METHODIST COLLEGE

OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

MINOR COURSE

IN

ROBOTICS

DEPARTMENT OF MECHANICAL ENGINEERING
Scheme of Instructions, Examinations
&
Syllabus

(Curriculum for Minor degree in Mechanical Engineering)
Academic Year 2023-2024.
(Courses to be studied in addition to the regular courses offered for the award of B.E)

S. No.	Code No.	Subject	Scheme of Instructions				Scheme of Examination		Credits
			L	T	P/D	Duration in Hrs.	CIE	SEE	
Theory Courses									
1	ROB-01	Introduction to Robotics	3	0	0	3	40	60	3
2	ROB-02	Mechanics of Robots	3	0	0	3	40	60	3
3	ROB-03	Microprocessor & Embedded Systems	3	0	0	3	40	60	3
4	ROB-04	Control of Robotic Systems	3	0	0	3	40	60	3
5	ROB-05	Robotics Lab	0	0	2	2	40	60	1
6	ROB-06	Microprocessor & Embedded Systems Lab	0	0	2	2	40	60	1
7	ROB-07	Project in Robotics	1	0	6	7	40	60	4
Total			**13**	**0**	**10**	**23**	**280**	**420**	**18**

Course Coding Nomenclature:

- ROB denotes that minor degree in “Robotics”.
- 01, 02, 03, 04, 05 and 06 are the courses in order they have to be taken, if taken in different semesters. Multiple courses may also be taken in the same semester (if required).
- It is preferable to take ROB-07 after completing all previous courses or at least after completing ROB-01, ROB-02, ROB-03, in parallel with ROB-04.

Course Code	Course Title	Course Type					
ROB 01	INTRODUCTION TO ROBOTICS	CORE					
		L	T	P/D	Credits	CIE	SEE
		3	0	0	3	40	60

Course Objectives: The main objective of the course is

- To familiarize students with basic terminologies of the robotics sciences and essential knowledge required to get started in the field of Robotics.

Course Outcomes: After completion of the course, the student will be able to

1. To express his views as per terminologies related to Robotics technology.
2. To apply logic for selection of robotic sub systems and systems.
3. To analyse basics of principals of robot system integration.
4. To understand ways to update knowledge in the required area of robotic technology.
5. To understand Socio-Economic aspects of robotisation

UNIT 1:

Introduction to robotics : Brief History, Basic Concepts of Robotics such as Definition, Three laws, Elements of Robotic Systems i.e. Robot anatomy, DOF, Misunderstood devices etc., Classification of Robotic systems on the basis of various parameters such as work volume, type of drive, etc., Associated parameters i.e .resolution, accuracy, repeatability, dexterity, compliance, RCC device etc., Introduction to Principles & Strategies of Automation, Types & Levels of Automations, Need of automation, Industrial applications of robot.

UNIT 2:

Grippers and Sensors for Robotics: Grippers for Robotics - Types of Grippers, Guidelines for design for robotic gripper, Force analysis for various basic gripper system.

Sensors for Robots - Types of Sensors used in Robotics, Classification and applications of sensors, Characteristics of sensing devices, Selections of sensors. Need for sensors and vision system in the working and control of a robot.

UNIT 3:

Drives and Control for Robotics: Drive - Types of Drives, Types of transmission systems, Actuators and its selection while designing a robot system.

Control Systems: Types of Controllers, Introduction to closed loop control.

UNIT 4:

Programming and Languages for Robotics: Robot Programming: Methods of robot programming, WAIT, SIGNAL and DELAY commands, subroutines, Programming Languages: Generations of Robotic Languages, Introduction to various types such as VAL,

RAIL, AML, Python, ROS etc., Development of languages since WAVE till ROS.

UNIT 5:

Related Topics in Robotics: Socio-Economic aspect of robotisation. Economical aspects for robot design, Safety for robot and standards, Introduction to Artificial Intelligence, AI techniques, Need and application of AI, New trends & recent updates in robotics.

Text Books:

1. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education.
2. Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford University Press.

Reference Books:

1. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House.
2. R. K. Mittal, I. J. Nagrath, Robotics and Control, TATA McGraw Hill Publishing Co Ltd, New Delhi .
3. S. B. Niku, Introduction to Robotics – Analysis, Contro, Applications, 3rd edition, John Wiley & Sons Ltd.
4. J. Angeles, Fundamentals of Robotic Mechanical Systems Theory Methods and Algorithms, Springer.
5. Industrial Robotics 2nd edition, SIE, McGraw Hill Education (India) Pvt Ltd.
6. R. D. Klafter, Thomas A. Chmielewski, and Mechael Negin, Robotic Engineering – An Integrated Approach, EEE, Prentice Hall India, Pearson Education Inc.

Course Code	Course Title	Course Type					
ROB 02	MECHANICS OF ROBOTICS	CORE					
		L	T	P/D	Credits	CIE	SEE
		3	0	0	3	40	60

Course Objective: This course aims to inculcate thorough understanding about basic knowledge of mathematics, kinematics and dynamics required for understanding motion programming and operational / control functionality in robotics.

Course Outcomes: After completion of course, the student will be able:

1. To understand terminologies related to Kinematics and Dynamics of Robotics.
2. To apply mathematics for manipulator positioning and motion planning.
3. To analyse basics of motion programming as per kinematics.
4. To estimate the force/torque required to drive a robot.

UNIT 1:

Mathematical Preliminaries of Robotics: Spatial Descriptions: positions, orientations, and frame, mappings: changing description from frame to frame, Operators: translations, rotations and transformations, transformation arithmetic, compound Transformations, inverting a transform, transform equations, Euler Angles, Fixed Angles, Euler Parameters.

UNIT 2:

Robot Statics: Statics Force balance equation, Forces, Velocity/Force Duality, Virtual Work, Force ellipsoid, Jacobian, Kinematic Singularity, Kinematics redundancy, Mechanical Design of robot linkages.

UNIT 3:

Robot Kinematics: Manipulator Kinematics, Link Description, Link to reference frame connections, Denavit-Hartenberg Approach, D-H Parameters, Position Representations, Homogeneous Transformation Matrix, Forward Kinematics. Inverse Kinematics, Geometric and analytical approach.

UNIT 4:

Robot Dynamics: Introduction to Dynamics, Velocity Kinematics, Acceleration of rigid body, mass distribution Newton's equation, Euler's equation, Iterative Newton –Euler's dynamic Formulation, closed dynamic, Lagrangian formulation of manipulator dynamics, dynamic simulation, computational consideration

UNIT 5:

Exploring Jacobians: Cross Product Operator for kinematics, Jacobians -Direct Differentiation, Basic Jacobian, Jacobian Jv / Jw, Jacobian in a Frame, Jacobian in Frame, Kinematic Singularity, Kinematics redundancy.

Text Books:

1. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education.
2. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House.

Reference Books:

1. Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford University Press.
2. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons.
3. J. J. Craig, “Introduction to Robotics: Mechanics and Control”, 3rd edition, Addison-Wesley.

Course Code	Course Title	Course Type					
ROB 03	MICROPROCESSOR & EMBEDDED SYSTEMS	CORE					
		L	T	P/D	Credits	CIE	SEE
		3	0	0	3	40	60

Course Objective: This course aims to teach the detailed functioning of microprocessors and the role of embedded systems in a robotic system.

Course Outcomes: After completion of course, the student will be able:

1. To learn the architecture and modes of 8086 Microprocessor.
2. To learn the architecture and pin configuration of 8051 Microcontroller and its Interfacing.
3. Explain architecture and programming model of ARM and different versions of ARM.
4. Implement simple Programs on the Arduino boards involving several peripherals.
5. Describe embedded system structure and working of real-time operating systems.

UNIT-I

BASICS OF MICROPROCESSOR

Architecture of 8086 - Segmented memory, Addressing modes, Instruction set, Minimum and maximum mode operations, Programmable peripheral interface (8255).

UNIT-II

MICROCONTROLLERS: Types of Microcontrollers, 8051MC – Architecture, I/O Port structures, Internal and external memories, Counters and timers, Serial data input/output, Interrupts, Addressing modes, 8051 instruction set, Classification of instructions. Simple programs. Interfacing with DAC, ADC, LCD & stepper motor.

UNIT-III

The ARM Architecture and Programmers Model: The Acorn RISC Machine, The RISC design philosophy, Core extensions, Architecture revisions, AMBA Bus System, ARM development tools.

The ARM7TDMI programmer's model: General purpose registers, CPSR, SPSR, ARM memory map, data format, load and store architecture, pipeline exceptions, interrupts and vector table.

LPC 214x microcontroller: Internal memory, GPIOs, Timers, ADC, UART and other serial Interfaces, PWM, RTC.

UNIT-IV

Introduction of Arduino Microcontrollers, Arduino history and family, I/O ports Capability of Arudino Uno-ADC & its features. Arduino Programming: Arduino programming basics, Analog/Digital components and its application with Arduino , IDE for

Arduino - Interfacing of Digital Input (LED) and output devices (Switch)-Interfacing of Current sensor and LCD.

UNIT-V

Introduction to Embedded Systems & RTOS: Introduction to Embedded Systems, Embedded System Applications, Block diagram of embedded systems, Trends in Embedded Industry, Embedded System development cycle, Characteristics and quality attributes of embedded systems, Challenges for Embedded System Design.

RTOS Concepts: Introduction to basic concepts of RTOS – Tasks and Data – Threads – Multiprocessing and Multitasking – Schedulers-Semaphores – Priority Inversion - Priority Inheritance – Inter task communication mechanisms-Queues – Pipes.

Text Books:

1. K. V. Shibu, Introduction to Embedded Systems, McGRAW Hill Publications
2. M. A. Mazidi, R.D. Mckinlay and D. Casey, PIC Microcontrollers and Embedded Systems, Pearson Publications

Reference Books:

1. Raj Kamal, Embedded Systems, TATA McGRAW Hill Publications .
2. M. Morris Mano, Computer System Architecture, 3ed, Pearson Publication.
3. D. V. Hall, 8086 Microprocessors and Interfacings, TATA McGRAW Hill.
4. B. B. Brey, The Intel Microprocessors, Prentice Hall Publications, 8th ed.
5. M. Predko, Programming and Customizing the PIC Microcontroller, McGRAW Hill Publications. 3ed.
6. R. Barnett, L. O'Cull and S. Cox, Embedded C Programming and Microchip PIC, Cengage Learning.

Course Code	Course Title	Course Type					
ROB 04	CONTROL OF ROBOTIC SYSTEMS	CORE					
		L	T	P/D	Credits	CIE	SEE
		3	0	0	3	40	60

Course Objective: This course aims to develop the understanding of control systems, its designing and application.

Course Outcomes: After completion of course, the student will be able to:

1. Describe the characteristics of a robotic system from its dynamic model.
2. Analyze the stability of robotic systems with the help of theorems.
3. Illustrate the various task space control schemes available.
4. Discuss about the various Non Linear Control schemes.
5. Explain the concepts of Motion Control System in robots

UNIT 1:

Basics of Control: Differential Equation, Transfer function, Frequency response, Routh-Hurwitz test, relative stability, Root locus design, construction of root loci, phase lead and phase-lag design, lag-lead design, Bode, polar, Nyquist plot.

UNIT 2:

Linear Control: Concept of states, state space model, different form, controllability, observability; pole placement by state feedback, observer design, P, PI & PID Controller, control law partitioning, modeling and control of a single joint.

UNIT 3:

Non-Linear Control System: Common physical non-linear system, phase plane method, system analysis by phase plane method, stability of non-linear system, stability analysis by describing function method, Liapunov's stability criterion, the control problems for manipulators.

UNIT4:

Motion Control: Point to Point Control, trajectory generation, Continuous Path Control, Joint based control, Cartesian Control.

UNIT 5:

Force and Impedance Control : Force Control, hybrid position/force control system, Force-Torque Sensors and Integration Hybrid Force/Position Control, Compliance and Impedance Control. Applications in Contact Tasks

Text Books:

1. M. Gopal, Control Systems, McGraw-Hill.
2. K. Ogata, "Modern Control Engineering", Prentice Hall India.

Reference Books:

1. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons.
2. J. J. Craig, "Introduction to Robotics: Mechanics and Control", 3rd edition, Addison-Wesley.
3. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education.
4. Thomas Kailath, "Linear Systems", Prentice Hall.
5. Alok Sinha, "Linear Systems: Optimal and Robust Control", Taylor & Francis.

Course Code	Course Title	Course Type					
ROB 05	ROBOTICS LAB	CORE					
		L	T	P/D	Credits	CIE	SEE
		0	0	2	1	40	60

Course Objectives: The main objective of the course is to

- To advance the field of robotics through cutting-edge research and development.
- To educate and train students and researchers in robotics technology.
- To facilitate innovation and technology transfer for real-world applications and industry solutions.

Course Outcomes: After completion of the course, the student will be able to

1. Gain a fundamental understanding of robotics principles, including robot kinematics, dynamics, control systems, and sensors.
2. Develop proficiency in programming languages commonly used in robotics, such as Python, C++, or ROS (Robot Operating System).
3. Write code to control and interact with robots.
4. Understand various control strategies used in robotics, including feedback control, motion planning, and path following algorithms.
5. Learn how to integrate sensors (e.g., cameras, LiDAR, IMUs) into robots and process sensor data for navigation, perception, and decision-making.

LIST OF EXPERIMENTS:

1. Determination of maximum and minimum position of links.
2. Verification of transformation (Position and orientation) with respect to gripper and world coordinate system.
3. Estimation of accuracy, repeatability and resolution.
4. Robot programming and simulation for pick and place.
5. Robot programming and simulation for Colour identification.
6. Robot programming and simulation for Shape identification.
7. Robot programming and simulation for assembly process.
8. Trajectory Control Modelling with Inverse Kinematics.
9. Robot programming for joint torque calculation.
10. Build a control system for a mobile robot using ARDUINO with sensors for obstacle detection systems.
11. Demonstration of Robot With 2 DOF, 3 DOF, 4 DOF Etc.
12. Two case studies of applications in industry (Welding &spray painting).

Note: Student has to perform a minimum of 10 experiments.

Course Code	Course Title	Course Type					
		CORE					
ROB 06	MICROPROCESSOR & EMBEDDED SYSTEMS LAB	L	T	P/D	Credits	CIE	SEE
		0	0	2	1	40	60

Course Objectives: The main objective of the course is to

- To provide students with hands-on experience in programming and interfacing microprocessors and microcontrollers to enhance their understanding of embedded systems.
- To foster innovation by enabling research and development of embedded systems solutions, including IOT devices and real-time control applications.
- To promote practical skills and knowledge transfer, preparing students and researchers for careers in industries relying on embedded systems technology, such as automotive, consumer electronics, and industrial automation.

Course Outcomes: After completion of the course, the student will be able to

1. Develop proficiency in programming microprocessors using assembly language and possibly high-level languages (e.g., C or Python) for embedded systems.
2. Learn about microcontroller units (MCUs) and their role in embedded systems. Understand the differences between microprocessors and microcontrollers.
3. Gain a comprehensive understanding of embedded systems, including their architecture, components, and applications in various domains.
4. Acquire skills in interfacing microprocessors with various hardware components, such as LEDs, switches, displays, sensors, and actuators
5. Write assembly language programs for microprocessors to perform tasks like data manipulation, arithmetic operations, and control flow.

List of Lab Experiments to be performed:

PART A

The following experiments by writing Assembly Language Program (ALP) using 8051/LPC2148 using an evaluation board/simulator and the required software tool.

1. Write an ALP to multiply two 16 bit binary numbers.
2. Write an ALP to find the sum of first 10 integer numbers.
3. Write an ALP to find factorial of a number.
4. Write an ALP to add an array of 16 bit numbers and store the 32 bit result in internal RAM.
5. Write an ALP to find the square of a number (1 to 10) using look-up table.
6. Write an ALP to find the largest/smallest number in an array of 32 numbers.
7. Write an ALP to arrange a series of 32 bit numbers in ascending/descending order.

8. Write an ALP to count the number of ones and zeros in two consecutive memory locations.

PART B

Conduct the following experiments on an ARM7TDMI (LPC2148)/ARDUINO evaluation board using evaluation version of Embedded 'C' & Keil Uvision-4 tool/compiler.

9. Display “Hello World” message using Internal UART.
10. Interface and Control a DC Motor.
11. Interface a Stepper motor and rotate it in clockwise and anti-clockwise direction.
12. Determine Digital output for a given Analog input using Internal ADC of ARM controller.
13. Interface a DAC and generate Triangular and Square waveforms.
14. Interface a 4x4 keyboard and display the key code on an LCD.
15. Demonstrate the use of an external interrupt to toggle an LED On/Off.
16. Display the Hex digits 0 to F on a 7-segment LED interface, with an appropriate delay
17. Introduction to Robotic controller card like Arduino UNO board and write program to blink LED using Arduino instructions, C language/ python & Assembly language.
18. Design a robotic car using Arduino and other accessories

Note: Student has to perform a minimum of 10 (5 from each Part) experiments.

Course Code	Course Title	Course Type					
ROB 07	PROJECT IN ROBOTICS	L	T	P/D	Credits	CIE	SEE
		1	0	6	4	40	60

Course Objective:
To assimilate the theoretical knowledge gained in the lecture courses (ROB-1 to 4) for real-life practical applications in order have effective learning and skill-development, mainly, from the point of view of the employability in industries.

Course Outcomes: After completion of course, the student will be able to:

1. Each participant will know students from other colleges/states and their work ethics/culture.
2. To Practice how to work together in a team. An essential skill in an industry.
3. To apply the theoretical knowledge learnt from other courses, which is required by an industry.
4. To learn how to make presentation in a team. A soft skill needed in research and industry.
5. Peer learning from the evaluation of other teams' work. A skill which is essential when one is in a workforce.
6. To examine different hardware components and their working/control using software.

Course Contents:
This course is a project type. The plan of conducting this course is given below:

1. Participants will be divided into teams of two/four members within first week of the starting of the course by the course coordinators/managers depending on the number of participants registered in the course. The benefits of such team-based projects are listed in the Course Outcomes below.
2. The teams will have a team coordinator or leader, which will be identified by the coordinators/managers of the course (may be the first name in the list of a student team).
3. The projects could be of the following types:

a. Literature search (LS) type: Studying about an aspect of robotics, say, vision, robot kinematics, dynamic, controls, etc.

b. Algorithm development (AD) type: Analyse, say, a robot kinematics using Robo Analyzer or Matlab/Octave/Freemat/Scilab or similar software or write an algorithm using any programming language (Python, etc.). For example, writing forward kinematics of a robot or image processing in Vision.

c. Design/synthesis (DS) type: Proposing a new type of system/device for performing certain task. For example, a mobile robot for Covid-19 isolation wards.

4. The teams will be asked to contact their team members within a week and decide their topic with two weeks, i.e., within first 3 weeks of the starting of the course.

5. Students MUST spend about 6 hours in a week to discuss their progress together, study together or individually, write programmes, fabricate circuits, etc.

6. During the one lecture hour the coordinators will explain how to do literature survey, how to find the sources of hardware, which software to use for a particular purpose, how to select an electric motor, etc., present case studies, etc.

7. At the end of the course duration, each team will submit not more than 10 slides in .pdf file and/or not more than a video of one min to showcase their project hardware/software/plots, etc. generated during the project to a cloud (say, Google Drive).

Text Books/References:

Since it is a project type, some experience sharing books and links to similar activities are listed.

1. Chuhan, M., and Saha, S.K., 2010, Robotics Competition Knowledge Based Eduation in Engineering, Pothi.com

2. Baun, M., and Chaffe, J., 2018, Engineering and Building Robots for Competitions, Amazon.com

Corresponding Online Resources:

1. http://www.ddrobocon.in/
2. http://courses.csail.mit.edu/iap/6.095/