.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME716 ADVANCED MATERIALS FOR AEROSPACE AND NUCLEAR APPLICATIONS** **3-0-0-3**

**Course Objectives:**

1. To learn new material on processing, characteristics and applications
2. To explore joining techniques for space and nuclear applications

**Course Outcomes (COs):**

| CO | Course Outcomes |
|---|---|
| CO01 | Gain knowledge about thermodynamics of interfaces and various interface |
| CO02 | Master the different modes of nucleation and its kinetics |
| CO03 | Apply the diffusion equation for simple and practical problems |
| CO04 | Select the appropriate strengthening method for alloys |
| CO05 | Acquire advanced knowledge about different material characterization techniques |

**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | - | - | 1 | - | 2 | - |
| CO02 | 1 | 1 | 1 | - | 2 | - |
| CO03 | 3 | - | 2 | 1 | 2 | - |
| CO04 | 3 | 2 | 3 | 2 | 3 | - |
| CO05 | 2 | 2 | 1 | 1 | 3 | - |

**Skills Acquired:**

About the materials and manufacturing process for aerospace and nuclear field Identification of new or futuristic requirement, design of materials for the same by metallurgical approach

**Syllabus:**

Detailed study and equipment design for advanced and high tech material processing : Introduction, definition and classification of different types of Engineering Materials for aerospace, space, nuclear and defence applications ( such as: Titanium alloys, super alloys, aluminium& light alloys, composites, tungsten –tantalum alloys, Moly and PM)
Elaborate study on properties, Composition and processing techniques of advanced materials, Layout of advanced processing techniques, classification, application and importance, Additive manufacturing, 3D metal printing, laser and electron beam processing, vacuum induction, electro-slag, vacuum arc, and controlled atmosphere processing.
Joining technologies for space and aerospace: EBW, Diffusion bonding, vacuum brazing, friction based joining techniques, atmosphere controlled joining of aero engine components, heavy alloy powder processing, functionally gradient materials
Aero-structures and nuclear power plant structural study, design of material for the same.

**Text Book/ References:**

1. Polmear, I. J., *"Light Alloys: From Traditional Alloys to Nanocrystals"*, 4th ed., Elsevier,2005 .
2. Reed, R. C., *"The Superalloys: Fundamentals and Applications"*, Cambridge Univ. Press, 2006.
3. J.A. Dantzig, C.L. Tucker, *"Modelling in Materials Processing"*, 1st ed., Cambridge University Press, 2001.
4. Dr. Horst Buhl,*"Advanced Aerospace Materials (Materials Research and Engineering)"*, ISBN: 978-3-642-50161-6 (Print) 978-3-642-50159-3 (Online), 1992.
5. M Peter and C Leyens, "*Material Science and Engineering, Vol III, Aerospace and space materials*", EOLSS, UNESCO.

**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 15 | - |
| Periodical 2 | 15 | - |
| Continuous Assessment * | 20 | - |
| End Semester | - | 50 |

*Can be assignments, tutorials, quizzes, term paper, experiments, presentations, etc.,

**21ME717 MULTI OBJECTIVE OPTIMIZATION 2-0-3-3**

**Course Objectives:**

1. Introduce the classical and evolutionary methods of optimization techniques used for solving engineering optimization problems with multiple objectives.
2. Considering the computational aspects, the course will involve a significant number of computational assignments using software tools and a term project focusing on solving multi-objective optimization problems in design and manufacturing fields.

**Course Outcomes:**

| COs | CO Description |
|---|---|
| CO01 | Formulate Engineering problem as a multi-objective optimization problem |
| CO02 | Apply evolutionary optimization techniques to solve complex Engineering problems involving multiple objectives using classical optimization approaches |
| CO03 | Appreciate the concepts of Pareto optimality and generate non-dominated solutions using evolutionary algorithms for solving multi-objective optimization problems |
| CO04 | Formulate and solve real-world MOOPs in Engineering Design / Manufacturing fields using Evolutionary Multi-Objective approaches and generate non-dominant solutions using software tools |

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO01 | 3 | 2 | 2 | - | - | - |
| CO02 | 3 | 2 | 2 | 3 | - | - |
| CO03 | 3 | 2 | 2 | 3 | - | - |
| CO04 | 3 | 2 | 2 | 3 | - | - |

**Skills Acquired:**

Formulate Engineering problem as a multi-objective optimization problem; Solve multi objective optimization problems using traditional and evolutionary muti- objective optimization algorithm; Generate solutions for muti-objective optimization problems using software tools.

**Syllabus:**

Problem Formulation: System characterization - Identification of objectives, design variables, constraints, subsystems - System-level coupling and interactions - Examples of Multi-Objective Optimization (MOO) Problems in practice - Visualization techniques in design optimization.

Optimization and Search Methods: Optimization and exploration techniques: Review of linear and nonlinear programming - Heuristic techniques: Genetic Algorithms (GA), Simulated Annealing (SA), Particle Swarm Optimization (PSO) – Constraint handling method for heuristic algorithms - Design Space Exploration.

Classical methods for MOO: weighted sum approach - ε constraint method – Goal Programming method.
Multi-Objective Optimization Problem: Principles of MOO – Dominance and Pareto Optimality – Optimality Conditions.

Evolutionary MOO approaches Non-Elitist Multi-Objective GA – Elitist Multi-Objective GA – Non-Dominated Sorting GA – Multi-Objective PSO algorithms - Representation of non-dominant solutions – Convergence issues.

**Lab Practice:**

- Solving multi-objective optimization problems using classical optimization approach (Goal programming / Weighted sum approach)
- Solving multi-objective optimization problems using evolutionary methods (NSGA-II / PSO based approach)
- Applications of Multi-Objective Evolutionary algorithms: Case Study - Mechanical Component Design – Shape, topology, and trajectory optimization – Implementation of MOO algorithms to solve real-world applications using software tools.

**Text Books/ References:**


1. Deb, Kalyanmoy, *"Multi-objective optimization using evolutionary algorithms"*, Vol. 16. John Wiley & Sons, 2011.
2. Coello, Carlos A. Coello, Gary B. Lamont, and David A. Van Veldhuizen.,*"Evolutionary algorithms for solving multi-objective problems"*. Vol. 5. New York: Springer, 2007.
3. Bechikh, Slim, Rituparna Datta, and Abhishek Gupta., *"Recent Advances in Evolutionary Multi-objective Optimization."* Springer 2018.
4. Mirjalili, Seyedali, and Jin Song Dong. *"Multi-objective optimization using artificial intelligence techniques"*. Springer, 2020.


**Evaluation Pattern:**

| Evaluation Components | Internal | External |
|---|---|---|
| Periodical 1 | 10 | - |
| Periodical 2 | 10 | - |
| Continuous Assessment (Theory)* | 10 | - |
| Continuous Assessment (Lab)* | 40 | - |
| End Semester | - | 30 |

5.

*Can be assignments, tutorials, quizzes, term paper, experiments, mini projects presentations, etc.,