

# GUJARAT TECHNOLOGICAL UNIVERSITY

## MECHANICAL (CAD/CAM) (08) AND MECHANICAL (MACHINE DESIGN) (09)

ROBOTICS ENGINEERING

SUBJECT CODE: 2730808

M.E. SEM-III

**Type of course:** Post Graduate

**Prerequisite:** Zeal to learn the subject

**Rationale:** To provide comprehensive knowledge of robotic configurations, kinematics, singularity, dynamics, Trajectory planning, and control of robot manipulators.

### Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P		Theory Marks		Practical Marks				
			ESE (E)	PA (M)	PA (V)		PA (I)			
				ESE	OEP	PA	RP			
3	2 <sup>#</sup>	2	5	70	30	20	10	10	10	150

### Content:

Sr. No	Topic	Lectures	Weightage
<b>1</b>	<b>General considerations of Robotic Manipulator</b> Robot anatomy; Feasible configurations of kinematic chains with prismatic, revolute, cylindrical and spherical joints. Degree of freedoms; Homogeneous transformation; Generalized rotations, Description of robotic pose, Orientation with RPY and Euler angles (Forward and inverse formulations)	<b>05</b>	<b>10%</b>
<b>2</b>	<b>Kinematics of Robotic Manipulators</b> Direct Kinematics, Inverse Kinematics for open and closed architectures; D-H representation; Work space analysis, Singularity analysis, Performance measurement indices (Condition number, reciprocal condition number, Manipulability index, GCI, GPI, GSI)	<b>10</b>	<b>25%</b>
<b>3</b>	<b>Dynamic Analysis of Robotic Manipulators</b> Considerations of forces, moments and torques for robotic configurations; Dynamics formulations using Newtonian, Lagrangian and Hamiltonian principle, Properties of dynamic equations	<b>09</b>	<b>25%</b>
<b>4</b>	<b>Trajectory Generation</b> Path and Trajectory, Joint space versus Cartesian space trajectories, Higher order polynomials; Linear function with parabolic blends; numerical based on different motion trajectories.	<b>06</b>	<b>10%</b>
<b>5</b>	<b>Introduction to grippers, sensors and actuators</b> Types of grippers, Properties of grippers, Types of sensors along with working principle, sensor properties, Translational and rotary actuators and their selection.	<b>04</b>	<b>10%</b>
<b>6</b>	<b>Motion Control of Robotic manipulators</b> Robotic open and closed loop control systems, Second order systems, Non – linear closed loop equation of motion, Different friction models, Control of	<b>10</b>	<b>20%</b>

Single axis robotic arm, Generalized motion control laws for robotic manipulators, Common control system for industrial robots, Error controlled Robotic dynamics, Independent joint PID control, Independent joint PID control with effective joint inertia, Force control of robotic manipulator, Tracking error analysis, Coordinated movement		
---	--	--

### Course Outcome:

On completion of this course students will:

1. Synthesize various configuration with different joints for required degrees of freedom
2. Understand the various approaches to write position as well as motion equations for open and closed loop configurations
3. Apply the concept of DH convention for forward and inverse kinematics
4. Know the role of friction models and control strategies for various tasks performed by robots

### References:

1. Robotics control, sensing, vision and intelligence, K S Fu, R C Gonzalez, CSG Lee, Tata McGraw Hill Edition 2008
2. Introduction to robotics, John J Craig, Pearson/Prentice Hall, 2005, Third edition
3. Introduction to Robotics: Analysis, Control, Applications , Saeed Niku, John Wiley & Sons
4. Introduction to Robotics, S K Saha, Tata McGraw-Hill
5. Robotics and control, R K Mittal, I J Nagrath, Tata McGraw Hill 2003
6. A Robot Engineering Textbook , Mohsen Shahinpoor, Harper and Row, Publisher, New York

### List of Experiments:

1. Synthesize the robotic configuration for specific degrees of freedom as given by instructor
2. Direct kinematics implementation for open/closed loop robotic configurations
3. Inverse kinematics implementation for open/closed loop robotic configurations
4. Coding/simulation of direct kinematics for open/closed loop configurations along with work space generation using high end software
5. Formulation of DH parameters of robot configuration and its simulation using open source software
6. Lagrangian formulation of the given configuration along with its coding/ validation using simulation software
7. Newtonian formulation of the given configuration along with its coding/ validation using simulation software
8. Design of trajectory for a specific task as given by instructor
9. Simulation/ performance of a trajectory planning of a robot
10. Simulation/performance on the control of open kinematic architecture

### Design based problems (DP)/open ended problem:

1. Design of pick and place robot for a given pay load capacity
2. Performance measurement of various configurations with same degrees of freedom
3. Determination of computational efficiency of different dynamic formulations of a robotic configuration

### Major Equipment:

- Robot kits
- MATLAB/ High end Simulation software for mechanisms/robots

**List of Open source software/learning website:**

- <http://www.roboanalyzer.com/>

**Review Presentation (RP):** The concerned faculty member shall provide the list of peer reviewed Journals and Tier-I and Tier-II Conferences relating to the subject (or relating to the area of thesis for seminar) to the students in the beginning of the semester. The same list will be uploaded on GTU website during the first two weeks of the start of the semester. Every student or a group of students shall critically study 2 papers, integrate the details and make presentation in the last two weeks of the semester. The GTU marks entry portal will allow entry of marks only after uploading of the best 3 presentations. A unique id number will be generated only after uploading the presentations. Thereafter the entry of marks will be allowed. The best 3 presentations of each college will be uploaded on GTU website.