Name: **Enrolment No:**	**UPES SAP ID:**

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, December, 2021

Course: Kinematics and Dynamics of Robotics — **Semester: I**
Program: M.Tech – Automation and Robotics Engineering — **Time: 3 hours**
Course Code: ECEG7013 — **Max. Marks: 100**
No. of Pages: 03

Note: The marks for each question is mentioned on the right hand side. Each question is mandatory. Section B – Q2. and Section C – Q1. have internal choices.

Section A

Q1.	Briefly discuss about the Joint-Space description versus the Cartesian-Space description.	**4**	**CO4**
Q2.	Briefly discuss differential motions of a frame versus a robot.	**4**	**CO3**
Q3.	Explain the term degeneracy as applicable to a robot.	**4**	**CO1**
Q4.	Classify robots as per Japanese Industrial Robot Association (JIRA).	**4**	**CO1**
Q5.	With neat sketch, illustrate any two robot configurations as per robot coordinates.	**4**	**CO1**

Section B

Q1. A camera is attached to the hand frame T of a Robot as given. The corresponding inverse Jacobian of the robot relative to the frame at this location is also given. The robot makes a differential motion, as a result of which, the change dT in the frame is recorded as given: **10** **CO3**

$$T=\begin{bmatrix}0&1&0&3\\1&0&0&2\\0&0&-1&8\\0&0&0&1\end{bmatrix}\quad {}^{T}J^{-1}=\begin{bmatrix}1&0&0&0&0&0\\2&0&-1&0&0&0\\0&-0.1&0&0&0&0\\0&-1&0&0&1&0\\0&0&0&1&0&0\\1&0&0&0&0&1\end{bmatrix}\quad dT=\begin{bmatrix}-0.02&0&-0.1&0.7\\0&0.02&0&0.08\\0&-0.1&0&-0.3\\0&0&0&0\end{bmatrix}$$

(a) Determine the new location of the camera after the differential motion.
(b) Determine the differential operator.
(c) Determine the joint differential motion values D_θ associated with this move.

Q2. It is desired to have the first joint of a six axis robot go from an initial angle of 50° to a final angle of 80° in 3 seconds. Determine 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. **10** **CO4**

OR

Joint 1 of a 6-axis robot is to go from an initial angle of θ_i = 30° to the final angle of θ_f = 120° in 4 seconds with a cruising velocity of ω_1 = 30°/sec. Determine the necessary blending time for a trajectory with linear segments and parabolic blends and plt the joint positions, velocities and accelerations.

Q3. An object is subjected to the following forces and moments relative to the reference frame. Attached to the object is a frame, which describes the orientation and the location of the object. Determine the equivalent forces and torques acting on the object relative to the current frame. **10** **CO3**

$$B = \begin{bmatrix} 0.707 & 0.707 & 0 & 2 \\ 0 & 0 & 1 & 5 \\ 0.707 & -0.707 & 0 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad F^T = [10,\ 0,\ 5,\ 12,\ 20,\ 0]\ \text{N, N.m}$$

Q4. The homogeneous transformation matrices between frames {1} – {2} and {2} – {3} are: **10** **CO2**

$$^{1}T_2 = \begin{bmatrix} 0.527 & -0.574 & 0.628 & 2 \\ 0.369 & 0.819 & 0.439 & 5 \\ -0.766 & 0 & 0.643 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \text{ and } {}^{2}T_3 = \begin{bmatrix} 0.92 & 0 & 0.39 & 5 \\ 0 & 1 & 0 & 6 \\ -0.39 & 0 & 0.92 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Determine $^{3}T_1$

Section C

Q1. For the 3-DOF manipulator arm as shown in Fig.1, assign frames and obtain the joint-link parameters (DH parameters). Also, determine the position of the tool tip with respect to the base frame {0}. Take the values of $\theta_1 = 30°$, $\theta_3 = 45°$, and $d_2 = 0.8m$. **20** **CO2**

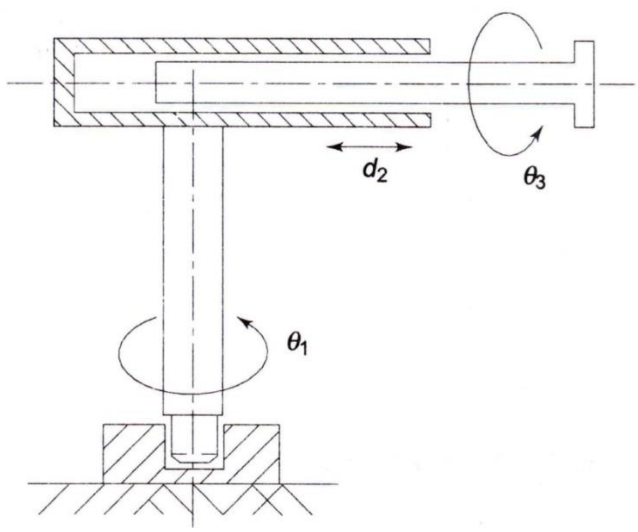


Fig. 1: A 3-DOF manipulator

OR

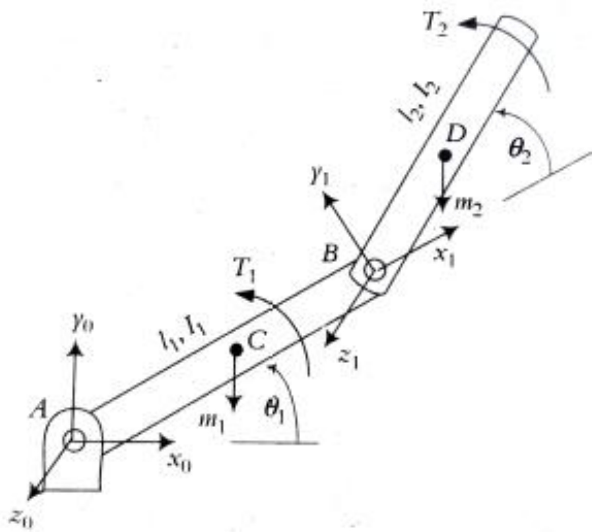
In a 3-DOF robot, the DH parameters are as given below:

	θ	d	a	α
0-1	θ_1	0	0	90º
1-2	θ_2	0	0	-90º
2-H	0	d_3	0	0

The transformation matrix is given as:

$$T = \begin{bmatrix} 0.354 & 0.866 & 0.354 & 0.106 \\ -0.612 & 0.500 & -0.612 & -0.184 \\ 0.707 & 0 & 0.707 & 0.212 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Determine the joint variables if $-100^o < \theta_1 < 100^o$, $-30^o < \theta_2 < 70^o$ and $0.05\ m < d_3 < 0.5\ m$

<table>
<tr>
<td>Q2.</td>
<td>Derive the equations of motion for the 2-link mechanism with distributed mass, as shown:


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<td>20</td>
<td>CO3</td>
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