SYLLABI
and
SCHEME OF TEACHING

MASTER OF ENGINEERING
IN
MECHANICAL ENGINEERING
(ROBOTICS)

MECHANICAL ENGINEERING DEPARTMENT
NATIONAL INSTITUTE OF TECHNICAL TEACHERS TRAINING & RESEARCH
CHANDIGARH
(BATCH 2020-2022)
### SUBJECT SCHEDULE FOR TEACHING

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>SCHEDULE FOR TEACHING</th>
<th>CREDITS</th>
<th>MARKS</th>
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* Internal assessment is based on the following criterion:

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<th>Grade</th>
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<tr>
<td>A+</td>
<td>Publication from Thesis in SCI indexed journal</td>
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<td>A</td>
<td>Publication from Thesis in Scopus indexed journal</td>
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<tr>
<td>B+</td>
<td>Publication from Thesis in UGC journal OR Scopus indexed conference proceedings</td>
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<td>B</td>
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**Final Grade will be average of the grades of internal assessment and university viva-voce examination**

**NOTE:** Requirement for the award of ME Mechanical Engineering (Robotics) degree is 75 credits with minimum CGPA of 6.0

### LIST OF ELECTIVES
**M.E.MECHANICAL ENGINEERING (ROBOTICS)**

<table>
<thead>
<tr>
<th>CODE</th>
<th>SUBJECT</th>
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<tr>
<td></td>
<td><strong>PROGRAM ELECTIVE– I</strong></td>
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<td>Computer Aided Design</td>
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<td>Mechatronics Systems &amp; Design</td>
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<td>Digital Signal Processing</td>
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<td>Rapid Manufacturing</td>
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<td>Manufacturing Systems Technology</td>
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<td>Mathematical Modeling Of Manufacturing Processes</td>
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<td>Industrial Safety Engineering</td>
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<td>System Design for Sustainability</td>
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<td>Deep Learning – Part 1</td>
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<td>Block-chain Architecture Design and Use Cases</td>
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<td>The Joy of Computing using Python</td>
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<td>Digital Image Processing</td>
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<td>Pattern Recognition and Application</td>
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<td>E-Business</td>
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<tr>
<td>noc19-hs67</td>
<td>Patent Law For Engineers And Scientists</td>
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<td>Soft skills</td>
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MER-601: INDUSTRIAL ROBOTICS

Maximum marks: 50
Time Allowed: 3 hours

PRE REQUISITES

• Basic Engineering Mathematics

OBJECTIVE

The objective of this course is to impart knowledge about industrial robots for their control and design.

LEARNING OUTCOMES

After the completion of this course, the students will be able to

• Perform kinematic and dynamic analyses with simulation
• Design control laws for a robot
• Integrate mechanical and electrical hardware for a real prototype of robotic device.
• Select a robotic system for given application.

DETAILED CONTENTS

1. Introduction to Robotics
   1.1. Robot Subsystems
   1.2. Classification of Robots
   1.3. Grippers
   1.4. Sensors
   1.5. Industrial Applications

2. Transformations
   2.1. Robot Architecture
   2.2. Pose of a Rigid body
   2.3. Coordinate Transformation
   2.4. Denavit and Hartenberg (DH) Parameters

3. Kinematics
   3.1. Forward Position Analysis
   3.2. Inverse Position Analysis
   3.3. Velocity Analysis: The Jacobian Matrix
   3.4. Link Velocities
   3.5. Jacobian Computations
   3.6. Forward and Inverse Velocity Analysis
   3.7. Acceleration Analysis

4. Statics and Manipulator Design
   4.1. Forces and Moments Balance
4.2. Equivalent Joint Torques
4.3. Role of Jacobian in Statics
4.4. Manipulator Design

5. Dynamics
5.1. Inertia Properties
5.2. Euler-Lagrange Formulation
5.3. Newton-Euler Formulation
5.4. Recursive Newton-Euler Algorithm
5.5. Dynamic Algorithms

6. Robot Trajectory Planning and Control
6.1. Multivariable Robot Control
6.2. Stability of Multi-DOF Robot
6.3. Linearized Control
6.4. Proportional Derivative (PD) Position Control
6.5. Computed-torque (Inverse Dynamics) Control
6.6. Joint Space Planning
6.7. Cartesian Space Planning
6.8. Point-to-Point vs. Continuous Path Planning

BOOKS:
- Introduction to Robotics – Analysis, Control, Applications, Saeed B. Niku, Wiley India Pvt. Ltd.
- Introduction to Robotics – Mechanics and Control, John J. Craig, Pearson Education Inc.
- Robotics for Engineers - Yoram Korean- McGrew Hill Co.
MER-602: MECHANISM DESIGN AND ANALYSIS

Maximum marks: 50
Time Allowed: 3 hours

PRE REQUISITES
- Engineering mathematics
- Engineering mechanics

OBJECTIVE
The objective of this course is to develop competency in graphical and analytical method for solving problems in static and dynamic force analysis.

LEARNING OUTCOMES
After the completion of this course, the students will be able to
- Understand the fundamentals of the theory of kinematics and dynamics of machines.
- Understand techniques for studying motion of machines and their components.
- Use computer software packages in modern design of machines

DETAILED CONTENTS

1. Basics of Mechanisms and Machines
   1.1 Types of Motion, Links, Kinematic Pair, Types of Joints, Degree of Freedom
   1.2 Classification of Kinematic Pairs, Kinematic Chain, Linkage, Mechanism and Structure
   1.3 Planar, Spheric, and Spatial Mechanisms
   1.4 Inversions of Four-bar and Slider Crank Mechanism
   1.5 Grashof’s Law and Mechanical Advantage
   1.6 Mobility of Mechanisms, Transmission Angle
   1.7 Pantograph, Straight Line Mechanisms

2. Kinematic Synthesis of Mechanisms
   2.1 Velocity and Acceleration Diagrams for four bar and six bar mechanisms, Velocity by Instantaneous Centre Method, Klein Construction, Aronhold-Kennedy Theorem of Three Centers
   2.2 Radius of Curvature of a Point Trajectory Using Kinematic Coefficients
   2.3 Stages of Kinematic Synthesis and Errors, Chebyshev Spacing of Precision points

3. Vibrations
   3.1 Definition and Types of vibrations
3.2 Natural frequencies of simple systems
3.3 Types of damping - Analysis with viscous damping - Derivations for over, critical and under damped systems, Logarithmic decrement and Problems.
3.4 Principle modes of vibrations, Normal mode and natural frequencies of systems
3.5 Dynamic testing of machines and structures

4. Friction and Friction Drives
4.1 Types & Laws of friction, Coefficient of Friction, Uniform Pressure and Uniform Wear
4.2 Law of Belting, Ratio of Friction Tensions in Belts, Power Transmitted by Belts and Ropes, Maximum Power Transmission by Belt
4.3 Classification of Gears, Gear Terminology
4.4 Law of Gearing, Velocity of sliding, Gear Teeth Profile, Path of Contact, Arc of Contact, Contact Ratio
4.5 Interference of in Involute Gears, Minimum Number of Teeth, Undercutting, Gear Forces, Different Types of Gear Trains, Analysis of Epicyclic Gear Train

5. Structural Analysis
5.1 Free body diagram and its importance
5.2 Classification of structures and components
5.3 Notion of stress – normal stress, shear stress and bearing stresses
5.4 Stresses on inclined plane in an axial member
5.5 Strain – normal strain, shear strain
5.6 Mechanical properties – elasticity, plasticity, creep, fatigue, buckling etc.
5.7 Deformation of axial members

6 Finite Element Analysis
6.2 Introduction to FEA
6.3 Steps of Finite Element Modeling & Analysis
6.4 Structural Analysis of mechanism
6.5 Modal Analysis of mechanism
6.6 Optimization using FEA Technique

Text books:


References:

PRE REQUISITES
- Basic electronics

OBJECTIVE
The objective of this course is to understand the basic concepts of sensor and instruments and to select appropriate instruments for various applications.

LEARNING OUTCOMES
After the completion of this course, the students will be able to
- Compare the different types of sensors and transducers.
- Classify the need of sensors for various processes
- Rectify errors in sensors.

DETAILED CONTENTS

1. INTRODUCTION
   1.1 Role of Sensors in Robotic system
   1.2 Internal and External Sensors
   1.3 Gripper for Mechanization and Automation
   1.4 Sensors specifications
   1.5 Selection of Sensors and Grippers

2. Proximity, Displacement, Velocity and Acceleration Sensors
   2.1 Proximity Sensors of various types
   2.2 Encoder
   2.3 Potentiometer
   2.4 LVDT
   2.5 Synchros and Resolvers
   2.6 Tachometer
   2.7 Hall-Effect Sensor
   2.8 Accelerometer

3. Force and Touch Sensors
   3.1 Strain Gauge
3.2 Piezoelectric Sensor
3.3 Current Based Sensing
3.4 Pressure transducers
3.5 Piezo resistive sensors
3.6 Surface acoustic wave

5. Range Sensors
   5.1 Ultrasonic sensors
   5.2 Microwave sensors
   5.3 Laser sensors
   5.4 Infrared range sensor

6. Vision System Sensors:
   6.1 Elements in Vision Sensor
   6.2 Camera Vision Sensing
   6.3 Image processing in vision system

7. End Effectors
   7.1 End Effectors and Types-Mechanical, Pneumatic and Hydraulic, Magnetic, Vacuum
   7.2 Two Fingered and Three Fingered Mechanical gripper
   7.3 Selection and Design Considerations.
   7.4 End Effector design case studies

Recommended Books:
MER-604: COMPUTER PROGRAMMING FOR ROBOT APPLICATIONS

Maximum marks: 50
Time Allowed: 3 hours

PRE REQUISITES

- Basic Engineering Mathematics

OBJECTIVE

The objective of this course is to provide a practical understanding and applications of various programming tools for industrial automation.

LEARNING OUTCOMES

After the completion of this course, the students will be able to

- Learn basics of MATLAB programming
- Understand the main features of the MATLAB program development environment to enable their usage in the higher learning.
- Interpret and visualize simple mathematical functions and operations thereon using plots/display.

DETAILED CONTENTS

1. Computer Programming
   1.1 Introduction to Computer Programming
   1.2 Algorithm and Pseudo-code
   1.3 Compilers and Interpreters
   1.4 Overview of High Level Programming Languages

2. Introduction to MATLAB
   2.1 MATLAB Environment
   2.2 Scalar and Vector Data types
   2.3 Matrix manipulation
   2.4 Saving and Retrieving Data using MAT-Files
   2.5 Cell Arrays and Structures
   2.6 Character Strings
   2.7 Relational and Logical Operations
   2.8 Plotting 2D and 3D graphs
   2.9 Applications – Solving linear systems of equations, Curve fitting and Interpolation

3. Programming using MATLAB
3.1 Introduction – M-Files, User Input/output, Script-Files and Function-Files
3.2 Control Flow – For Loops, While Loops, If-Else-End Constructs, Switch-Case Constructs, Try-Catch Blocks
3.3 Functions – Function Construction Rules, Input and Output Arguments, Scope of Variables, Function Handles, Anonymous Functions, Nested Functions, Private Functions, Overloaded Functions
3.4 Exchanging Data with MAT-Files
3.5 Low level File I/O

4. **Modeling and Simulation using MATLAB/Simulink**
   4.1 Introduction to Graphical Programming
   4.2 Simulink Basics
   4.3 Creating Models using Blocks and Signals
   4.4 Running Simulations and Analyzing Results
   4.5 Modeling and Simulating Dynamic Systems

5. **Robotics System Toolbox**
   5.1 Features of Robotic System Toolbox
   5.2 Building Robot Models
   5.3 Coordinate System Transformations
   5.4 Inverse Kinematics and Dynamics
   5.5 Trajectory Tracking
   5.6 Using Robot Operating System (ROS)

**BOOKS:**
PRE REQUISITES

- NIL

OBJECTIVE

The objective of this course is to provide an introduction into engineering design and communication through the use of computer aided design (CAD) software.

LEARNING OUTCOMES

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

- Integrate the role of graphic communication in the engineering design process.
- Generate and interpret engineering technical drawings of parts and assemblies according to engineering design standards.
- Use CAD software to generate a computer model and technical drawing for a simple, well-defined part or assembly.

DETAILED CONTENTS

1. Computer Aided Design
   1.1 Design processes and computer aided design
   1.2 Hardware and software in CAD
   1.3 Parametric and variational design
   1.4

2. CAD Features
   2.1 Components of CAD software and their function
   2.2 Introduction and essential features of graphics package
   2.3 Configuration of graphics package
   2.4 Geometric transformations-2D and 3D

3. Geometric Modelling
   3.1 Curves-mathematical representation of analytical and synthetic curves
   3.2 Curve manipulation
   3.3 Surfaces and their representation
   3.4 Solids-representation techniques and manipulation of solids

4. CAD Database
   4.1 Need and features of CAD data base
   4.2 Data structures
   4.3 Data exchange and data exchange formats
5. Features of some Software Packages
5.1 Pro-Engineer
5.2 CATIA or INVENTOR
5.3 Geometrical modeling of simple components

6. CAD in Robotics
6.1 Geometrical Modeling of Manipulator Links
6.2 Assembly of Links and Joints
6.3 Kinematic Analysis

BOOKS:
PRE REQUISITES

- Basic Electronics and Mathematics

OBJECTIVE

The objective of this course is to provide the student with basic skills useful in identifying the concepts of automated machines and equipment and describe the terms and phrases associated with mechatronics.

LEARNING OUTCOMES

After the completion of this course, the students will be able to

- Select & identify suitable mechatronics hardware for the given application.
- Describe & explain potential areas of mechatronics
- Differentiate various control aspects of automation
- Demonstrate the self-learning capability of Industrial Automation.

DETAILED CONTENTS

1. Introduction
   1.1. Mechatronics & its Elements
   1.2. Mechatronics Design Process
   1.3. Integrated Design Issues in Mechatronics
   1.4. Applications of Mechatronics

2. Modeling & Simulation of Physical Systems
   2.1. Mathematical modeling of physical systems
   2.2. Dynamic response of first and second order systems
   2.3. System transfer functions
   2.4. Block Diagram Approach
   2.5. State Space Approach

3. Actuators
   3.1. Fluid power control elements and standard graphical symbols
   3.2. Directional, Pressure and Flow Control Valves – Construction and Working
   3.3. Basic fluid power circuits
   3.4. Mechanical & Solid state switches
   3.5. AC and DC motors
   3.6. Stepper motors
4. **Control Theory**
   4.1. Introduction to Open Loop & Closed Loop Control
   4.2. Transient & Steady state performance characteristics
   4.3. Frequency response
   4.4. PID Controllers & their Tuning
   4.5. Adaptive Control

5. **Data Acquisition**
   5.1. Sensors
   5.2. Operational amplifier
   5.3. Protection and filtering
   5.4. Digital signals
   5.5. Data acquisition systems

6. **Mechatronics System Design**
   6.1. Traditional & Mechatronics Design
   6.2. Possible Mechatronics Design Solutions
   6.3. Digital logic
   6.4. Programmable logic controllers
   6.5. Microcontrollers
   6.6. Simple Logic Circuits using PLC and microcontroller

**BOOKS:**
Maximum marks: 50
Time Allowed: 3 hours
MEI-6103: DIGITAL SIGNAL PROCESSING
(Common with M.E. Electrical Engineering – Instrumentation & Control)

Maximum marks: 50  L  P
Time Allowed: 3 hours  4  --

PRE REQUISITES
- Signal and system
- Engineering mathematics

OBJECTIVE
The objective of this course is to provide a thorough understanding and working knowledge of design, implementation and analysis DSP systems.

LEARNING OUTCOMES
After the completion of this course, the students will be able to
- Interpret, represent and process discrete/digital signals and systems
- Thorough understanding of frequency domain analysis of discrete time signals.
- Ability to design & analyze DSP systems like FIR and IIR Filter etc.
- Practical implementation issues such as computational complexity, hardware resource limitations as well as cost of DSP systems or DSP Processors.
- Understanding of spectral analysis of the signals

DETAILED CONTENTS

1. Transformations:
   1.1 Review of Z-Transform
   1.2 Solution of Linear Difference Equations
   1.3 Fourier series and Fourier Transform, Discrete Fourier Transform, Radix-2 FFT
   1.4 Introduction to Radix-4 and Split Radix FFT
   1.5 Discrete Cosine Transform, DCT as Orthogonal Transform, Walsh Transform, Hadamard Transform, Wavelet Transform.

2. Digital Filters
   2.2 Realization Structures, Finite Word Length Effects.
   2.3 IIR Filter Design: Specifications, Coefficient Calculation methods- Pole-Zero Placement method, Impulse Invariant method,
2.4 Matched Z- Transform method, Bilinear Z- Transformation method, Use of BZT and Classical Analog Filters to design IIR Filters
2.5 Realization Structures, Finite Word Length Effects.
2.6 Qualitative and quantitative methods

3. **Multirate Digital Signal Processing:**
   3.1 Sampling Rate Alteration Devices, Multirate Structures for sampling rate conversion
   3.2 Multistage design of Decimator and Interpolator, The Polyphase Decomposition
   3.3 Arbitrary Rate Sampling Rate Converter, Filter Banks, QMF banks
   3.4 Multilevel Filter Banks, Sub-band Coding, Discrete Wavelet Transform.

4. **Linear Prediction and Optimum Linear Filters:**
   4.1 Forward and Backward Linear Prediction
   4.2 Properties of Linear Prediction-Error Filters
   4.3 AR Lattice and ARMA Lattice-Ladder Filters
   4.4 Wiener Filters for Filtering and Prediction.

5. **Adaptive Digital Filters:**
   5.1 Concepts of Adaptive Filtering
   5.2 LMS Adaptive Algorithm, Recursive Least Squares Algorithm, Applications.

6. **Power Spectrum Estimation:**
   7.8 Nonparametric methods for Power Spectrum Estimation
   7.9 Bartlett method, Welch method, Blackman and Tukey method
   7.10 Parametric methods for Power Spectrum Estimation, Yule- Walker method, Burg method
   7.11 Unconstrained Least-Squares method, Sequential Estimation methods
   7.12 Selection of AR Model Order, MA model for Power Spectrum Estimation,
   7.13 ARMA model for Power Spectrum Estimation.

7. **Monitoring DSP Chips:**
   7.1. Introduction to fixed point and floating point processors
   7.2. ADSP21xx and TMS320Cxx- Architecture, Memory, Addressing Modes, Interrupts, Applications.
   7.3. Comparison of ADSP21xx and TMS320Cxx series.

**BOOKS:**

2 “Digital Signal Processing: Principles, Algorithms and Applications”, by Proakis & Manolakis, 4e, - Pearson Education
4 “Discrete Time Signal Processing”, Oppenheim & Schafer. PHI
7 “Modern Filter Theory”, by Johnson & Johnson
8 “Theory and application of Digital Signal Processing”, by Rabiner& Gold
9 “Digital Signal Processing”, Schuam’s Series.
MER-704: ROBOT MOTION PLANNING

Maximum marks: 50

Time Allowed: 3 hours

PRE REQUISITES

- Engineering Mathematics and Basics of Robotics

OBJECTIVE

The objective of this course is to provide the student with some knowledge and analysis skills associated with trajectory planning and robot control.

LEARNING OUTCOMES

After the completion of this course, the students will be able to

- demonstrate knowledge of the relationship between mechanical structures of industrial robots and their operational workspace characteristics
- demonstrate an ability to generate joint trajectory for motion planning
- demonstrate knowledge of robot controllers

DETAILED CONTENTS

1. **Configuration Space**
   1.1 Specifying a Robot's Configuration
   1.2 Obstacles and the Configuration Space
   1.3 The Dimension of the Configuration Space
   1.4 The Topology of the Configuration Space
   1.5 Parameterizations of $SO(3)$
   1.6 Example Configuration Spaces
   1.7 Transforming Configuration and Velocity Representations

2. **Motion Planning**
   2.1 Joint Space Planning
   2.2 Cartesian Space Planning
   2.3 Position and Orientation Trajectories
   2.4 Point-to-Point Planning
   2.5 Continuous Path Generation
3. **Trajectory Planning**
   
   4.1 Preliminaries
   
   4.2 Decoupled Trajectory Planning
   
   4.3 Direct Trajectory Planning

4. **Robot Motion Control**

   5.1 Control Systems
   
   5.2 Controllability
   
   5.3 Simple Mechanical Control Systems
   
   5.4 Motion Planning

**BOOKS:**

MMT-608: DIGITAL MANUFACTURING

Maximum marks: 50
Time Allowed: 3 hours

PRE REQUISITES
- Basics of manufacturing

OBJECTIVE
The objective of this course is to understand the transformation taking place, throughout the world, in design and manufacturing of products through digital manufacturing—a shift from paper-based processes to digital processes in the manufacturing industry.

LEARNING OUTCOMES
After the completion of this course, the students will be able to
- Understand product design and development process, along with the manufacturing aspects.
- Use parametric 3D CAD software tools in the correct manner for making geometric part models, assemblies and automated drawings of mechanical components and assemblies.
- Apply geometric transformations on the created wireframe, surface and solid models

DETAILED CONTENTS

1. Introduction
   1.1. Types of manufacturing systems and their characteristics
   1.2. Computer aided Manufacturing (NC, CNC, DNC and adaptive control systems)
   1.3. Computer Network architectures and protocols
   1.4. Computer Integrated Manufacturing Systems
   1.5. What makes a manufacturing process “digital”

2. CNC Machines
   2.1. Constructional details
   2.2. Design features
   2.3. Safety devices
   2.4. Part programming

3. Group Technology and Cellular Manufacturing
   3.1. Parts classification and part coding – approaches and systems
   3.2. Benefits of group technology
   3.3. Cellular manufacturing-basics, layout considerations
   3.4. Cell formation approaches and evaluation of cell designs
   3.5. Planning and control in cellular manufacturing
3.6. Applications in Manufacturing

4. **Computer Aided Process Planning**
   4.1. Role of Computer in Planning function
   4.2. CAPP Approaches
   4.3. Benefits of CAPP
   4.4. Machinability Data Systems
   4.5. Computer – Generated Time Standards

5. **Computer Aided Quality Control**
   5.1. Computers in quality control
   5.2. Contact and non-contact inspection methods
   5.3. Computer aided testing

6. **Flexible Manufacturing Systems**
   6.1. FMS and its Components
   6.2. Layout considerations in FMS
   6.3. Material Handling in FMS

7. **Reverse Engineering**
   7.1. Reverse Engineering – Principles and Technology
   7.2. Contact type methods
   7.3. Non-contact type methods
   7.4. Applications in Product Manufacturing

8. **Additive Manufacturing**
   8.1. Additive Manufacturing Processes
   8.2. Steps in Additive Manufacturing
   8.3. Materials used in Additive Manufacturing
   8.4. Post processing
   8.5. Challenges, Benefits and Applications

9. **Cloud Based Manufacturing**
   9.1. Introduction to Cloud computing
   9.2. Data Analytics in Manufacturing
   9.3. Networked manufacturing
   9.4. Industrial Internet of Things
   9.5. Industry 4.0 Standard
   9.6. Applications of Cloud based Manufacturing

**BOOKS:**


REFERENCE BOOKS


PRE REQUISITES

- Back ground in differential calculus and basic mathematics

OBJECTIVE

The objective of this course is to formulate mathematical models and to understand solution methods for real life optimal decision problems.

LEARNING OUTCOMES

After the completion of this course, the students will be able to
- Cast engineering minima/maxima problems into optimization framework.
- Learn efficient computational procedures to solve optimization problems.
- Use MATLAB to implement important optimization methods.

DETAILED CONTENTS

1. Numerical Techniques
   1.1 Introduction to numerical techniques
   1.2 Numerical differentiation and numerical integration
   1.3 Eigen value problems
   1.4 Newton-Raphson’s method
   1.5 Computer based numerical analysis.

2. Introduction to optimization
   2.1 Introduction and Engineering applications of optimization
   2.2 Optimal Problem Formulation; Design – variables, Constraints, Objective function, Variable bounds.
   2.3 Integer Programming
   2.4 Geometric Programming

3. Single-variable Optimization
   3.1 Optimality Criteria
   3.2 Bracketing Methods – Exhaustive search and Bounding phase methods
   3.3 Region-Elimination Methods-Interval halving method; Fibonacci search method, golden section search method
   3.4 Point-Estimation Method : Successive quadratic estimation method
   3.5 Gradient-based Methods : Newton-Raphson method, Bisection method, Secant method, Cubic search method

4. Multivariable Optimization
   4.1 Optimality Criteria
4.2 Unidirectional Search
4.3 Direct Search Methods: Simplex, Hooke-Jeeves pattern search and Powell’s conjugate direction method.
4.4 Gradient-based Methods: Cauchy’s (steepest descent) method, Newton’s method, conjugate gradient method, variable – metric method.

5. **Constrained Optimization**
5.1 Kuhn-Tucker Conditions
5.2 Transformation Methods: Penalty function method.
5.3 Sensitivity Analysis
5.4 Direct Search for Constrained Minimization : Variable elimination, Complex search and Random search methods.
5.5 Linearized Search Techniques: Frank-Wolfe method, Cutting plane method, Feasible Direction Method, Generalized Reduced Gradient Method, Gradient Projection Method.

**BOOKS:**
MMT-657: RESEARCH METHODOLOGY

Maximum marks: 50
Time Allowed: 3 hours

PRE REQUISITES

• NIL

OBJECTIVE

The objective of this course is to introduce students to quantitative and qualitative methods for conducting meaningful research.

LEARNING OUTCOMES

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

• Understand the important concepts of research design, data collection, statistical and interpretative analysis, and final report presentation
• Learn systematic approach to research studies
• Learn statistical data analysis techniques
• Apply estimation & hypothesis technique for engineering problems

DETAILED CONTENTS

1. Introduction Research Methodology
   1.1 Definition of Research
   1.2 Need of Research
   1.3 Concept and steps of Research Methodology
   1.4 Uses of Research Methodology, Research Techniques

2. Reviewing Literature
   2.1 Need
   2.2 Sources – Primary and Secondary
   2.3 Purposes of Review
   2.4 Scope of Review
   2.5 Steps in conducting review

3. Identifying and defining research problem
   3.1 Locating, analyzing stating and evaluating problem
   3.2 Generating different types of hypotheses
   3.3 Hypothesis evaluation

4. Method of Research
   4.1 Descriptive research design-survey
   4.2 Case study
   4.3 Content analysis
4.4 Ex-post Facto Research
4.5 Co-relational and Experimental Research

5. **Sampling Techniques**
   5.1 Concept of population and sample
   5.2 Sampling techniques
      5.2.1 Simple random sampling
      5.2.2 Stratified random sampling
      5.2.3 Systematic sampling
      5.2.4 Cluster sampling
   5.3 Quota sampling techniques
   5.4 Determining size of sample

6. **Procedure of data collection**
   6.1 Aspects of data collection
   6.2 Techniques of data Collection

7. **Statistical Methods of Analysis**
   7.1 Descriptive statistics
      7.1.1 Meaning
      7.1.2 Graphical representations
      7.1.3 Mean, range and standard deviation
   7.2 Characteristics and uses of normal curve.

8. **Inferential Statistics**
   8.1 T-test
   8.2 Chi-square tests
   8.3 Correlation (rank difference and product moment)
   8.4 ANOVA (one way)
   8.5 Softwares for statistical analysis: SPSS, MATLAB

9. **Procedure for writing a research proposal and report**
   9.1 Purpose, types and components of research proposal
   9.2 Audiences and types of research reports
   9.3 Format of Research report and journal

10. **Case Studies on software tools used for research work**

**BOOKS:**