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# Robotics Engineering Foundation

## Target Audience

This course is designed for engineering students, diploma holders, STEM enthusiasts, automation professionals, CAD designers, and aspiring robotics engineers seeking a comprehensive foundation in robotics engineering. The curriculum combines mechanical design, CAD modeling, robot mechanisms, kinematics, dynamics, control systems, sensing technologies, embedded systems, computer vision, and industrial robotics applications.

## Course Outcomes

- Understand robotics engineering principles and applications.
- Design robot components and assemblies using CAD software.
- Analyze robot mechanisms and motion systems.
- Apply forward and inverse kinematics techniques.
- Evaluate robotic dynamics and control systems.
- Integrate sensors and actuators into robotic systems.
- Develop embedded robotic applications.
- Apply computer vision techniques for robotic perception.
- Create integrated robotic systems through projects.

## Course Objectives

- Introduce robotics engineering fundamentals.
- Develop CAD-based robot design proficiency.
- Build competency in mechanisms and motion analysis.
- Strengthen understanding of kinematics and dynamics.
- Develop sensing, actuation and control knowledge.
- Prepare learners for industrial robotics environments.

## Course Outline

The course comprises approximately **80 hours of theory and lab** sessions and is divided into 5 stages containing 21 modules. Each stage will be followed by practical laboratory exercises and project activities to reinforce learning and gauge understanding of the topics covered.

## TABLE OF CONTENTS

- History and Evolution of Robotics
- Types of Robots
- Components of Robotic Systems
- Robot Architectures
- Industrial Applications
- Service Applications
- Human-Robot Interaction

## Module 2: Mathematics for Robotics

- Vectors and Geometry
- Coordinate Systems
- Matrix Operations
- Linear Transformations
- Rotation Representations
- Homogeneous Coordinates
- Engineering Calculations
- Mathematical Modeling

## Module 3: Engineering Fundamentals

- Mechanical Systems
- Electrical Fundamentals
- Electronics Basics
- Power Transmission Systems
- Sensors and Actuators Overview
- Motion Systems
- Introduction to Control Systems
- Engineering Safety Practices

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# STAGE 2: CAD DESIGN & ROBOT MECHANISMS

## Module 4: Engineering Graphics and CAD Fundamentals

- Engineering Drawings
- Orthographic Projections
- Isometric Views
- Sectional Views
- Dimensions and Tolerances
- CAD Workflow
- Design Intent
- CAD Documentation Standards

## Module 5: CAD Modeling Fundamentals

- Sketch Creation
- Sketch Constraints and Relations
- Feature-Based Modeling
- Extrude Features
- Revolve Features
- Sweep Features
- Loft Features
- Design Tables and Configurations

## Module 6: Robot Part Design

- Robot Chassis Design
- Structural Components
- Bracket Design
- Shaft Design
- Gear Modeling
- Mounting Features

- Material Selection
- Design Validation

### Module 7: Assembly Modeling and Motion Analysis

- Assembly Creation
- Assembly Constraints
- Mates and Relationships
- Subassemblies
- Motion Studies
- Collision Detection
- Interference Analysis
- Assembly Optimization

### Module 8: Linkages and Mechanical Systems

- Four-Bar Mechanisms
- Slider-Crank Mechanisms
- Gear Trains
- Belt Drive Systems
- Pulley Systems
- Mechanical Advantage
- Motion Transmission
- Linkage Analysis

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## STAGE 3: ROBOT MODELING & MOTION

### Module 9: Rigid Body Motion

- Position Representation
- Orientation Representation
- Rotation Matrices

- Transformation Matrices
- Exponential Coordinates
- Twists and Screws
- Frame Transformations
- Motion Representation

## Module 10: Forward Kinematics

- Kinematic Chains
- Joint Representation
- Manipulator Modeling
- End-Effector Position Analysis
- Workspace Analysis
- Coordinate Transformations
- Serial Manipulators
- Practical Applications

## Module 11: Inverse Kinematics

- Problem Formulation
- Analytical Solutions
- Numerical Solutions
- Redundant Manipulators
- Workspace Constraints
- Joint Limits
- Singular Configurations
- Practical Applications

## Module 12: Velocity Kinematics and Jacobians

- Differential Motion
- Jacobian Matrix

- Velocity Relationships
- Manipulability
- Singularities
- Force Relationships
- Motion Constraints
- Performance Evaluation

### Module 13: Robot Dynamics

- Force Analysis
- Torque Analysis
- Newton-Euler Formulation
- Lagrangian Formulation
- Dynamic Modeling
- Equations of Motion
- Energy Methods
- Dynamic Simulation

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## STAGE 4: SENSORS, CONTROL & INTELLIGENCE

### Module 14: Sensors and Instrumentation

- Position Sensors
- Velocity Sensors
- Force and Torque Sensors
- Proximity Sensors
- Distance Sensors
- Sensor Calibration
- Sensor Integration
- Signal Conditioning

## Module 15: Actuators and Drive Systems

- Servo Motors
- Stepper Motors
- DC Motors
- Motor Drivers
- Power Transmission
- Actuator Selection
- Motion Control
- Performance Characteristics

## Module 16: Embedded Systems and Microcontroller Programming

- Microcontroller Architecture
- Development Environment Setup
- Digital Inputs and Outputs
- Analog Inputs
- PWM Control
- Sensor Interfacing
- Motor Control
- Embedded Applications

## Module 17: Robot Control Systems

- Open-Loop Control
- Closed-Loop Control
- Feedback Systems
- PID Control
- Stability Analysis
- Controller Tuning
- Motion Control

- System Optimization

### Module 18: Computer Vision Fundamentals

- Image Acquisition
- Image Processing
- Feature Extraction
- Object Detection
- Object Recognition
- Camera Systems
- Vision-Based Measurement
- Robotics Applications

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## STAGE 5: ROBOTICS APPLICATIONS

### Module 19: Industrial Robotics

- Industrial Manipulators
- Manufacturing Automation
- Material Handling
- Assembly Operations
- Welding Applications
- Inspection Systems
- Collaborative Robotics
- Industry 4.0 Integration

### Module 20: Service and Intelligent Robotics

- Medical Robotics
- Agricultural Robotics
- Logistics Robotics
- Domestic Robotics

- Inspection Robots
- Search and Rescue Systems
- Autonomous Systems
- Intelligent Automation