**OBJECTIVES**

The objective of the course is to enable the student in;

I. Understanding basic concepts of robots and their development.
II. To know various configuration of robots used in industry, role of robots in industrial automation.
III. Analyze the forces acting on gripper and selection and design of grippers, actuators and sensors.
IV. Transformation of motion of robot endeffector with Denavit and Hartenberg parameters.
V. Euler-Lagrange and Newton-Euler equations of motion are used for finding force and torque required at each of the joint actuators.

| S. No. | Question | Blooms Taxonomy Level | Course Outcomes |
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| | **UNIT-I** | | |
| 1 | Discuss the following types of automation<br>i. Fixed automation<br>ii. Flexible automation | Understanding | I |
| 2 | Explain the following types of grippers with application<br>i. Magnetic grippers<br>ii. Vacuum cups. | Applying | III |
| 3 | a. Draw and explain the four basic configurations of robot.<br>b. Explain the different types of joints used in robots with neat sketch. | Remembering | I |
| 4 | a. What are the various factors in gripper's selection and design? Explain.<br>b. What is meant by position and orientation of robot? Explain RPY representation of orientation. | Applying | III |
| 5 | a. Define manipulator.<br>b. Describe the types of manipulators generally adopted for basic motions 5. Establish the mathematical expressions of forward transformation of a spatial 2 degree of freedom arm. With two revolute joints. | Understanding | I |

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| 6 | Write a detailed note about programmable automation. With the applications. | Understanding | I |
| 7 | a. Define a Robot.<br>b. Discuss the advantages and disadvantages of using robots in industry? | Understanding | I |
| 8 | a. What is industrial automation? What are its types?<br>b. Compare hard automation with soft automation? | Applying | I |
| 9 | a. Explain how the performance of robotic system in studied?<br>b. Define repeatability, resolution and accuracy. | Analyzing | I |
| 10 | a. Discuss the gripper design considerations in robotics.<br>b. An industrial robot with a prismatic joint has a telescoping range of 0.6m. The robots control memory has the following bit storage capacity.<br>i. 10 bit storage capacity<br>ii. 12 bit storage capacity<br>Determine the control resolution for the two cases separately. | Applying | I |
| **UNIT – II** | | | |
| 1 | Compute the homogeneous transformation representing a translation of 3 units along the x-axis followed by a rotating of $\pi/2$ about the current z-axis followed by a translation of 1 unit along the fixed y-axis. Sketch the frame. What are the coordinates of the $o_1$ with respect to the original frame in each case. | Applying | IV |
| 2 | A Cartesian co-ordinate robot of configuration L L L is to move its three axes from position (x,y,z)=(0,5,5) to position (x,y,z)=(20,35,15). All distance measures are given in mm the maximum velocities for the three joints are respectively 20mm/sec 15 mm/sec and 10mm sec determine the time required to move each joint if slew motion is used. | Applying | IV |
| 3 | a. Explain the importance of homogenous transformations.<br>b. For the vector v=25i+10j+20k, perform a translation by a distance of 8 in the x-direction, 5 in the y-direction and 0 in the z-direction. | Analyzing | I |
| 4 | Draw any two Euler angle systems and show rotation and angles. | Understanding | II |
| 5 | Give Euler angles representation for the RPY system and derive the rotation matrix. | Applying | II |
| 6 | Explain the homogeneous transformation matrix and interprete the partitioning with application. | Applying | II |
| 7 | a. Find the transformation matrices for the following operations on the point<br>$2\hat{i} - 8\hat{j} + 3\hat{k}$<br>i. Rotate $30^0$ about x-axis and then translate -5 units along y-axis.<br>ii. Translate 2 units along y-axis and rotate $60^0$ about z-axis | Applying | III |
| 8 | For the point $a_{uvw}=(6,2,4)^T$ perform following operations.<br>a. Rotate $30^0$ about the $X$ axis, followed by translation of 6 units anling $Y$ axis.<br>b. Translate 6 units along $Y$ axis, followed by rotation | Applying | III |

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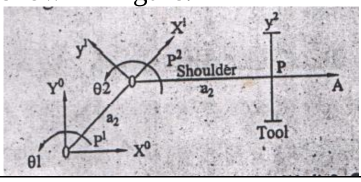
| | of $30^0$ about *X* axis.<br>c. Rotate $60^0$ about *Z* axis followed by translation of 10 units along the rotated *U* axis. | | |
| 9 | a. Briefly explain about the following<br>i. Homogeneous coordinates<br>ii. Homogenous Transformation<br>b. For the point $3i+7j+5k$ perform the following operation:<br>Translates 6 units along *Y* then rotate $30^0$ about *X*. | Analysis | III |
| 10 | Find an expression for general rotational transformation that rotates a body about arbitrary direction $1\leq k$ x $i$ $k$ $y$ $j$ $+k$ $z$ $k$ by an angle Θ. | Analysis | III |
| **UNIT – III** | | | |
| 1 | Write short notes on<br>a. Direct and inverse kinematics<br>b. DH convention | Understanding | I |
| 2 | Write short notes on inverse transforms. | Applying | II |
| 3 | a. Explain co-ordinate frame assignment of DH representation.<br>b. List the steps involved in DH convention. | Applying | II |
| 4 | Derive the arm matrices for a cylindrical robot. Hence obtain the kinematic equations for the same. | Analyzing | II |
| 5 | Get Euler angles for system I representation by applying inverse kinematic solution. | Applying | I |
| 6 | Derive the kinematic equations for the SCARA robot giving co-ordinate frame diagram and the kinematic parameters. | Applying | II |
| 7 | Using DH method and by symbolic sketch, write down the transformation matrices for each link and determine the position and orientation of end effector with respect to the base in a Cartesian robot configuration. | Analyzing | I |
| 8 | a. Discuss about direct and inverse kinematics<br>b. Arrive at the rotation matrices for the angle of rotations $\alpha$, $\beta$ and Θ about x,y and z axes respectively. | Analyzing | II |
| 9 | Define and illustrate the link and joint parameters. Explain their uses. | Understanding | I |
| 10 | Explain and derive inverse kinematic solution for the variables of a cylindrical robot. | Applying | II |
| 11 | Derive the kinematic equation for the elbow manipulator with co-ordinate frame diagram and kinematic parameters. | Applying | II |
| **UNIT – IV** | | | |
| 1 | Find the manipulator jacobian matrix j(q) of the two-axis planer articulated robot shown in figure.<br> | Analyzing | I |
| 2 | Compute the Jacobian $J_{11}$ for the three linked spherical manipulator. | Applying | II |

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| 3 | Find the 6 x 2 Jacobian for the first three links of a cylindrical manipulator. Suppose a Cartesian robot with rolling, pitching and yawing (Euler angles), find the rolling, pitching and yawing of the DH matrix given by: $$T = \begin{bmatrix} 0.527 & -0.574 & 0.628 & 4 \\ 0.369 & 0.819 & 0.439 & 6 \\ -0.766 & 0 & 0.643 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ | Applying | IV |
| 4 | The Jacobian of robot at particular time is given. Calculate the linear and angular differential motion of the robot hand. $$[B] = \begin{bmatrix} 2 & 0 & 0 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \text{ and } dq = \begin{bmatrix} 0 \\ 0.1 \\ -0.1 \\ 0 \\ 0 \\ 0.2 \end{bmatrix}$$ | Applying | IV |
| 5 | Find the total differential transformation caused by small rotation about three axes of dx=0.1, dy =0.05 and dz=0.02 rad. | Analyzing | III |
| 6 | The hand frame of a robot with five degrees of freedom, its numerical jacobian for the instant and a set of differential motion are given. Find the new location of the hand after differential motion. $$T = \begin{bmatrix} 1 & 0 & 0.1 & 5 \\ 0 & 0 & 1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, B = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 0 \end{bmatrix} \text{ and}$$ $$dq = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix}$$ | Applying | II |
| 7 | As a result of applying a set of differential motion to frame T is given and it has changed about dT is also given. Find the magnitude of the differential changes made (dx, dy, dz, dx, dy, dz) and the differential operator with respect to T. $$T = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 0 & 1 & 3 \\ 0 & -1 & 0 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix} \text{ and } dT = \begin{bmatrix} 0 & -0.1 & -0.1 & 0.6 \\ 0.1 & 0 & 0 & 0.5 \\ -0.1 & 0 & 0 & -0.5 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$ | Applying | III |

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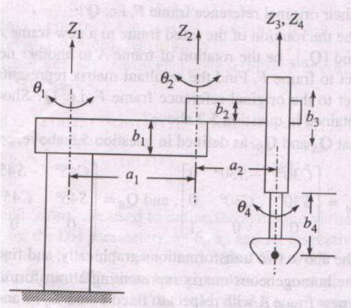
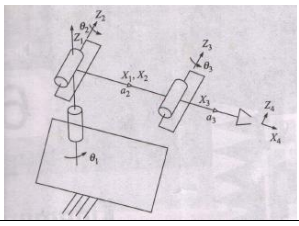
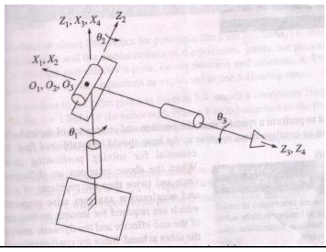
| 8 | a. What is Jacobian of a robot system?<br>b. Derive the Jacobian matrix for the to 2-link planer manipulator. | Analyzing | II |
| 9 | Express the Jacobian matrix for SCARA robot shown in fig.<br> | Applying | II |
| 10 | Express the Jacobian matrix for the robot architecture shown in figure.<br> | Applying | II |
| 11 | Express the Jacobian matrix for the robot architecture shown in figure.<br> | Applying | II |
| **UNIT – V** | | | |
| 1 | a. Explain Newton-Euler formulation of a robotic system.<br>b. Derive the equation of motion for a single link manipulator given mass and length of link. | Analysis | V |
| 2 | a. What is Lagranjian?<br>b. Give derivation of Lagranjian-Euler formulation of joing force/torque for single link manipulator of given length and mass. | Applying | V |
| 3 | Explain the following briefly as applied to robot arm dynamics analysis.<br>i. Kinematic energy<br>ii. Potential energy<br>iii. Joint velocities | Understanding | I |
| 4 | Derive the equation of motion for a single link manipulator given the mass and length of the link. | Applying | II |
| 5 | Give the derivation of Lagrange-Euler formulation for the joint force/torque. | Applying | II |
| 6 | Derive the dynamic equation of motion for a Revolute-Prismatic (RP) robot arm manipulator. | Applying | II |
| 7 | Develop a state model for the single link (single-axis) robot manipulator, shown in Figure. | Analyzing | I |

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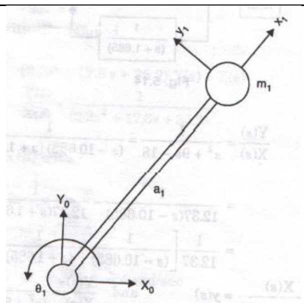
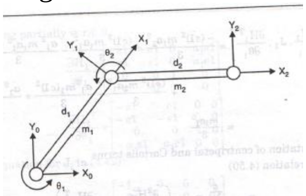
| |  | | |
| 8 | a. Explain the Lagrance Euler's formulation for robot arm.<br>b. Differentiate clearly with reference to 2-jointed manipulator of RR type and LL type. | Applying | V |
| 9 | Establish the dynamic model of a one axis robot (inverted pendulum) with Newton-Euler formulation. | Analysis | I |
| 10 | Derive a dynamic model for a two axis planar articulated robot given the mass and length of the links<br> | Applying | V |
| | **UNIT – VI** | | |
| 1 | a. Determine the time required for each joint of a three-axis RRR manipulator to travel the following distances using slew motion; joint 1, $100^0$; joint 2, $30^0$; and joint 3, $60^0$. All joints travel at a rotation velocity of $15^0$/s.<br>b. Find expressions for the joint motion parameters by using cubic polynomial fit in joint space scheme.<br>Use the following data: $\Theta_0$=20, $\Theta_f$=70 t=3seec. | Applying | II |
| 2 | a. Enumerate trajectory generation of polynomial type.<br>b. One of the joints of articulated robot has to travel from initial angle of $20^0$ to final angle of $84^0$ in 4 seconds. Using $3^{rd}$ degree polynomials calculate joint angles at one, two, three seconds. | Understanding | II |
| 3 | a. Explain the parameters involved in path planning with $3^{rd}$ degree polynomial.<br>b. A single link rotary robot is required to move from $\Theta_{(0)}=45^0$ to $\Theta_{(2)}=90^0$ in two seconds. Joint velocity and acceleration are zero at initial and final positions. What is the highest degree polynomial that can be used to accomplish the motion? | Applying | II |
| 4 | a. Explain the following terms<br>i. Trajectory<br>ii. Joint space trajectory planning.<br>b. A single link robot with a rotary joint is motionless at $\Theta_0=15^0$ it is desired to move the joint in a smooth manner to $\Theta_f=75^0$ in 3sec. Find the coefficients of a cubic which accomplishes this motion and brings the arm to rest at the goal. | Understanding | II |
| 5 | a. Explain trajectory planning with respect to PTP robot considering modified constant velocity of joint.<br>b. A single link rotary robot is required to move from $\Theta_{(0)}=45^0$ to $\Theta_{(2)}=90^0$ in two seconds. Joint velocity and acceleration | Understanding | II |

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| | are zero at initial and final positions. What is the highest degree polynomial that can be used to accomplish the motion? | | |
| 6 | Explain trajectory planning and show how trajectory planning is done in case of PTP (Point-to-point) robot having constant maximum velocity and finite acceleration and deceleration. | Applying | I |
| 7 | Describe different path control modes in robotics. | Analyzing | I |
| 8 | Discuss the advantages and disadvantages between joint space and scheme and Cartesian-space schemes. | Understanding | I |
| 9 | Enumerate trajectory generation polynomial types. | Understanding | I |
| 10 | Explain the parameters involved in the path planning with 3rd degree polynomial. | Applying | II |
| 11 | Explain the following<br>i. Manual programming<br>ii. Lead through teaching | | |
| | **UNIT – VII** | | |
| 1 | a. Compare the features of most commercially used electrical actuators in robots.<br>b. A stepper motor is used to drive a prismatic joint of Cartesian robot. Motor shaft is connected to a screw shaft with a pitch of 3mm. The control resolution 0.6mm is desired for the controller. Determine<br>i. Number of step angles in motor to achieve this resolution.<br>ii. Pulse rate required to drive the joint with a linear speed 75mm per second. | Understanding | I |
| 2 | a. Explain the following hydraulic actuator with a neat sketch:<br>i. Robot actuators<br>ii. Linear actuators<br>b. A hydraulic rotary vane actuator is used to drive the revolute joint of cylindrical robot with power source delivery of 27 cc/sec of oil at a pressure of 705N/$cm^2$ the outer and inner vane radius are 10cm and 5cm respectively. Thickness of vane is 1cm. Determine angular velocity of motion and torque in the motor shaft. | Understanding | I |
| 3 | a. Give a brief classification of actuators used in robots.<br>b. Explain various types of touch sensors with neat sketch. | Understanding | I |
| 4 | a. With a neat sketch explain tactile sensors and range sensors.<br>b. Explain features and application of hydraulic actuators in robotics. | Understanding | I |
| 5 | With a neat sketch explain the following hydraulic actuator.<br>i. Rotary actuator<br>ii. Linear actuator. | Understanding | I |
| 6 | Compare the features of most commonly used electric actuators in robotics. | Analyzing | II |
| 7 | Explain the performance and selection criteria of electric motors in robotics. | Analyzing | I |
| 8 | With a neat sketch explain the tactile sensors and the range sensors. | Understanding | I |
| 9 | Explain the types of touch sensors with neat sketches. | Understanding | I |
| 10 | a. Explain principle and construction of inductive type proximity sensors.<br>b. Explain the constructions and operation of ultrasonic | Understanding | I |

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| | proximity sensors. | | |
| 11 | a. Explain the working of DC servo Motor.<br>b. Discuss the principle of a Resolver. | Understanding | I |
| 12 | Enlist the main elements of a hydraulic system used in robot and explain their functions briefly. | Understanding | I |
| **UNIT – VIII** | | | |
| 1 | a. What are the considerations of Robots in material handling?<br>b. What are the features of robot in machine loading and unloading applications? | Applying | I |
| 2 | a. What are the applications of robots?<br>b. Explain spray painting by robots. | Analyzing | II |
| 3 | Explain function of robots in assembly and inspection | Applying | II |
| 4 | Explain various methods of part presentation in assembly process | Applying | II |
| 5 | Explain pick and palce robots for machining operation die costing and plastic moulding. | Understanding | I |
| 6 | Explain use of Robots in the fields of welding and painting. | Applying | II |
| 7 | Explain with the neat diagram how Robot can be gainfully employed in the inspection methods of component made in large number. | Analyzing | I |
| 8 | Explain automation in inspection. | Understanding | V |
| 9 | Explain various assembly systems configuration. | Understanding | I |
| 10 | Explain compliances and remote control compliance device for assembly operations. | Applying | II |