Roll No: --------------------------

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program : M.Tech Automation & Robotics Engg **Semester – I**
Subject (Course): Introduction To Robotics **Max. Marks : 100**
Course Code : ECEG7002 **Duration : 3 Hrs**
No. of page/s: 4

Section – A (4 X 5 = 20)

1. Figure 1 shows a frame {B} that is rotated relative to frame {A} about $\hat{X}$ by 60 degrees CW, translated 20 units along $\widehat{Y_A}$ and 15 units along $\widehat{Z_A}$. Calculate ${}^B_AT$. Assume $\hat{X}$ is perpendicular to the page.
   The frame defining [B] is

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & .866 & 20 \\ 0 & -0.866 & 0.5 & 15 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

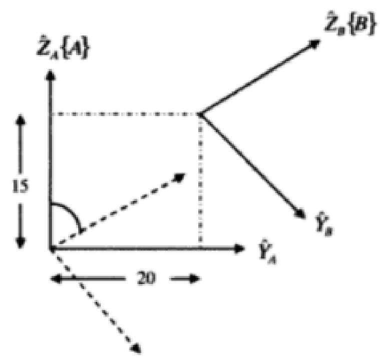
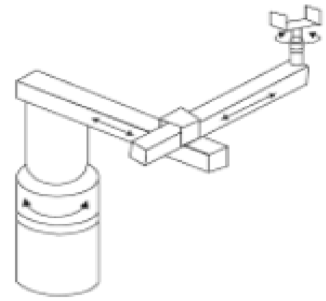


Fig.1

2. It is desired to have the first joint of a 6-axis robot go from an initial angle of 50 deg to a final angle of 80 deg in 3 seconds. Calculate the coefficients for a third-order polynomial joint-space trajectory. Determine the joint angles, velocities, and accelerations at 1,2 and 3 seconds. It is assumed that the robot starts from rest, and stops at its destination.

3. Sketch the approximate workspace for the following robot. Assume that the dimensions of the base and other parts are of the robot structure are as shown.

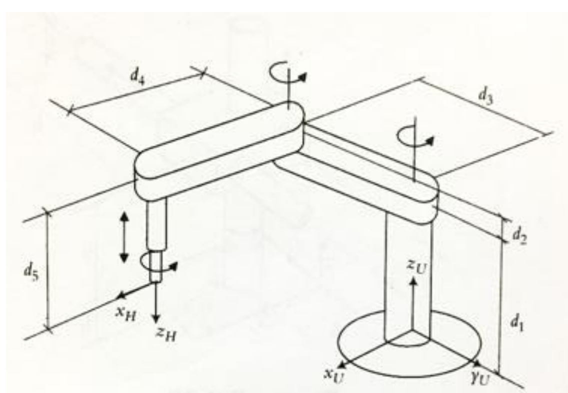


4. A point P in space is defined as ${}^{B}P = (2.3,5)$ relative to frame B which is attached to the origin of the reference frame A and is parallel to it. Apply the following transformations to frame B and evaluate ${}^{A}P$
   • Rotate 90 about x-axis, then
   • Rotate 90 about local a axis. then
   • Translate 3 units about y-, 6 units about z-, and 5 units about x-axes.

Section – B (4 X 10 = 40)

Answer any four questions

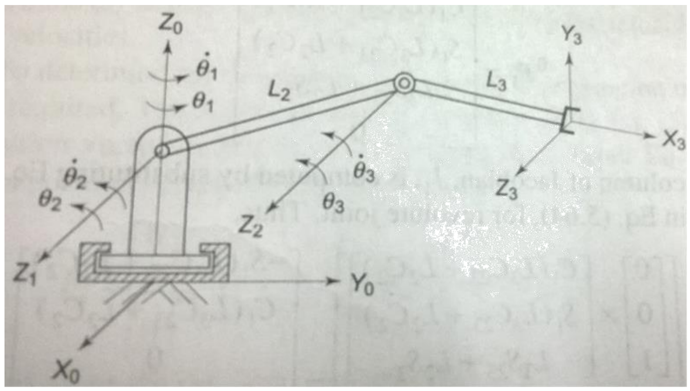
5. For the following SCARA-type robot:
   • Assign the coordinate frames based on the D-H representation.
   • Fill out the parameters table.
   • Evaluate all the A matrices.



6. Suppose that a robot is made of a Cartesian and RPY combination of joints, calculate the necessary RPY angles to achieve the following:

$$T=\begin{bmatrix} 0.527 & -0.574 & 0.628 & 4 \\ 0.369 & 0.819 & 0.439 & 6 \\ -0.766 & 0 & 0.643 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

7. Calculate the manipulator Jacobian matrix for a 3DOF articulated arm shown in figure.



8. The motion of a joint of 3DOF arm is constrained by an actuator that can produce a maximum acceleration of 0.35 rad/s^2 and maximum velocity of 1.5 rad/s. If trapezoidal velocity profile is assumed, determine the trajectory if the joint moves by Π rad in 10 s.

9. Derive dynamic equations of a three-link PPP planar manipulator whose axes of joints are mutually perpendicular using Lagrangian method.

Section – C (2 X 20 = 40)

10. A 2-DOF planar robot is to follow a straight line in Cartesian-space between the start (2.6) and the end (12,3) points of the motion segment. Evaluate the joint variables for the robot by (deriving) inverse kinematics if the path is divided into 10 sections. Each link is 9 inches long.

11. Determine the equations of motion for the 2DOF RP planar manipulator arm using the Lagrange Euler formation. Assume both links have equal length (L1=L2=L) and have equal mass (m1=m2=m). Assume further that the links are slender members with a uniform mass distribution i.e. the center of mass of each link is located at the midpoint of the link.

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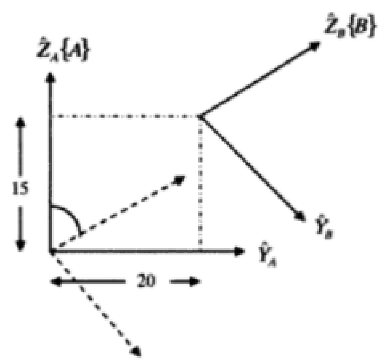

Fig.1

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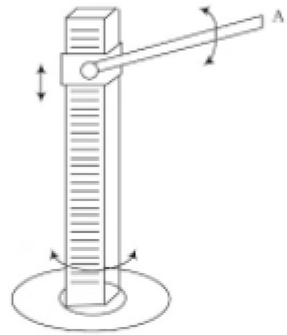

4. A frame B is rotated 90 about the z-axis, then translated 3 and 5 units relative to the n and o axes respectively, then rotated another 90 about the n-axis, and finally 90 about the y-axis. Find the new location and orientation of the frame.

$$B=\begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Section – B (4 X 10 = 40)

Answer any four questions

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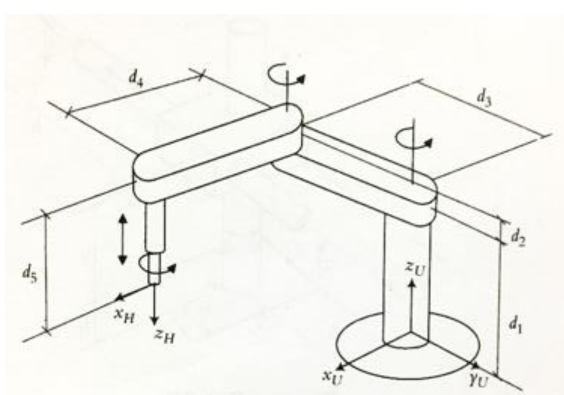


6. For a 4-DOF RPPR manipulator, the joint link transformation matrices with joint variables $\Theta_1,\ d_2, d_3, \Theta_4$

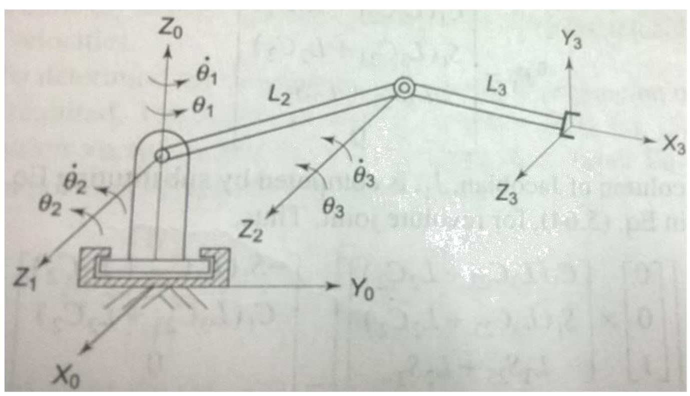
$$ {}^0_1T = \begin{bmatrix} C_1 & -S_1 & 0 & 0 \\ S_1 & C_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},\ {}^1_2T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix},\ {}^2_3T = \begin{bmatrix} 1 & 0 & 0 & \mathbf{5} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^3_4T = \begin{bmatrix} C_4 & -S_4 & 0 & 0 \\ S_4 & C_4 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. $$

If tool configuration matrix at a given instant is given as below, determine the magnitude of each variable

$$ T_E \begin{bmatrix} -0.250 & 0.433 & -0.866 & -89.10 \\ 0.433 & -0.750 & -0.500 & -45.67 \\ -0.866 & -0.500 & 0 & 50.00 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

7. Calculate the manipulator Jacobian matrix for a 3DOF articulated arm shown in figure



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