DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET921	**Applied Machine Learning**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Basic fundamentals of statistics and mathematics

COURSE OUTCOMES:

CO1	To introduce students to the basic concepts and techniques of Machine Learning
CO2	To develop skills of using recent machine learning software for solving practical problems
CO3	To develop an aptitude towards identifying appropriate machine learning algorithm
CO4	To apply machine learning algorithms on real life problems

COURSE CONTENTS

Introduction to Machine Learning: Definition of Artificial Intelligence (AI) and Machine Learning (ML), difference between AI and ML, types of ML, applications of ML, types of data in ML, exploring structure of data, quality of data

Data pre-processing and visualization: Missing value analysis, data imputation, Outliers, histograms, scatter plots, heat map, pair plots, box plots, time series plots, graph visualization

Modelling and Evaluation: Model selection (predictive and descriptive models), feature transformation, feature sub-set selection, Bias, variance and complexity, confusion matrix, model accuracy measures

Supervised Learning: Classification steps, k-nearest neighbor, decision tree, random forest model, support vector machines, logistic regression

Re-sampling methods: Bootstrapping, LOOCS, k-fold

Unsupervised learning: Factor analysis, principle component analysis, K –means

Artificial Neural Network (ANN): Understanding biological neuron, single layer feed forward network, back propagation algorithm, learning process in ANN, Simulation of ANN

TEXT BOOKS/ REFERENCE BOOKS

1. Machine Learning, Saikat, D., Pearson, 2019.
2. Machine Learning in Production, Kellaher, A. and Kellaher, Pearson, 2019
3. The StatQuest Illustrated Guide to Machine Learning, Starmer, J., Kindle, 2021

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical
22MET922	**Mechatronics in Manufacturing**	**3**	**2**	**1**	**0**

PREREQUISITE : None

COURSE OUTCOMES:

CO1	Understand the concept of industrial automation involving mechatronics and measurement systems.
CO2	Understand the basic mechatronics elements like sensors & signal conditioning and their design processes, systems and components.
CO3	Understand the basic mechatronics elements like actuators & electronics interface and their design processes, systems and components.
CO4	Design and analyze various mechatronics cases such as Material Handling Systems, CNC Machines, Industrial Robots, etc. involving controllers.

COURSE CONTENTS

Mechatronics Introduction for Manufacturing Automation: Need of Manufacturing Automation, Design Thinking for Society Specific Automatic Products and Processes, Automation in Industry 4.0 era. Definitions of mechatronics, modification in product / process design process due to Mechatronics, Mechatronic systems and components, Introduction to mechatronics-based case studies i.e., CNC Machines, Industrial Robots, Modern Mobility Vehicles etc.

Sensors and signal conditioning: Introduction, Sensor classification, Based on the Physics, Based on Application, Signal conditioning, Sensor Models, Sensor/ Transducer types.

Measurement Systems: Data input Devices, Data output / display devices, Data presentation devices, Data Storage, Data Handling, measurement errors, Data Acquisition (DAQ), Data Logger

Actuators and their interface:

Classification of actuators, Mechanisms, Electric actuators, Pneumatic/Hydraulic Actuators, Electro Hydraulic/ Electro Pneumatic Actuators, Mechanical Actuators

Controllers and their programming:

Classification of controllers, Microcontrollers, Micro Processors, Programmable Logic Controller, Pseudo Codes, Low level Programming, Programming Strategies. Control Schemes:

Manufacturing Automation / Mechatronics Design Case Studies from Industry:

Industry Specific lectures: Industry case studies from industrial experts.

TEXT BOOKS/ REFERENCE BOOKS: -

1. Cochin, Era and Cadwallender, “Analysis and design of Dynamic Systems”, Addison- Wesley, 1997.
2. Tomkinson, D. And Horne, J. Longman, “Mechatronics Engineering”, Mc Graw Hill, 1996.
3. Bolton, W., “ Mechatronics”, Pearson.
4. Handbook of design, manufacturing & Automation : R.C. Dorf, John Wiley and Sons.
5. Automation, Production Systems and Computer Integrated Manufacturing, M.P. Groover, Pearson Education.
6. Industrial Automation : W.P. David, John Wiley and Sons.
7. Computer Based Industrial Control, Krishna Kant, EEE-PHI
8. An Introduction to Automated Process Planning Systems, Tiess Chiu Chang & Richard A. Wysk
9. Manufacturing assembly Handbook:-BrunoLotter
10. Anatomy of Automation, Amber G.H & P. S. Amber, Prentice Hall.
11. Performance Modeling of Automated Manufacturing Systems, Viswanandham, PHI
12. Automation by W. Buekinsham

ONLINE/E RESOURCES

1. Downloads - Harlal Singh Mali
2. Mechatronics - Course (nptel.ac.in)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET923	**Work Study and Ergonomics**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE: None

COURSE OUTCOMES: The course objectives define the student learning outcome for the course. After completing the above course, student is expected to:

CO1	Learn the objectives and scope of work study and productivity.
CO2	Compute basic work content of a particular job.
CO3	Investigate the existing methods of doing a specific task and develop an efficient method.
CO4	Learn and apply the principles of motion economy to solve method study problems.
CO5	Determine the standard time to accomplish a unit of work with application of work measurement techniques.
CO6	Learn and apply the basic tools and techniques of ergonomics to design or modify the work to fit the worker.

COURSE CONTENTS

Productivity and Work Study: Productivity, Human relations approach to productivity, Causes of Low Productivity, Productivity measurement techniques, Productivity improvement techniques; Work Study, Work content, Relationship of work-study man with management, supervisor & workers.

Method Study: Definition, objective and procedure of method study, Recording tools: Process Chart, Flow diagram, String Diagram, Travel Chart, Multiple Activity Chart, Two- Handed process chart.

Micro and Memo Motion Study: Micro and Memo-Motion study, Principles of Motion Economy, Therbligs, SIMO Chart, Cyclegraph and Chronocycle graph; Development, definition and installation of the improved method.

Work Measurement: Work Measurement, Techniques of Work Measurement, Performance rating, methods of rating, Allowances and their types, Work Sampling, Confidence levels, Standard time determination, Time Study. Predetermined Motion Time Systems (PMTS)- Method time measurement (MTM). Wages and Incentive plans.

Ergonomics: Ergonomics, Aspects of Ergonomics, Human-Machine System, Types of Ergonomics. NIOSH lifting equation, Strain Index, RULA, REBA. Anthropometry; Design of display and control. Effect of vibration/ noise, temperature, illumination and dust on human health and performance. Case Study

REFERENCES:

1. Barnes Ralph M., "Motion & Time study: Design and Measurement of Work", Wiley Text Books, 2001.
2. Marvin E, Mundel & David L, "Motion & Time Study: Improving Productivity", Pearson Education,2000.
3. Benjamin E Niebel and Freivalds Andris, "Methods Standards & Work Design", Mc Graw Hill, 1997.
4. International Labour organization, "Work-study", Oxford and IBH publishing company Pvt. Ltd., N.Delhi, 2001.
5. Sanders Mark S and McCormick Ernert J, "Human Factors in Engineering and Design", McGraw-Hill Inc., 1993.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET925	**Automobile Engineering**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : I. C. Engines, Engineering Mechanics and Theory of machines.

COURSE OUTCOMES:

CO1	To understand the history of automobile and its classification. To know about automobile power plants and their power requirements. To understand the working of Clutch, Gear box, Overdrive, Universal joints, Propeller shaft, Differential, Rear and Front Axle.
CO2	To understand type of Wheels and Tyres, Need of steering, Steering gear box, Power steering, Steering mechanisms, Wheel angles, Wheel alignment and Wheel balancing, under steer and over steer
CO3	To explain construction, working and features of different elements of brakes and suspension systems
CO4	To explain, compare and get familiarized with different layout of chassis, bodies of automobile
CO5	To explain the construction, features and working of automotive electrical circuits, starting circuit, ignition circuit, charging circuit and lighting & accessories circuit.

COURSE CONTENTS

Introduction, Classification of automobiles, Power plants for Automobiles, Power requirements in Automobiles, Clutch, Gear box & Torque convertors, Overdrive, Universal joints, Propeller shaft, Differential, Rear and Front Axle
Wheels and Tyres, Need of steering, Steering gear box, Power steering, Steering mechanisms, Wheel angles, Wheel alignment and Wheel balancing, under steer and over steer
Necessity, classification, construction and working of brakes. Suspension system types, construction & working. Shock absorber types, construction & working of telescopic shock absorber.
Chassis and Body: Types of chassis and layouts, components of chassis, Loads acting on frame, Types of bodies in automobiles.
Automobile electrical circuits and accessories: Starting circuit, ignition circuit, charging circuit and lighting & accessories circuit. Types of battery, testing and charging. Automobile air conditioning. Recent developments in automotive technology.

TEXT BOOKS/ REFERENCE BOOKS:-

1. Newton, K., Steeds, W., & Garret, T.K., The Motor Vehicle, Butterworth Heinemann, Oxford, UK.
2. Reimpell, J., and Stall, H., Automotive Chassis Engineering Principles, Society of Automotive Engineers Inc., USA
3. Judge, W., Motor Manuals; Vol.1 - Automobile Engines in Theory, Design, Construction, Operation and Testing, Chapman and Hall –London.
4. Crouse, W.H., Automotive Mechanics, International Student Edition, McGraw Hill Inc. USA.
5. Gupta R.B., Automobile Engineering, Satya Publications.

ONLINE/E RESOURCES

1. https://nptel.ac.in/courses/107106088
2. https://nptel.ac.in/courses/107103084

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET928	**Design of Heat Exchangers**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE : Fluid Mechanics, Heat Transfer

COURSE OUTCOMES

After attending the course, the student will be able to demonstrate following skills which would be evaluated though various assessments

CO1	Understand the working principle of different heat exchanger(s)
CO2	Select/ propose potential heat exchanger(s) for the given application
CO3	Understand the factors affecting effectiveness of different of heat exchanger(s)
CO4	Solve engineering problems involving rating and sizing of heat exchanger(s)
CO5	Analyze the factors causing performance decline and corrective measures

COURSE CONTENTS

Basic Design Methodologies: Classification of heat exchanger, selection of heat exchanger, thermo-hydraulic fundamentals, Overall heat transfer coefficient, LMTD method for heat exchanger analysis for parallel, counter, multi-pass and cross flow heat exchanger, e-NTU method for heat exchanger analysis, Rating and sizing problems, heat exchanger design methodology. Fouling of heat exchangers and effect of fouling, design of heat exchangers subject to fouling, fouling resistance, cleanliness factor, fouling prevention techniques.

Double Pipe Heat Exchangers: Thermal design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, parallel and series arrangements, pressure drop. Shell & Tube Heat Exchangers: Basic components, preliminary design procedure, TEMA code.

Compact Heat Exchangers: Heat transfer enhancement, fundamental of extended surfaces (fins). Finned tube heat exchanger, types. Plate fin heat exchanger (PFHE), construction, types, design, application, performance characteristics.

Phase change Heat Exchangers: Evaporators and condensers, types, design and operational considerations. Heat pipes, construction, working principle, application, effect of working fluid and operating temperatures, types of heat pipes.

Direct contact Heat Exchangers: Cooling towers, types, application, basic relations, thermal characteristics, effect of packing, maintenance, environmental effects, wind load, typical installations.

REFERENCES-

Text Books/ Reference books-

1. Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication, 2003.
2. Heat Exchanger Selection, Rating and Thermal Design by Sadik, Kakac, CRC Press.
3. Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill.
4. Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press.

Online/E resources

1. NPTEL, Heat Exchangers: Fundamentals and Design Analysis, IIT Kharagpur, Prof. Prasanta Kr Das, Prof. Indranil Ghosh (https://nptel.ac.in/courses/112105248)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET929	**Design of Mechanisms**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE : Engineering Mechanics; Kinematics of Machines; Dynamics of Machines

COURSE OUTCOMES

CO1	Understand the fundamentals of the theory of kinematics and dynamics of machines
CO2	Analyze the motion characteristics of the machine analytically, graphically or computationally
CO3	Synthesize mechanisms according to motion requirement
CO4	Dynamic analysis and Balancing

COURSE CONTENTS

Introduction To Kinematics And Mechanisms: Introduction, Motion, The Four-Bar Linkage, Science of Relative Motion, Kinematic Diagrams, Six-Bar Chains, Degrees of Freedom, Analysis Versus Synthesis.

Kinematic Synthesis-Graphical And Linear Analytical Methods: Tasks of Kinematic Synthesis, Number Synthesis , Tools of Dimensional Synthesis -Graphical Synthesis - Motion Generation: Two and three positions; Graphical Synthesis for Path Generation: Three and four Positions ; Function Generator: Three Precision Points; Analytical Synthesis Techniques, Complex Number Modeling in Kinematic Synthesis, The Dyad or Standard Form, Number of Prescribed Positions versus Number of Free Choices , Three-Precision-Point Synthesis Program for Four-Bar Linkages , Three-Precision-Point Synthesis: Analytical versus Graphical , Circle-Point and Center-Point Circles , Loop-Closure-Equation Technique.

Dynamics Of Mechanisms: Introduction to Force and Moment Balancing of Linkages, Optimization of Shaking Moments, Shaking Moment Balancing, Effect of Moment Balance on Input Torque, Other Techniques for Balancing Linkages, Computer Program for Force and Moment Balance.

Spatial Mechanisms: Kinematic Analysis of an Industrial Robot, Position Analysis, Velocity Analysis, Acceleration Analysis

TEXT BOOKS/ REFERENCE BOOKS

1. Mechanism Design: Analysis and Synthesis, Vol. I & II, A.G. Erdman and G.N. Sandor, Prentice-Hall
2. Kinematic Synthesis of Linkages, R. S.Hartenberg, and J Denavit,., McGraw-Hill
3. Dynamics and Balancing of Multibody systems, Himanshu Chaudhary and S.K Saha, Springer

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET930	**Design Thinking for Innovations**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE None

COURSE OUTCOMES:

CO1	Demonstrate knowledge of design thinking process
CO2	Apply design thinking techniques to design relevant products/services for a customer base.
CO3	Apply human-centered design (HCD) methodology for product or service design.
CO4	Apply ideation techniques for developing innovative products or services for a specific target market.
CO5	Perform the steps to gain practical knowledge of prototyping, testing, and validation

COURSE CONTENTS

Overview of Design Thinking Process

Design Thinking Process: The business context of innovation for applying design thinking, two models of design thinking, phases of design thinking, correlation with other philosophies. Introduction to design thinking: Definition, Origin of design thinking, Importance of design thinking, Design vs Design Thinking, Problem-solving, Understanding design thinking and its process model, Design thinking tools. 3-laws of DT, Knowledge Funnel, Human-Centered Design (HCD) process - Empathize, Define, Ideate, Prototype and Test and Iterate or Empathize, Analyze, Solve and Test. Understanding 13 musical nodes.

Empathize

Design thinking phases, How to emphasize, Role of empathy in design thinking, the purpose of empathy maps (say, think, feel & do), LDO (Listening, Dialogue & Observation), Things to be done prior to empathy mapping, creation of user personas, customer journey mapping, How might we questions, Patterns, and Anti-Patterns.

Unit III Analyze or Define

Root cause analysis (Five Why Tools), conflict of interest, perspective analysis, big picture thinking through system operator, big picture thinking through function modeling, Ice cream stick (indicative prop).

Solve or Ideate

Silent brainstorming & Jam board use, metaphors for ideation, CREATE and What-If tool for ideation, Visualization Tools, introduction to TRIZ, Inventive principles and their applications.

Test (Prototyping, Validation, and Presentation)

Prioritizing i.e., identification of 1000 gm idea, Prototyping, Assumptions during the design thinking process, Validation in the market, best practices of presentation i.e. Persona-based Story Telling.

Innovation Cases

Benefits of iteration in the design thinking process, Understanding Creativity, Research, Invention, and Innovation, Taking the idea to the market, Innovation management in an organization, Relating 13-Musical Nodes to the Team Work, Importance of special units for DT, Innovation cases like Jaipur Foot, Procter & Gamble, Intellect Design Arena etc.

Industry Specific lectures: Industry case studies from industrial experts.

TEXT BOOKS/ REFERENCE BOOKS: -

1. Karmic Design Thinking by Dr. Bala Ramadurai, Edition, 2020. Edition,
2. UnMukt Science and Art of Design Thinking by Arun Jain, 2020 Edition,
3. The Design of Business: Why Design Thinking is the Next Competitive Advantage by Rodger L. Martin, 2009 Edition
4. Designing for Growth: a design thinking tool kit for managers By Jeanne Liedtka and Tim Ogilvie
5. 101 Design Methods: A Structured Approach for Driving Innovation in Your Organization by Vijay Kumar
6. Human-Centered Design Toolkit: An Open-Source Toolkit to Inspire New Solutions in the Developing World by IDEO

ONLINE/E RESOURCES

1. https://www.interaction-design.org/literature/topics/design-thinking
2. https://www.interaction-design.org/literature/article/how-to-develop-an-empathic-approach-in-design-thinking
3. https://medium.com/dc-design/what-is-human-centered-design-6711c09e2779
4. https://think.design/user-design-research/user-testing/
5. https://nptel.ac.in/courses/110106124 , NOC: Design Thinking – A primer, IIT Madras (Dr. Ashwin Mahalingam, Prof. Bala Ramadurai)
6. https://nptel.ac.in/courses/107101086 , NOC: Innovations by Design IIT Bombay (Dr B.K. Chakravarthy

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET935	**Product Design and Development**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE : None

COURSE OUTCOMES:

CO1	To develop competence with a set of tools and methods for product design and development
CO2	To develop abilities to create a new product
CO3	To able to use software tools for developing products.
CO4	To understand the role of multiple functions in creating a new product (e.g. marketing, finance, industrial design, engineering, production).

COURSE CONTENTS

- Issues & Challenges of Product development, Product development process, product planning process, design thinking
- Identifying customer needs, setting Product specifications
- Concept generation, concept selection, concept testing, prototyping
- Product architecture, platform planning
- Industrial design, design for manufacturing, robust design, product development economics

References-

Text Books/ Reference books-

1. Ulrich, Karl, and Steven Eppinger. *Product Design and Development.* 4th ed. New York, NY: McGraw-Hill, 2008.
2. Lindbeck, J.R. “Product Design and Manufacture” Prentice Hall, 1995.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	L	T	P	Studio
22MET936	**Robotics Engineering**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Kinematics of Machines, Dynamics of Machines

COURSE OUTCOMES:

CO1	To understand the basics of robots.
CO2	To understand different sensors and actuators used in robots.
CO3	To apply the spatial transformation to obtain the forward kinematics equation of manipulators.
CO4	To solve the inverse kinematics problem of simple manipulators.
CO5	To create joint trajectory for motion planning.

COURSE CONTENTS:

Introduction to robotics: classification of robots, workspace analysis.

Manipulator Kinematics: Convention for affixing frames to links – DH Representation, Derivation of Direct kinematic equations for various types of robots.

Transducers and Sensors: Definition and classification of transducers & sensors. Performance characteristics, working principle of light sensors, proximity sensors, Pyro-electric transducers, Pneumatic sensors and Hall Effect sensors. Different Actuation Systems: Electrical actuators, Pneumatic and Hydraulic, Mechanical switches, solid-state switches, DC Motors, configurations of DC Motors, Stepper motors, control of stepper motors.

Jacobians: Velocities and static forces: Linear and rotational velocity of rigid bodies, velocity propagation from link to link, jacobians, singularities, static forces in manipulators, jacobians in force domain, Cartesian transformation of velocities and static forces. Dynamics of robots.

Trajectory Generation and control: General consideration in path description and generation, joint space schemes, collision free path planning, Robot programming. Control Loops of Robotic Systems, velocity and force control, Computed Torque control, adaptive control, and Servo system for robot control.

TEXT BOOKS/ REFERENCE BOOKS

1. Introduction to Robotics, S.K. Saha, Tata Mc Graw Hill Education, 2008
2. Introduction to Robotics: Mechanics and Control, John J. Craig, Prentice-Hall, 2009.
3. Robotics Control, Sensing, Vision and intelligence, K S Fu R C Gonzales, C S G Lee: McGraw Hilll, 1986
4. Robot Dynamics and Control, Mark W Spong & M Vidyasagar, John Wiley & Sons, 1989.
5. Robot Manipulators Mathematics Programming, Control, The computer control of robotic manipulators, R P Paul: The MIT Press, 1981
6. Fundamentals of Robotics, Analysis and Control. Robert J Schilling: Prentice Hall of India 1996.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	L	T	P	Studio
22MET940	**Finite Element Methods**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Engineering Mathematics, Solid Mechanics

COURSE OUTCOMES:

CO1	Comprehend basic concepts of the finite element method
CO2	Develop and generate the governing FE equations for systems governed by partial differential equations;
CO3	Apply basic finite elements for structural applications using truss, beam, frame, and plane elements
CO4	Apply finite elements to dynamics and vibration problems

COURSE CONTENTS:

Introduction to FEM: history and basic concepts of FEM, Integral Formulations and Variational Methods: Weighted integral forms.

One Dimensional Problems: Finite Element Modeling, Coordinates and Shape Functions, Galerkin's approach, Assembly of the Global stiffness Matrix and Load Vector, Treatment of Boundary Conditions – Elimination Approach, Penalty Approach, Quadratic Shape Functions, Temperature Effects. Plane Trusses: Local and Global Coordinate System, Element Stiffness Matrix, Stress Calculations, Temperature Effects. Beams and Frames: Finite Element Formulation using Potential Energy Approach and Galerkin's Approach, Load Vector, Boundary Conditions, Shear Force and Bending Moment, Beams on Elastic Supports, Plane Frames

Two Dimensional Problems: Constant Strain Triangle Element:, Potential Energy Approach, Element Stiffness Matrix, Force Terms, Galerkin's Approach, Stress Calculations, Temperature Effects. Axisymmetric Solids Subjected to Axisymmetric Loading: Formulation, Potential Energy Approach, Body Force, Rotating Flywheel, Surface Traction, Galerkin's Approach, Stress Calculations, and Temperature Effects.

Isoparametric Formulation and Numerical Integration: Four nodded quadrilateral, Numerical Integration, Higher Order Elements.

Dynamic Considerations: Formulation, Element Mass Matrix, Eigenvalue and Eigenvector evaluation, Determination of Critical Speeds, Guyan Reduction, Rigid Body Modes.

TEXT BOOKS/ REFERENCE BOOKS

1. The Finite Element Method: Its Basis & Fundamentals, Zienkiewicz.O.C, Taylor.R.L,&Zhu,J.Z, , India published by Elsevier India Pvt. Ltd., New Delhi.,2013
2. Textbook of Finite element Analysis, P. Seshu , PHI, Eighteenth Printing, 2019
3. Introduction To Finite Element Method, J. N. Reddy, McGraw Hill, 2020
4. A First Course in the Finite Element Method, Daryl L Logan, CL Engineering, 2016

DETAILS OF THE COURSE:

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET941	**Friction, Wear and Lubrication**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Material science, fluid mechanics, solid mechanics, mechanical measurement & metrology, machining science,
COURSE OUTCOMES: After completion of this course, the student should be able to:

CO1	Understand the aspects of friction, like laws, causes, types, measurements, etc., that cause the degradation of industrial components and be able to create appropriate solutions.
CO2	Understand wear mechanisms that bring surface degradation of industrial components and be able to create appropriate solutions.
CO3	Understand the role of lubrication in monitoring and controlling the tribology of the contact surfaces and be able to create appropriate solutions.
CO4	Understand various surface-dependent engineering properties and surface-initiated engineering failures. It helps them to create solutions for various surface degradation phenomena through surface engineering.

COURSE CONTENTS

- Friction, Laws of friction, Friction classification, Causes of friction; Theories of Dry Friction; Friction Measurement; Stick-Slip Motion and Friction Instabilities
- Wear, Wear classification/types; Factors affecting wear; Measurement of wear; Theories of Wear; Cryogenic wear; Wear between solids; Wear between solid and liquid; Friction and wear of engineering materials, Friction and wear of metallic materials; Friction and wear of ceramic materials; Approaches to Friction Control and Wear Prevention
- Defining Tribology, Tribology in Design, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives
- Introduction to materials, surface, thermodynamics of surface, surface dependent engineering properties Common surface-initiated engineering failure; mechanism of surface degradation Role of microstructure and materials behavior in controlling the surface-dependent failure of components, importance of surface engineering, classification, and scope of surface engineering of Materials. Introduction to surface modification and coating techniques. Conventional surface modification methods like case hardening, Physical vapor deposition, Chemical vapor deposition, Electro/electroless deposition, Thermal Spraying, etc.; Surface characterization and Testing

TEXTBOOKS/ REFERENCE BOOKS (Title, Authors, Publisher & Year): -

1. Friction, Wear, Lubrication: A textbook in Tribology, 2nd edition; Kenneth C Ludema, Layo Ajayi; CRC Press
2. Engineering Tribology, Prasanta Sahoo, PHI Learning Pvt. Ltd.
3. Tribology: Friction and wear of engineering materials; Ian Hutchings, Philips Shipway; Butterworth-Heinemann.
4. Materials and Surface Engineering in Tribology; Jamal Takadoum, John Wiley & Sons
5. Tribology of Ceramics and Composites: A Materials Science Perspective, Bikramjit Basu, Mitjan Kalin; John Wiley & Sons

ONLINE/E RESOURCES

1. https://nptel.ac.in

Details of the Course

Course Code	Course Title	Credits	L	T	P	Studio
22MET944	**Mechanical Vibrations and Control**	**3**	**3**	**0**	**0**	**0**

Prerequisite: Solid Mechanics, Dynamics of Machines

Course Outcomes:

CO1	To understand the basics of mechanical vibrations.
CO2	To apply the concept of vibration to mechanical systems.
CO3	To measure the vibrations of the machines.
CO4	To analyze and solve the vibration problems in the machines.

Course Contents:

Fundamentals of Vibration: Basic concepts of Vibration, Vibration Analysis Procedures, Harmonic analysis, Free and Forced Vibration analysis of single degree of freedom system, Stability conditions, Methods of analysis, single degree of freedom systems with viscous, Coulomb and Hysteresis damping, Vibration under general forcing conditions.

Multi-Degree Freedom System: Far Coupled and Closed Coupled Systems, Generalized Coordinates and Generalized Forces, Lagrange's Equation, Eigen Value Problem, Orthogonality of Mode Shapes, Modal Analysis, Forced Vibration using Modal Analysis.

Continuous Systems: Transverse Vibration of a String or Cable, Longitudinal Vibration of a Bar or Rod, Torsional Vibration of a Shaft or Rod, Lateral Vibration of Beams.

Vibration Measurement and Applications: Transducers, Vibration Exciters, Vibration Measuring Instruments, Random Vibrations, Signal Analysis, Experimental Modal Analysis, Machine Condition Monitoring, and Diagnosis.

Vibration Control: Strategies and steps in vibration control, Passive vibration control, Vibration Isolation, Vibration Absorbers, Active vibration control, feedback control, state space control.

Text Books/ Reference Books

1. Mechanical Vibrations, Rao, S.S., Pearson, 2017.
2. Mechanical Vibration Theory and Application, Kelly, S.G., Cenage, 2015
3. Fundamentals of Vibrations; Leonard Meirovitch, Waveland Pr Inc.,2010
4. Principles of Passive and Active Vibration Control, Asok Kumar Mallik, Shhyamal Chatterjee, Affiliated East-West Press, 2014

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET945	**Metal Forming**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Manufacturing processes, machine tool and material science.

COURSE OUTCOMES

CO1	Select and describe the metal forming operation (rolling, forging, extrusion, drawing etc.) according to application and raw material.
CO2	Calculate the requirements of raw material, tools and design the dies for a metal forming process
CO3	Observe and remedy of the defects of different metal forming processes.
CO4	Analyze the economics and efficiency of metal forming processes and high energy rate forming

COURSE CONTENTS

1. Fundamentals of Metal Forming: Classification of forming processes, mechanism of metal forming, temperature of metal working, hot working, cold working, friction and lubricants.
2. Rolling of metals: Rolling processes, forces and geometrical relationship in rolling, simplified analysis, rolling load, rolling variables, theories of cold and hot rolling, problems and defects in rolling, torque and power calculations.
3. Forging: Classification of forging processes, forging of plate, forging of circular discs, open die and closed-die forging, forging defects, and powder metallurgy forging.
4. Extrusion: Classification, Hot Extrusion, Analysis of Extrusion process, defects in extrusion, extrusion of tubes, and production of seamless pipes.
5. Drawing: Drawing of tubes, rods, and wires: Wire drawing dies, tube drawing process, analysis of wire, deep drawing and tube drawing.
6. Sheet Metal forming: Forming methods, Bending, stretch forming, spinning and Advanced techniques of Sheet Metal Forming, Forming limit criteria, defect in formed parts. Advanced Metal forming processes: HERF, Electromagnetic forming, residual stresses, in-process heat treatment and computer applications in metal forming.
7. Introduction to Press tool design: Design of various press tools and dies like piercing dies, blanking dies, compound dies and progressive blanking dies, design of bending, forming and drawing dies.

TEXT BOOKS/ REFERENCE BOOKS:-

1. Mechanical Metallurgy / G.E. Dieter / Tata McGraw Hill, 1998. III Edition
2. Principles of Metal Working / Sunder Kumar
3. Principles of Metal Working processes / G.W. Rowe
4. Kalpakjian Serope, Manufacturing engineering and Technology, Wesley Publishing Co., 1995.
5. William F. Hosford & Caddel Robert M., Metal forming (Mechanics & Metallurgy), Prentice Hall Publishing Co., 1990.
6. P. N. Rao, Manufacturing Technology, Volume 1, Tata McGraw-Hill Education, 2013
7. Amitabh Ghosh and Ashok Kumar Mallik, Manufacturing science, East west press private limited 1985.

ONLINE/E RESOURCES

1. SWAYM/NPTEL Portal

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET946	**Power Plant Engineering**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Engineering Thermodynamics, Fluid Mechanics, Heat Transfer and combustion

COURSE OUTCOMES:

CO1	To explain various terms used in power plant economics such as load curve, performance and operating characteristics
CO2	Explain the layout, construction and working of the components inside a steam power plant
CO3	Explain the layout, construction and working of the components inside a diesel and gas turbine plant
CO4	Explain the layout, construction and working of the components inside a nuclear power plants and hydro power plants
CO5	To understand and explain working, component layout and selection criteria of wind turbines and solar power plants

COURSE CONTENTS

Introduction to Power Plants: Introduction and need of power plant, present energy scenario

Power Plant Economics: Various terms and definitions, load curves, cost of electricity generation, performance and operating characteristics, combined operation of power plants, load division.

Steam Power Plant: Layout, site selection, coal burning methods, disposal of ash and dust, combined cycle power plants, integrated coal gasification, major plant components: condensers, cooling towers.

Diesel and Gas Turbine Plant: General Layout, plant components, comparison with steam plant.

Nuclear Power Plants: Location, component of nuclear plants, types of reactors, Uranium enrichment, safety, disposal of nuclear waste, comparison with thermal plants.

Hydro-electric Power Plant: Classification, layout, components and auxiliaries of hydro power plant, Selection of turbines, micro hydro plants, pumped storage.

Other power plants: Wind resource assessment, types and selection of wind turbines; working and control of machines; Solar PV power plants: system components, selection criteria; Solar Power Pants: Types of solar plants, component description, auxiliary heating requirement.

Recent Developments: Recent developments in power plants, Future vision and India's way forward in power sector

References-

Text Books/ Reference books-

1. Power Plant Engineering, Frederick T. Morse, East West Press.
2. Power Station Engineering & Economy, Skrotzki&Vopat, Tata McGraw Hill.
3. Power Plant Technology, El-Wakil M.M, Tata McGraw-Hill.
4. Power Plant Engineering, P.K. Nag, Tata McGraw Hill, New Delhi.
5. Power Plant Engineering, R. K Rajput, Laxmi Publications Pvt Ltd

Online/E resources

1. NPTEL Course on Power Plant Engineering by Prof. Ravi Kumar, IIT Roorkee https://nptel.ac.in/courses/112107291

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET949	**Project Management**	**3**	**3**	**0**	**0**	**0**

PREREQUSITE- NO
COURSE OUTCOMES:

CO1	Understand the concept of projects and project life cycle and map the PM tools and techniques to different phases of a project life cycle
CO2	Apply project evaluation techniques and define project scope and estimate cost of the project
CO3	Create work breakdown structure and integrating it with project organizational structure
CO4	Develop project network and apply network techniques PERT/CPM and project crashing
CO5	Allocate scarce resources to project activities and develop a precedence and resource project schedule
CO6	Develop a project base plan and apply concepts of earned value management system for project monitoring and control

COURSE CONTENTS

- Introduction to project and project management, Project v/s Program management, Qualities of a project manager, Project life cycle phases
- Project initiation, Need identification, Project feasibility, Project selection- Economic evaluation, MADM techniques, Mathematical programming approach, Project portfolio approach
- Project definition, Project scope, Work breakdown structure and its integration with organizational structure, Cost estimating and budgeting, learning curves
- Network development-AOA and AON networks, Basic scheduling with deterministic activity durations, PERT and Simulation, Project crashing
- Resource loading, Resource levelling, Resource constrained scheduling-integer programming and heuristic methods
- Earned value management system, scope changes control, Critical chain project management, Project organization and teams, Project management software

References-

Text Books/ Reference books:

1. J.D. Wiest and F.K. Levy, Management Guide to PERT/CPM with GERT/PDM/DCPM John, Prentice Hall;
2. Jack R. Meredith and Samuel J. Mantel Jr., Project Management, A Managerial Approach, 6th Edition, John Wiley & Sons.
3. Gray Clifford F. and Erik W. Larson. 2011. Project Management: The Managerial Process. 5th edition. McGraw-Hill Irwin Publishers
4. Arun Kanda., Project Management – A Life Cycle Approach, Ist edition, PHI Learning

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET950	**Quality System Engineering**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE: None

COURSE OUTCOMES:

CO1	Understand the fundamental principles of Quality Engineering
CO2	Understand the contribution of Quality Gurus in TQM Journey
CO3	Choose appropriate statistical techniques for improving processes
CO4	Able to explain the concept of Six Sigma its DMAIC process
CO5	Develop skills that will allow them to keep abreast of changes in the field of Total Quality Management

COURSE CONTENTS

Introduction to quality management- Define Quality, Quality cost, Statistics for quality, Continuous improvement in quality, Management Aspects of Quality, Quality planning, improvement and assurance Contributions of Quality Guru's

Quality principles- Quality Guru's, Continuous improvement, Deming and Juran's philosophy, Basic problem-solving tools for quality improvement, OC curve and sampling plans, Process capability

Taguchi quality engineering- Taguchi loss function and robust design concept, Design of Experiments, Total productive maintenance, Failure mode effect analysis

Quality improvement and lean manufacturing- Quality through improvement, Lean manufacturing, Six sigma, KAIZEN, 5S, DMAIC and its examples

Quality awards and documentation- Quality awards, quality management systems, Quality through innovation (TRIZ), Quality through IT (CRM)

REFERENCES-

TEXT BOOKS

1. A First Course in Quality Engineering: Integrating Statistical and Management Methods of Quality, by V. Ram Krishnamoorthi, Arunkumar Pennathur, K.S. Krishnamoorthi, CRC Press, 2019
2. Quality Engineering in Production Systems, by G Taguchi, McGraw Hill, 1989.
3. Optimization &Variation Reduction in Quality, by W.A. Taylor, Tata McGraw Hill, 1991.

REFERENCE BOOKS-

1. Taguchi Techniques for Quality Engineering, (2ndEdition) by Philipposs, McGraw Hill, 1996.
2. Six Sigma for Managers, by Greg Brue, TMH, 2002.
3. Implementing Quality: A Practical Guide to Tools and Techniques by Ron Basu, THOMPSON, 2006.

ONLINE/E RESOURCES

1. Total Quality Management: https://nptel.ac.in/courses/110104080
2. Quality Design and Control: https://nptel.ac.in/courses/110105088
3. Inspection and Quality Control in manufacturing: https://nptel.ac.in/courses/112107259
4. Design for quality, manufacturing and assembly: https://nptel.ac.in/courses/112106249

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET952	**Supply Chain Management**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE None

COURSE OUTCOMES:

CO1	To understand the fundamentals of elements and functions of supply chain, role of drivers.
CO2	To understand and develop a distribution and global supply chain network
CO3	To understand obstacle and managerial lever for improving supply chain coordination
CO4	To apply various techniques of inventory management in the supply chain

COURSE CONTENTS

Understanding the supply chain: evolution, decision phases.

Strategic fit in a supply chain: competitive and supply chain strategy, demand and supply uncertainty, strategic fit,

Supply chain drivers and metrics: Facility, transportation, inventory, Information, Pricing, Sourcing

Distribution network: Factors affecting distribution network, design options for a distribution network, selecting a distribution network

Network design: factors influencing network dsign decision, optimization models to design a network configuration

Supply chain risk: Risk management in global supply chain, risk mitigation strategies, flexibility, chaining and containment

Sales and operation planning: predictable variability in the supply chain, managing supply and demand

Coordination in a supply chain: Bullwhip effect, obstacles to coordination in a supply chain, managerial levers to improve coordination

Inventory management: Cycle and safety inventory, Economic order quantity, short term discounting, product availability, measuring demand and supply uncertainty, impact of aggregation on safety inventory

Transportation in a supply chain: transportation modes, design options for a transportation network

Sustainability in a supply chain: the tragedy of commons, corporate social responsibility, sustainability and supply chain drivers, role of incentives and regulation for sustainability, recycling and closed loop supply chains

REFERENCES-

1. Chopra, Sunil and Peter Meindl. *Supply Chain Management*. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 2004
2. Simchi-Levi, David, Philip Kaminsky, and Edith Simchi-Levi. *Designing and Managing the Supply Chain*. 2nd ed. New York, NY: McGraw-Hill, 2003.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET954	**Air-Conditioning System Design**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Engineering Thermodynamics, Fluid Mechanics & Machines, Heat Transfer and Refrigeration & Air-conditioning

COURSE OUTCOMES:

CO1	Basic concept of thermal comfort, comfort requirements and comfort indices, indoor and outdoor design conditions
CO2	Understanding about fundamental thermal-fluid science behind working of HVAC equipment
CO3	Ability to carry out heat load and system sizing calculation including solar heat gain
CO4	Ability to propose heating and cooling coil design, cooling tower design and selection, selection of hydronic heating and cooling systems, selection of humidification and dehumidification equipment.
CO5	Ability to estimate the duct losses and Understanding about selection of air distribution component and configuration
CO6	Ability to make an understanding about energy conservations, waste heat recovery and cogeneration in air conditioning systems, air conditioning of industrial processes.

COURSE CONTENTS

Design Conditions: Preliminary Considerations; inside, outside and supply design conditions; critical loading calculations; comfort; clean spaces; Central and Unitary systems

Load calculations and applied Psychrometrics: Load Estimating: Internal heat gain, System heat gain, Ventilation load, Solar gain in building; Cooling and Heating load estimate; selection of air-conditioning apparatus

Design of air-conditioning apparatus: Cooling and dehumidifying coil equipment; Spray equipment- Air washer and cooling tower, noise reduction; Selection of air cleaners.

Transmission and Distribution of air: Air diffusion, rules for positioning inlets and outlets in air-conditioning space, fundamental of losses in ducts, pressure loss, air-duct design,

Energy conservations and air conditioning for special applications: Waste heat recovery, cogeneration of power and refrigeration, industrial air conditioning for textile processing, pharmaceutical, preservation and transport, passive cooling and heating, geothermal and earth air tunnel heat exchanger (EATHE) air conditioning system.

REFERENCES-

TEXT BOOKS/ REFERENCE BOOKS-

1. Air conditioning principles and systems by Edward G. Pita, PHI (Prentice Hall of India)
2. Air conditioning system design, Roger legg, Butterworth-Heinemann, Elsevier. Elementary
3. Prasad, M., “Refrigeration and Air Conditioning”, 2nd Ed., New Age International
4. Howell, R.H., Saucer, H.J., and Coad, W.J., “Principles of Heating, Ventilation and Air Conditioning”, ASHRAE
5. Arora, C. P., “Refrigeration and Air Conditioning”, Tata McGraw-Hill 5. ASHRAE Handbook (Fundamentals) 2005

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET957	**Entrepreneurship and Business Incubation**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE None

COURSE OUTCOMES

CO1	Understand the fundamentals of Entrepreneurship.
CO2	Understand the entrepreneurial behaviour.
CO3	Business Creation and Start-up Development
CO4	Implementation of Business Plan

COURSE CONTENTS

Introduction to entrepreneurship and intrapreneurship, Success stories of 6-8 entrepreneurs. Identification of critical success factors to be a successful entrepreneur, Entrepreneurship as a career option; profile of a successful entrepreneur; process of becoming an entrepreneur; personal assessment and understanding of self.

Business plan preparation; constituents of a business plan. Statuary requirements for becoming an entrepreneur. Governmental rules and regulations. Government Startup Promotion Schemes like Startup India, Development of a Business Idea.

Start-Ups and Micro Businesses, Self-Employment. Motivations and the Process of Self-Assessment, Risks and Rewards. Dealing with business failure. Overcoming Social, Economic and Cultural barriers to Entrepreneurships; Process of Idea Generation, Invention, Discovery, Innovation and Expansion. Franchising and Business Partnerships; Working in teams, finding your co-founder, team dynamics. Negotiation skills; Types of Legal Entities, Incorporation and Exit.

Familiarizing with the Companies Act and other Legal Aspects of running a business. Taxes and Exemptions relevant to StartUps.

Product and Service Design – Creative Problem Solving and Process of Solutions design; Opportunity Identification, Estimation and Evaluations.

Industry Specific lectures- Industry case studies from industrial experts.

Mini Project:

Student should prepare a business plan in a group and register themselves as a startup in an incubation center.
(Finalization of business plan; floating their own company; start prototype development; customer identification; market survey; demand analysis; start the enterprise after arranging funds/ finances from venture capitalists/ angle investors/ govt. agencies etc.)

Suggested readings:

1. Stay Hungry Stay foolish: Rashmi Bansal; CIIIE, IIM Ahmadabad, 2008.
2. Arise, Awake: The Inspiring Stories of Young Entrepreneurs Who Graduated From College Into A Business of Their Own, Westland Books Private Limited (20 January 2015)
3. Moodi, Y. (2012). Game changers: 20 extraordinary success stories of entrepreneurs from IIT Kharagpur. Noida: Random House.
4. Bansal, R. (2013). Follow every rainbow: the inspiring stories of 25 women entrepreneurs whose gentle touch created strong business. Chennai: Westland Ltd

DETAILS OF THE COURSE

Course Code	Course Title	Credits	L	T	P	Studio
22MET959	**Industry 4.0**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE: NIL

Course Objectives:

CO1	Develop an understanding of Industry 4.0 philosophy
CO2	Acquire an understanding of technology such as IoT, AI, Big Data, Data analytics and CPS in the context of Industry 4.0.
CO3	Develop the skills necessary to communicate the results of an Industry 4.0 project for decision-making and potential trade-offs
CO4	Develop a comprehensive understanding of technologies adopting for modern industrial operations and in smart manufacturing.
CO5	Apply and solve practical decision-making problems. Application of Industry 4.0 technology to real-world scenarios in various domains, such as manufacturing, health and Logistics.

COURSE CONTENTS:

Introduction to Industry 4.0- Evolution of manufacturing and digital transformation. Overview of the fourth Industrial Revolution, Key concepts and principles of Industry 4.0, Drivers and pillars of Industry 4.0,

Technological Framework- Introduction to the Internet of Things (IoT) and its role in Industry 4.0, Artificial Intelligence (AI) technology enabler for Industry 4.0, Introduction to Big Data analytics and its role in Industry 4.0, Understanding the importance of cybersecurity in Industry 4.0 environments, Cloud Technology in the Manufacturing Industry, Cyber-physical systems (CPS).

Smart manufacturing operation - Understanding the concept of smart manufacturing and its significance in modern industrial operations, Lean production system, smart factories, Key components of smart manufacturing systems: Cyber-Physical Systems (CPS), Internet of Things (IoT), Data Analytics, and Artificial Intelligence (AI), Integration of smart manufacturing with Industry 4.0 principles.

Industrial Automation- Automation technologies in Industry 4.0 manufacturing, Programmable Logic Controllers (PLCs), Collaborative Robots (Cobots). Human-Machine Interaction (HMI) and control systems for automated manufacturing processes, Programming, and collaboration.

Industry 4.0 Applications - Real-world examples of Industry 4.0 implementations, Analysis of successful Industry 4.0 projects, Challenges, and future trends in Industry 4.0 in manufacturing, healthcare, and Logistics.

REFERENCES-

TEXT BOOKS/ REFERENCE BOOKS

1. "Industry 4.0: The Industrial Internet of Things", Gilchrist Alasdair ,Apress ,2019
2. "The Fourth Industrial Revolution" Schwab Klaus , Portfolio Penguin,2017
3. "Industry 4.0: Managing The Digital Transformation" , Alp Ustundag and Emre Cevikcan,springer(2018)
4. ."The Internet of Things (IoT) in Industrial Applications" Qusay F. Hassan,Chapman and Hall/CRC(2017)

References

1. IIT Jodhpur: Certificate Programme in Introduction to Industry 4.0 and Industrial Internet of Things (https://iitj.ac.in/uploaded_docs/UG/ME/1.%20B.Tech%20ME_24092020.pdf)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET960	**Intellectual Property Rights and Technology Transfer**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE: None

COURSE OUTCOMES:

CO1	Learner will be able to understand the fundamentals of IPR and the associated laws in India.
CO2	Learner will be able to differentiate between IPs like Patent, Design, Software, Copyrights, Trademarks, Trade secrets and GIs with respect to their nature, process and application.
CO3	Learner will be able to understand the need and supplier side process technological transfer and licensing of IPs and take appropriate decisions regarding his/her technologies.
CO4	Learner will be able to implement the know how in the cases and IPs developed by him/ her

COURSE CONTENTS

Overview of IPR: Introduction to Intellectual Property Rights, Kinds of Intellectual Property Rights, Industrial property, need for intellectual property rights, rationale for protection of IPR, Intellectual Property – Policy Consideration – National and International, PCT (Patent Corporation Treaty), Some important examples of IPR.

Patents and Filing Process in India: Definition, types of inventions protected by patent, Patentable and non-patentable inventions, process and product patent, Legal requirements for patents, granting of patent, Patent application process: Searching a patent, drafting of a patent, Filing of a patent, Types of patent applications, patent document: specification and claims, Request for Examination, Tracking the status of the Patent Application. Non-functional patents i.e. Design: Difference from functional patents, registration process.

Copyrights and Registration Process in India: Rights and protection covered by copyright, law of copy rights: Fundamental of copy right law, originality of material, copy right ownership issues, and notice of copy right. Computer program: Brief history of protection of computer programs, protection of computer programs under patent or under copyright, International norms concerning copyright protection of computer programs.

Other IPs and Registration Process in India: Rights of trademark, Types of signs used as trademarks, purpose and functions of trademark, trademark protection, trademark registration, acquisition of trade mark rights, selecting and evaluating trademark, trademark registration processes. Why and How GI need protection and GI Laws, Indian GI act, Industrial Designs: Protection, kind of protection is provided by industrial designs, Trade Secrets: Trade secrete law, determination of trade secrete status, liability for misappropriations of trade secrets, protections for submission, trade secret litigation

Technological Transfer and Licensing: The need and motivation for Licensing / Technology Transfer in Technological Institutions, Understanding Technology Readiness Level (TRL) of Technology, An overview of Licensing / Technology Transfer stratus in Indian context, Characterizing features of licensing, Technology Transfer Mechanism.

Industry Specific lectures: Industry case studies from industrial experts.

REFERENCES:

1. Fundamentals of IP for Engineers, K. Bansal and P. Bansal
2. B.L.Wadehra; Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India 2000
3. P. Narayanan; Law of Copyright and Industrial Designs; Eastern law House, Delhi , 2010
4. Intellectual property right, Deborah, E. Bouchoux, cengage learning.
5. Intellectual property right - Unleashing the knowledge economy, prabuddha ganguli, Tata Mc Graw Hill Publishing Company Ltd.
6. https://nptel.ac.in/noc/courses/noc18/SEM2/noc18-hs45/
7. J.P.Mc Manus, Intellectual Property,: From Creation to Commercialization-A practical Guide for Innovators & Researchers.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET961	**Lean Six Sigma**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: NIL

COURSE OUTCOMES:

CO1	Understand the scope and breadth of a Lean Six Sigma initiative.
CO2	Gain an understanding of what waste is and how to identify it so that it can be reduced.
CO3	Become aware of variation and techniques to reduce it.
CO4	Become familiar with the DMAIC team project model.
CO5	Be aware of the infrastructure needed to support a Lean Six Sigma effort.

COURSE CONTENTS

Evolution of Quality Improvement: History of continuous improvement, Management and Planning Tools, maximizing value and minimizing waste in the manufacturing processes, Six Sigma Applications, Lean Manufacturing: A "Holistic" View.

Lean Manufacturing and Tools: Lean Manufacturing Approach, Five Primary Elements, SMED, Lean Assessment, Current State Gap, Future State Design, Deployment, Affinity Diagram, Value Stream Mapping, A Business simulation, Lean Material Systems, Standard Work, TPM, Workplace Organization

DMAIC: The process of Lean Six Sigma: Introduction, Six Sigma as a Statistical Measure, Define Phase, Measure Phase, Analyze Phase, Improve Phase, Control Phase, GR&R, Cause and Effect Analysis, FMEA, VSM, RSM, Regression, Statistical Process Control, Control Charts, Project Scope, Project Management, Strategic Planning and Development, Project selection

SIX SIGMA IMPLEMENTATION CHALLENGES: Design for Six Sigma (DFSS): DMADV, DMADOV, Design for Six Sigma (DFSS): DFX, Team Management, Six Sigma: Case study, Six Sigma: Summary of key concepts

Lean Six Sigma Implementation: Lean Six Sigma Team, Case Study: Lean Six Sigma implementation using Software.

REFERENCES-

TEXT BOOKS/ REFERENCE BOOKS-

1. Roderick A. Munro and Govindarajan Ramu and Daniel J. Zrymiak, The certified six sigma Green Belt Handbook, ASQ Quality Press and Infotech Standards India Pvt. Ltd.
2. Erick C. Jones. Quality Management for Organizations Using Lean Six Sigma Techniques, Taylor & Francis
3. Richard Schonberger. Best Practices in Lean Six Sigma Process Improvement, John Wiley & Sons, Inc.
4. William M. Feld. Lean Manufacturing: Tools, Techniques, and How to Use Them, the CRC Press, APICS the Educational Society for Resources Management.

Online/E resources

1. https://nptel.ac.in/courses/110105039

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET962	**Material Selection in Mechanical Design**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Material Science

COURSE OUTCOMES:

On successful completion of the course, the students will be able to:

CO1	Understand the evolution of engineering materials and design processes.
CO2	Clarify the basic steps of material selection in the design process.
CO3	Identify different constraints and objectives in the material selection process.
CO4	Design different hybrid materials and analyze their impact on the environment.
CO5	Criticize and compare alternative materials solutions for designs.

COURSE CONTENTS

INTRODUCTION: Materials in design, evolution of engineering materials, design process, types of design, design tools and materials data, function, material, shape, and process, evolution and design process case studies.

MATERIALS SELECTION: The selection strategy, attribute limits and material indices, selection procedure, structural index, case studies.

PROCESSES & PROCESS SELECTION: Classifying processes, systematic process selection, ranking process cost, process selection case studies.

MULTIPLE CONSTRAINTS AND OBJECTIVES: Selection with multiple constraints, conflicting objectives, penalty-functions, and exchange constants, case studies.

SELECTION OF MATERIAL AND SHAPE: Shape factors, microscopic or micro-structural shape factors, limits to shape efficiency, exploring and comparing structural sections, material indices that include shape, case studies.

DESIGNING HYBRID MATERIALS: Introduction, possibilities of hybridization, different types of hybrid materials and their structures, hybrid case studies.

MATERIALS AND THE ENVIRONMENT: The material life cycle, material and energy-consuming systems, eco-attributes of materials, eco-selection, case studies.

MATERIALS AND INDUSTRIAL DESIGN: Requirements pyramid, product character, using materials and processes to create product personality.

TEXT BOOKS/ REFERENCE BOOKS:

1. Materials Selection in Mechanical Design by Michael F. Ashby
2. Materials and Design: The Art and Science of Material Selection in Product Design by Kara Johnson and Michael F. Ashby
3. Materials and the Environment: Eco-informed Material Choice by Michael F. Ashby
4. Materials: engineering, science, processing and design by David Cebon, Hugh Shercliff, and Michael F. Ashby

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET963	**Mechanics of Composite Materials**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Basic knowledge of Solid Mechanics and Engineering Mathematics

COURSE OUTCOMES

CO1	Understanding of mechanical behaviour of lamina/layered composites compared to isotropic materials.
CO2	Explain and apply constitutive equations of composite materials for the mechanical behaviour at micro, macro and meso levels.
CO3	Apply failure criteria and critically evaluate the results (stresses and strains)
CO4	Design of basic structural elements made of composite under various loading Conditions

COURSE CONTENTS

Introduction: Introduction to Composite Materials Constituents, Material forms Processing, Applications Definition –Need – General Characteristics, Applications. Fibers – Glass, Carbon, Ceramic and Aramid fibers. Matrices – Polymer, Graphite, Ceramic and Metal Matrices – Characteristics of fibers and matrices.

Micromechanics and Macromechanics of a Lamina: Lamina Constitutive Equations:Lamina Assumptions – Macroscopic Viewpoint. Generalized Hooke's Law. Reduction to Homogeneous Orthotropic Lamina – Isotropic limit case, Orthotropic Stiffness matrix (Qij), Typical Commercial material properties, Rule of Mixtures. Generally Orthotropic Lamina –Transformation Matrix, Transformed Stiffness.

Macromechanics of a Laminate: Definition of stress and Moment Resultants. Strain Displacement relations. Basic Assumptions of Laminated anisotropic plates. Laminate Constitutive Equations – Coupling Interactions, Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates. Laminate Structural Moduli. Evaluation of Lamina Properties from Laminate Tests. Quasi-Isotropic Laminates. Determination of Lamina stresses within Laminates.

Failure Analysis and Design of a Laminate: Introduction - Maximum Stress and Strain Criteria. Von-Misses Yield criterion for Isotropic Materials. Generalized Hill's Criterion for Anisotropic materials. Tsai-Hill's Failure Criterion for Composites. Tensor Polynomial (Tsai-Wu) Failure criterion. Prediction of laminate Failure

Equilibrium Equations of Motion: Energy Formulations. Static Bending Analysis. Buckling Analysis. Free Vibrations – Natural Frequencies

Modification of Hooke's Law due to thermal properties: Modification of Laminate Constitutive Equations. Orthotropic Lamina - special Laminate Configurations – Unidirectional, Off-axis, Symmetric Balanced Laminates - Zero C.T.E laminates, Thermally Quasi-Isotropic Laminates

TEXT BOOKS/ REFERENCE BOOKS:

1. Engineering Mechanics of Composite Materials, I. M. Daniel, O. Ishai, Oxford University Press, 2006.
2. Mechanics of Composite Materials, Jones, R.M., McGraw-Hill, Kogakusha Ltd., 1998.
3. Analysis and Performance of Fibre Composites, Agarwal, B.D., and Broutman, L.J., John Wiley and sons. Inc., 2017.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET965	**Occupational Health and Safety**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Industrial Engineering

COURSE OUTCOMES: After completing the above course, student is expected to:

CO1	To identify the different fields of occupational safety and risk management.
CO2	To describe the organization and hygiene of working environment.
CO3	To identify and assess various exposures at work place.
CO4	To describe the organization of regulatory agencies that deal with issues of occupational safety and health, environmental health, and risk management.

COURSE CONTENTS:

Introduction: Workplace risk factors, Environmental law, Environmental Issues, Health and Safety Law, Health and Safety and Industrial relation law, Principles of Safety Management.

Occupational Health & Industrial Hygiene: Industrial Hygiene Overview, The organization of working environment, temperature, lighting and ventilation, welfare amenity provision, cleaning and hygiene.

Assessment of Exposure: Measurement of noise and vibration exposure. Heat stress monitoring, dust exposure and respiratory health. Work Posture, Musculoskeletal disorders, Strain Index, Lifting Equation, and Occupational Audiometry.

International bodies in Health and safety: Industrial Safety, Health & Environment (SHE) Acts, ILO, Occupational Health and Safety Assessment Series (OHSAS) & International Organization for Standardization (ISO).

References:

1. James Kohn and Mark A. Friend, "Fundamentals of Occupational Safety and Health", Bernan Press, 2018.
2. Melissa A. Bailey and Matthew C. Cooper, "Occupational Safety and Health Law Handbook", Bernan Press; Third edition, 2016.
3. Jeremy W. Stranks, “Handbook of Health and safety Practice” Pitman Publishing, 1994.
4. Dharmendra S Sengar, “Environmental law” Prentice Hall of India, New Delhi.
5. Malcolm J Crocker, “Noise and Noise Control” CRC Press.
6. Maryanne Maltby, “Occupational Audiometry” Butterworth-Heinemann Imprint of Elsevier

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET967	**Tool Engineering**	**2**	**2**	**0**	**0**	**0**

PREREQUISITE : None

COURSE OUTCOMES:

CO1	Select proper tool for given manufacturing operation. Interpret designation system of cutting tool.
CO2	Select and design jig and fixture for given simple component
CO3	Classify and explain various press tools and press tools operations.
CO4	To be able to apply limits, fits and tolerances on the given job and select grades, fits and tolerances from tolerance chart for the given sample
CO5	Design and drafting of press tools for considering real time issues of manufacturing, Testing and Assembly

COURSE CONTENTS

Cutting Tool Design

General considerations, study of angle for single point cutting and drill. Principles of different cutting tool materials and their important characteristics. Geometry of a drill. Basic principles of design of a single point and multiple point tools i.e broaches and twist drill**.**

Jigs and Fixtures

Introduction, Degree of freedom, 3-2-1 principles, Locating Devices: Locating methods and chip control, Clamping and Guiding element, Design of Jigs: Plate jigs, Box jigs, indexing jigs, Design of Fixture: Milling fixtures, and Indexing-milling fixtures, turning fixtures, Grinding fixtures, Universal jigs and fixtures, welding fixtures, Broaching fixtures and Assembly Fixtures**.**

Metrology

Introduction to Metrology, Terminology, System of Limits, Fits, Tolerance and Gauging, Allowances, Interchangeability, Limit gauges**.**

Press Tool Design

Introduction: Elements of press tools, classification of presses, high speed presses, press brakes, shearing theory, cutting force, clearance between punch and die. Design of Press Tool Elements: Design of Die plates, punches, punch holder plates, stripper plates, and calculation of stripping force, bolster plates, pilots, ejectors, shedders, pillar, bush, slender punches, Stock guides and feeding device and die sets

Bending Die: Theory of bending, development of bend, spring back, correcting spring back, bending tools, U -bending, V bending, bending on press brake, bending force, different methods of compensation for spring back in V-bending and U-bending.

Forming Dies: Sheet metal deformation during forming, forming tools, rubber forming, hydroforming, explosive forming, stretch forming, and spinning.

TEXT BOOKS/ REFERENCE BOOKS: -

1. Metrology and Measurement, Anand Bewoor & Vinay Kulkarni McGraw-Hill
2. P. H. Joshi" Jigs and Fixtures", 2nd Edition TMH
3. Geoffrey Boothroyd, "Fundamentals of Metal Machining & Machine Tools", TMH
4. Tool Engineering and design by G.R Nagpal, khanna publication

DETAILS OF THE COURSE:

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET968	**Welding Engineering and Technology**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Basic knowledge of welding processes and finite element method.

COURSE OUTCOMES: After completion of this course, the students will be able:

CO1	To explain the physics involved in advanced welding processes.
CO2	To understand the basic metallurgy of fusion welds.
CO3	To apply appropriate mathematical models for different welding processes.
CO4	To calculate magnitude of residual stresses and distortions in weldments.
CO5	To design heavy welded fabrications.
CO6	To select suitable weldability test for a specific application.

Course Content:

Introduction
Classification of welding processes; types of weld joints; welding symbols; physics of arc welding; power sources for arc welding; parameters of welding processes; metal transfer in welding; thermal cutting.

Modern Welding Processes
Variants of fusion welding processes; solid state welding processes; hybrid welding processes; power beam welding processes; microjoining and nanojoining processes; underwater welding; metal printing.

Welding Metallurgy
Solidification of welds; Chemical reaction in welds; Metallurgy of fusion welds; Residual stresses and distortions; heat treatment of welds; weldability of metals and non-metals; dissimilar welding.

Computational Welding Mechanics
Power densities; analysis of heat flow; 2D and 3D heat sources; thermo-mechanical modelling, fluid flow modelling.

Design of Weld Joints
Design for static loads; design for fatigue loads; design for pressure vessels and tubular joints.

Weld Testing and Quality Control
Weld defects; service weldability tests; destructive and non-destructive evaluation (NDE); pressure and leak testing.

Reference Book(s)/ Text Book(s)

1. Welding Handbook, American Welding Society, Vol. 2, Eighth Edition, 1991.
2. Robert Messler, Principles of Welding, John Wiley & Sons, 1999.
3. J.A. Goldak and M. Akhlaghi, Computational Welding Mechanics, Springer, 2005.
4. S. Kou, Welding Metallurgy, John Wiley & Sons, Second Edition, 2003.
5. S.V. Nadkarni, Modern Arc Welding Technology, Ador Welding Limited, 2010.
6. V. M. Radhakrishnan, Welding Technology and Design, New Age Publishers, 2002.
7. Y. Zhou, Microjoining and Nanojoining, Woodhead Publishing, 2008.

DETAILS OF THE COURSE:

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET969	**Advanced Engineering Materials**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Material Science and Engineering

COURSE OUTCOMES:

CO1	Select a suitable composite material for the development of a composite as per desired application.
CO2	Understand the various application areas of the advanced ceramics.
CO3	Select a suitable super alloy for the high temperature applications.
CO4	Understand the advanced polymers and their application areas.
CO5	Select a smart material for the development of smart system used for a specific application.

COURSE CONTENTS

Composite Materials Introduction to composites, Fiber reinforcements, Particulate materials, Nano-Reinforcements, Polymer matrix materials, Metallic matrix materials, Ceramic matrix materials, Carbon–Carbon composites, Nanocomposites.

Advanced Ceramics Introduction to ceramics, Powder preparation, Shaping of ceramics, Preparation of ceramics, Engineering applications of advanced ceramics: Transparent ceramics, coatings and films, Porous ceramics and ceramic membrane, Bio-medical applications of ceramic materials, Ceramics for energy and environment technologies, Exotic ceramics.

Super Alloys Introduction to super alloys, Nickel superalloys, Cobalt-based superalloys, Iron superalloys, Single-crystal superalloys for blade applications, Superalloys for turbine disc applications, Environmental degradation: the role of coatings

Polymers and Elastomers Introduction to Polymers, Thermoset polymers, Thermoplastics, elastomers, Polymerization, Renewable sources for polymers, Polyelectrolytes, Biopolymers, Structures in biopolymers, Liquid crystalline polymers, Copolymers, Biomimetic polymers, Biopolymer applications, Biodegradation of polymers, Applications of Polymers.

Smart Materials Introduction to Smart Materials, Piezoelectric Materials, Electrostrictive Materials, Magnetostrictive Materials, Active Smart Polymer, Shape Memory Alloys, Electrorheological and Magnetorheological Fluids, Application area of Smart Materials

REFERENCES-

1. “Fundamentals of Smart Material Systems”, Mohsen Shahinpoor, Royal Society of Chemistry (2020).
2. “Fundamental of Ceramics”, Michel W. Barsoum, McGraw Hill International edition (1997).
3. “Handbook of Advanced Ceramics”, by S. Somiya, Academic Press (2003).
4. “The Superalloys Fundamentals and Applications”, Roger C. Reed, University of Birmingham (2008).
5. “Composite Materials and Processing”, M. Balasubramanian, CRC Press (2014).
6. “Introduction to Polymers”, R. J. Young and P. A. Lovell, Springer-Science+Business Media, B.V. (1991).
7. “Superalloys Analysis and Control of Failure Process”, Nataliya V. Kazantseva, Natalia N. Stepanova, Mikhail B. Rigmant, CRC Press (2021).

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET970	**Computational Fluid Dynamics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Fluid Mechanics Transport Phenomena, Heat transfer

COURSE OUTCOMES:

CO1	develop numerical algorithms for solution of fluid dynamic equations, including the incorporation of proper boundary conditions
CO2	Understand the concepts of stability, convergence, consistency and accuracy of numerical schemes and better assess the results produced
CO3	Implement any numerical technique or overcome any implementation difficulty on computer
CO4	Use any commercial/open source CFD software as a tool to make prediction of fluid motion

COURSE CONTENTS

Introduction to CFD: Methods of prediction, potential and limitation of CFD; Review of numerical techniques: Solution of IVP and BVP, Euler method, Runge-Kutta method, accuracy and errors, solution of linear algebraic equations, convergence.

Mathematics of physical model: conservation laws, classification of PDE's, initial and boundary conditions, coordinate systems; Discretization methods: Method of weighted residuals, finite difference method (FDM), finite volume method (FVM), implicit and explicit schemes, consistency, stability and convergence.

Modelling of diffusion problems: Numerical solution of one dimensional steady state heat conduction, unsteady heat conduction, Crank-Nicolson scheme, ADI scheme, heat conduction in multidimensional cases.

Modelling of convection diffusion problems: One dimensional convection-diffusion using central difference scheme, upwind scheme, transportive property, numerical diffusion (artificial viscosity), higher order schemes.

Modelling fluid flow: Discretization of incompressible Navier Stokes equations, vorticity and pressure based methods, staggered and collocated grid.

TEXT BOOKS/ REFERENCE BOOKS-

1. W Malalasekera. An introduction to computational fluid dynamics: the finite volume method, Pearson Prentice Hall, 2007.
2. Suhas Patankar. Numerical heat transfer and fluid flow. CRC press, 1980.

DETAILS OF THE COURSE:

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET971	**Data Analytics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Fundamentals of statistics and mathematics

COURSE OUTCOMES:

CO1	Understand basic concepts and techniques of Data analytics
CO2	Develop skills of storing, extracting, analyzing and decision making from the data
CO3	Gain experience of doing data driven independent study and research
CO4	Develop an aptitude towards performing data analytics on a real-life problem

COURSE CONTENTS

Introduction to data analytics: Data science vs. data analytics, Data analytics in business, types of analytics (descriptive, diagnostic, predictive and prescriptive), data ecosystem, data lifecycle, data privacy and ethics, data integrity

Data exploration: Types of data, descriptive measures for numerical and categorical variables, outliers and missing values, filtering and sorting, finding relationships among variables, pivot tables

Statistical inference: One way-ANOVA, Generalized linear model, MANOVA, MANCOVA

Regression analysis and time series forecasting: Correlation, simple linear regression, multiple regression, validation of fit, multicollinearity, violation of regression assumptions, forecasting models, testing of randomness, regression-based trend models, auto regression models

Importing and storing data: Rearranging data, importing text data, importing relational database, introduction to SQL, introduction to data mining

TEXT/REFERENCE BOOKS

1. Data Analytics, Edward M., Create space Independent Pub, 2017.
2. Data Analysis and Decision Making, Albright, S.C., Winston, W.L. and Zappe, C.J Cengage, 2015.
3. Guide to Data Analytics Basics for Managers, Harvard Business Review, HBR, 2018.

DETAILS OF THE COURSE:

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET972	**Flexible Manufacturing System**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: None

COURSE OUTCOMES:

CO1	To be able to introduce the concepts of flexibilities and its importance in batch manufacturing.
CO2	To be able to introduce the concepts of various types of FMS configurations and their planning and control.
CO3	To be able to Identify various workstations, system support equipment.
CO4	To be able to gain an experience in the implementation of flexible systems for industrial automation

COURSE CONTENTS

Introduction: Definition and classification of manufacturing systems, fundamentals of automated production cycle, need of flexibility, concept of flexibility, various types of flexibility, measures of flexibility.

Flexible Manufacturing System (FMS) Type: Introduction of FMS, definition of FMS, types of FMS, applications of FMS, FMS configuration, FMS host operator interface.

FMS Planning and Control: Functional requirements of FMS equipment, functions of FMS host computer, host system design, planning, scheduling of FMS, FMS simulation, Databases in FMS, GT in FMS, cell design and layout design, CAPP in FMS.

Material handling in FMS: Material handling principles in FMS, applications of robots in FMS.

Case Studies: Cases on FMS installation and implementation –acceptance testing and maintenance.

TEXT BOOKS/ REFERENCE BOOKS-

1. “Automation, Production System and CIM”, Groover, M. P., 2nd Ed., Prentice Hall. 2000
2. “Design and Operations of FMS”, Rankey, P., North-Holland Publishing. 1983
3. “Flexible Manufacturing System”, Warnecke, H. J. (Ed.), Springer. 1985

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET973	**Fracture Mechanics**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Basic knowledge of Solid Mechanics, Material Science and Engineering Mathematics

COURSE OUTCOMES

CO1	Understand and explain the basic concepts, physical and mathematical principles of the fracture mechanics (FM).
CO2	Explain and apply the basic principles of Linear Elastic Fracture Mechanics (LEFM) and Nonlinear Elastic-Plastic Fracture Mechanics (NLEFM), respectively, to linear and nonlinear (elasto-plastic) materials.
CO3	Compute various fracture characterizing parameters, viz. stress intensity factor (SIF), strain energy release rate (ERR), J-integral, and crack-tip opening displacement (CTOD), stress and strain/deformation fields around a crack tip, and crack growth due to fatigue.
CO4	Apply the concepts of FM to engineering materials and design structural components considering the presence of flaws, nature of loading and constitutive behaviour of the material.

COURSE CONTENTS

Introduction: Kinds of failure and history Conventional failure criteria, Characteristic brittle failures, Griffith's work, Fracture mechanics, Dilemma of Griffith, Surface energy, Griffith's realization, Griffith's analysis, Mathematical formulation, Thin plate vs thick plate Critical energy release rate.

Stress intensity factor (SIF): Linear elastic fracture mechanics (LEFM), Stress and displacement fields in isotropic elastic materials, Elementary properties of complex variables SIF of more complex cases: Application of the principle of superposition, Crack in a plate of finite dimensions, Edge cracks, Embedded cracks, Relation between GI and KI

Anelastic deformation at the crack Tip: Further Investigation at the crack tip, Approximate shape and size of the plastic zone, Effective crack length, Effect of plate thickness. Elastic plastic analysis through

J-Integral: Relevance and scope, Definition of J-Integral, Path independence, Stress-strain relation.

Crack tip opening displacement (CTOD): Relationship between CTOD, KI and GI for small scale yielding, Equivalence between CTOD and J. Test methods KIC test techniques, Test methods to determine JIC, Test methods to determine GIC and GIIC, Determination of critical CTOD.

Fatigue failure: Terminology, S-N curve, Crack initiation, Crack propagation, Effect of an overload, Crack closure, Variable amplitude fatigue load. Mixed mode crack initiation and growth: Fracture surface, Mixed mode crack propagation criteria, Crack growth.

NDT: Visual, LPI, Magnetic Methods, Radiography, Ultrasonics

TEXT BOOKS/ REFERENCE BOOKS:

1. Elements of Fracture Mechanics, Prashant Kumar, Tata McGraw-Hill Publishing Company Ltd., 2017.
2. Fracture Mechanics, T .L. Anderson - Fundamentals and Applications, Taylor and Francis Group, 2005.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET974	**Machinery Fault Diagnosis**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE: Nil

COURSE OUTCOMES:

CO1	To understand the condition-based monitoring used in industries
CO2	To identify suitable methods for machine diagnoses.
CO3	To apply condition monitoring techniques.
CO4	To analyze the vibration signals in time and frequency domains.
CO5	To diagnose the faults in machines.

COURSE CONTENTS:

Introduction to condition-based monitoring: Fault diagnosis and prognosis, machine learning in fault diagnosis. Condition monitoring techniques: vibration and noise monitoring, wear debris and oil analysis, thermography, acoustic emission, ultrasonics, Eddy current.

Vibration Analysis: Basics of vibration, free and forced response, vibration control, random vibration, statistical parameters i.e. RMS value, peak value, crest factor, kurtosis, and standard deviation of vibration signals.

Instrumentation: data recording, data acquisition, errors in measurements, transducers, accelerometers, sound level meter.

Signal processing: sample rate and aliasing, filtering, time domain signal analysis, frequency domain signal analysis, non-stationery signal analysis, Fourier series, Fast Fourier Transform, wavelet transform, Hilbert transform, modulation and sidebands, orbit and order analysis, cepstrum analysis.

Faults in rotating machines: unbalance, misalignment, crack, spalling, loosening, fault in electrical machines. Failure analysis of rotating machines, bearings, and gears, fans, blowers, pumps, IC Engines.

TEXT BOOKS/ REFERENCE BOOKS

1. Machinery Condition Monitoring: Principles and Practices, Mohanty A.R., CRC Press, 2014.
2. Vibration Condition Monitoring, Rao J. S., Narosa Publishing House, 2000.
3. Hand book of Condition Monitoring, Allan Davis, Chapman and Hall, 2000.
4. Instrumentation, Measurement and Analysis, Choudary K K., Tata McGraw Hill, 2012
5. Vibration Based Condition Monitoring, Randall R. B., Wiley, 2010
6. Fault Diagnosis Application, Isermann R., Springer-Verlag Berlin, 2011.

DETAILS OF THE COURSE:

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET975	**Microfluidics**	**3**	**3**	**1**	**0**	**0**

PREREQUISITE: Fluid Mechanics

COURSE OUTCOMES:

CO1	To develop understanding related to flows at micro scale.
CO2	To develop understanding of phenomena underlying working of Lab on chip devices.

COURSE CONTENTS

- Introduction to Microfluidics, Equations of Conservation, Navier Stokes Equation, Energy Equation, Pressure –driven Microflows, Stokes Drag on a Sphere, Lubircation Theory, Boundary Condition in Fluid Mechanics :Slip or Noslip
- Interfacial phenomeana: curvature pressure, minimal surfaces, static drops and bubbles, static menisci, floating bodies: extending Archimedes Principle to small bodies, Surface Tension Driven Flows, Modulating Surface Tension, Thin Film Dynamics
- Introduction to Microfabrication, Electrokinetics, Biomicrofluidics

REFERENCES-

TEXT BOOKS/ REFERENCE BOOKS-

1. Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves by P.G. de Gennes, F. Brochard-Wyart and D. Qu´er´e. Springer Publishing.

Online/E resources

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET976	**Reliability and Maintainability Engineering**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : Fundamentals of statistics and mathematics

COURSE OUTCOMES:

CO1	Use statistical tools to characterize the reliability of an item and determine the reliability of a system, and will also understand the application of maintenance strategies in a manufacturing environment
CO2	Establish maintenance strategies according to system characteristics and design transition programs to implement these strategies
CO3	Develop ability in formulating suitable maintenance strategies to enhance system reliability of a manufacturing system
CO4	Develop an aptitude towards understating the system condition and taking relevant decisions to ensure maintainability

COURSE CONTENTS

Introduction to reliability: Failures of engineering systems, causes of failures, bathtub curve, component reliability from test data, logic diagrams, reliability improvement techniques

Statistical methods in Reliability: Probability theory, random variables, discrete variables, continuous variables, joint probability distributions, discrete failure time distributions

Reliability testing: Objectives of life testing, types of tests, Accelerated life test, stress combinations, step-stress methods

Data analysis and reliability estimation: Point estimation, goodness of fit tests, moment estimation, maximum likelihood estimator

Economics of Reliability: Economic issues, Manufacturer's cost, customer's cost, reliability achievement cost, reliability utility cost models, depreciation cost models, availability cost mode

Basics of Maintainability: System, maintenance, downtime and maintainability

Measurement: Maintainability Measures and Prediction Measures of maintainability, maintenance tasks

Maintainability design and testing: Maintainability design process and features, maintainability tools

TEXT BOOKS/ REFERENCE BOOKS-

1. Reliability and Maintainability Engineering, Charles E. Ebeling, Tata McGraw Hill, 2000.
2. Reliability Engineering, Balagurusamy, E., Tata McGraw-Hill Publishing Company Limited, 2002.
3. Statistical Methods for Quality, Muralidharan, K. and Syamsundar, A., Reliability and Maintenance, 2010

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET977	**Smart Manufacturing**	**3**	**3**	**0**	**0**	**0**

PREREQUISITE : None

COURSE OUTCOMES:

CO1	Apply the knowledge to the solution of complex engineering problems.
CO2	Design solutions for complex engineering problems and design system components or processes that meet the specified needs.
CO3	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling.
CO4	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
CO5	The student can identify different areas of IOT and Smart Manufacturing.
CO6	Can find the applications of all the areas in day-to-day life.

COURSE CONTENTS

Introduction: To Smart Manufacturing**:** What is "smart manufacturing" really and how does it differ from conventional/legacy manufacturing, Computer Integrated Manufacturing Systems Structure and functional areas of CIM system, - CAD, CAPP, CAM, CAQC, ASRS. Advantages & Disadvantages of CIM.

The Internet of Things: An overview; Design Principles for Connected Devices; Internet Principles.

Prototyping Embedded devices: Electronics, Embedded Computing Basics, Arduino/ Raspberry Pi/ BeagleBone Black/ etc., Electric Imp and other notable platforms Prototyping of Physical Design.

Automatic Storage Management in a Cloud World: Introduction to Cloud, Relational Databases in the Cloud, Automatic Storage Management in the Cloud. Smart Connected System Design Case Study

Smart Design/Fabrication: Smart Design/Fabrication - Digital Tools, Product Representation and Exchange Technologies and Standards, Agile (Additive) Manufacturing Systems and Standards. Mass Customization, Smart Machine Tools, Robotics and Automation (perception, manipulation, mobility, autonomy), Smart Perception – Sensor networks and Devices.

REFERENCES-

1. McEwen and H. Cassimally, Designing the Internet of Things, 1st edition, Wiley, 2013, ISBN-10: 111843062X.
2. N. Vengurlekar and P. Bagal, Database Cloud Storage: The Essential Guide to Oracle Automatic Storage Management, 1st edition, McGraw-Hill Education, 2013, ISBN-10: 0071790152.
3. M. Kuniavsky, Smart Things: Ubiquitous Computing User Experience Design, 1st edition, Morgan Kaufmann, 2010, ISBN-10: 0123748992.

ONLINE/E RESOURCES

https://nptel.ac.in/courses/106105195

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
22MET978	**Sustainable Manufacturing and Life Cycle Engineering**	**3**	**2**	**1**	**0**	**0**

PREREQUISITE: None

COURSE OUTCOMES:

CO1	To be acquainted with sustainability in manufacturing and its evaluation.
CO2	To apply the tools and techniques for the environment and social sustainability.
CO3	To provide the student with the knowledge of sustainability standards.
CO4	To familiarize with trends in Life cycle assessment tools and techniques
CO5	To create awareness of current sustainable measures and practices in the manufacturing industry.

COURSE CONTENTS

Introduction to sustainable manufacturing- Concepts of sustainability and sustainable development – Need for sustainable development-Components of sustainability- Social, Economic, Environmental dimensions-Linkages between technology and sustainability - Sustainable Manufacturing, Sustainability Index

Tools for sustainable manufacturing- Tools and Techniques of Sustainable Manufacturing – Environmental Conscious, Life cycle assessment, Design for Environment, R3 and R6 cycles, Design for Disassembly -Sustainable Product Development – Various Phases. Frameworks for measuring sustainability

Environmental sustainability- EIA Methods –CML, EI 95 and 99, ISO 14001 EMS and PAS 2050 standards, Environmental Impact parameters - Interactions between energy and technology and their implications for the environment and sustainable development phases.

Life cycle assessment- Introduction, Life Cycle Assessment concepts. LCA Methodology- Goal Definition, Life Cycle Inventory, Life Cycle Impact Assessment, Life Cycle Interpretation Procedural framework of Life-cycle inventory: Environmental Data Collection, Statistical Analysis of Environmental Data, Common Analytical Instruments,

Sustainability indicators- Indicators of sustainability – Environmental, Economic, Societal and Business indicators - Concept Models and Various Approaches, Product Sustainability and Risk/Benefit assessment– Corporate Social Responsibility. Green Supply Chain: Carbon footprints in transportation Green Supply chain: techniques and implementation Green Supply chain, Logistics management

REFERENCES-

1. G. Atkinson, S. Dietz, E. Neumayer, — "Handbook of Sustainable Manufacturing". Edward Elgar Publishing Limited, 2007.
2. D. Rodick, "Industrial Development for the 21st Century: Sustainable Development Perspectives", UN New York, 2007.
3. Rogers, P.P., Jalal, K.F. and Boyd, J.A., "An Introduction to Sustainable Development", Earthscan, London, 2007.
4. P. Lawn, "Sustainable Development Indicators in Ecological Economics", Edward Elgar Publishing Limited.
5. S. Asefa, "The Economics of Sustainable Development", W.E. Upjohn Institute for Employment Research, 2005.

TEXT BOOKS/ REFERENCE BOOKS-

1. Davim J.P., "Sustainable Manufacturing", John Wiley & Sons., United States, 2010, ISBN: 978-1-848-21212-1.
2. Ibrahim Garbie, "Sustainability in Manufacturing Enterprises Concepts, Analyses and Assessments for Industry 4.0", Springer International Publishing., United States, 2016, ISBN-13: 978-3319293042.
3. Jovane F., Ęmper, W.E. and Williams, D.J., "The ManuFuture Road: Towards Competitive and Sustainable High-Adding-Value Manufacturing", Springer,2009, United States, ISBN 978-3-540-77011-4.
4. Kutz M., "Environmentally Conscious Mechanical Design", John Wiley & Sons., United States, 2007, ISBN: 978-0-471-72636-4.
5. Seliger G., "Sustainable Manufacturing: Shaping Global Value Creation", Springer, United States, 2012, ISBN 978-3-642-27289-9.
6. Ciambrone, DF Environmental Life Cycle Analysis, CRC Press, 1997 2. Handbook on Life Cycle Assessment: Operational Guide to the ISO standards, Kluwer Academic Publishers, 2004

ONLINE/E RESOURCES

1. Sustainability through Green Manufacturing Systems: An Applied Approach, IIT Kanpur-NPTEL
2. Sustainable Engineering Concepts and life cycle analysis, IIT Kharagpur -NPTEL