Name: **Enrolment No:**	UPES UNIVERSITY OF TOMORROW

End Semester Examination, December 2024

Course: Introduction to Robotics **Semester: I**
Program: M. Tech in Robotics Engineering **Time : 03 hrs.**
Course Code: ECEG7043 **Max. Marks: 100**

Instructions:

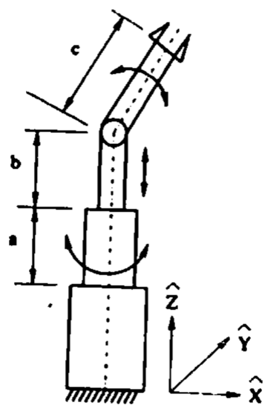
1. Read the instructions carefully.
2. The use of a scientific calculator is permitted.
3. You may assume any missing but relevant information and data.
4. All questions are compulsory.

SECTION A
(5Qx4M=20Marks)

S. No.		Marks	CO
Q1	Define the degree of freedom of a robot.	**4**	**CO1**
Q2	Calculate the missing elements of the following frame representation: $$F = \begin{bmatrix} 0 & ? & 0 & 3 \\ 1 & 0 & 0 & 2 \\ 0 & 0 & -1 & 8 \\ ? & 0 & 0 & 1 \end{bmatrix}$$	**4**	**CO2**
Q3	Distinguish between the hand frame and the universal frame	**4**	**CO1**
Q4	Describe redundant and underactuated manipulator.	**4**	**CO1**
Q5	Define the trajectory of a robot.	**4**	**CO1**

SECTION B
(4Qx10M= 40 Marks)

S. No.		Marks	CO
Q6	Derive the matrix that represents a pure rotation about the *z*-axis of the reference frame.	**10**	**CO3**
Q7	Calculate the coordinates of point $P(2,3,4)^T$ relative to the reference frame after a rotation of 47° about the *x*-axis followed by 72° rotation about y-axis of the frame.	**10**	**CO4**
Q8	Explain the following statement: Lagrangian of a mechanical system is a function of the generalised coordinates defined as the difference between the kinetic energy and the potential energy of the system. **OR**	**10**	**CO5**

	Define the differential operator (Δ). Derive the differential operator for differential transformation of a 3D frame.		
Q9	Analyze the kinematic diagram of a robot as shown in the figure and answer the following questions: a) Identify the configuration of the robot and the shape of its work volume. b) Create a Denavit-Hartenberg table for this robot.  (a)	**10**	
SECTION-C **(2Qx20M=40 Marks)**			
Q10	The hand frame T_H of a robot is given. The corresponding inverse Jacobian of the robot at this location relative to this frame is also shown. The robot makes a differential motion relative to this frame described as ${}^{T_H}D = [0.05 \quad 0 \quad -0.1 \quad 0 \quad 0.1 \quad 0.1]^T$ a. Find which joints must make a differential motion, and by how much, in order to create the indicated differential motions. b. Calculate the change in the frame. c. Find the new location of the frame after the differential motion. d. Find how much the differential motions (given above) should have been if measured relative to the Universe, to move the robot to the same new location as in Part c. $T_H = \begin{bmatrix} 0 & 1 & 0 & 3 \\ 1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix}, [{}^{T_H}J]^{-1} = \begin{bmatrix} 5 & 0 & 0 & 0 & 0 & 0 \\ 2 & 0 & -1 & 0 & 0 & 0 \\ 0 & -0.2 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$	**20**	**CO5**

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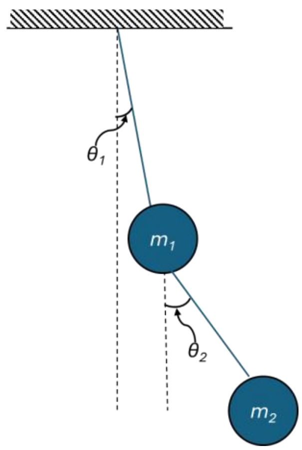
<td>Q11</td>
<td>Answer the following questions:
a) Explain the role of dynamic analysis in robotics and its importance in understanding robot performance and control. (5 Marks)
b) Discuss forward and inverse dynamics. How do these concepts help in the simulation and control of robotic systems? (5 Marks)
c) Using the Lagrangian formulation, derive the equation of motion of a simple pendulum. Provide a step-by-step derivation. (10 Marks)
OR
Using the Lagrangian formulation, derive the equation of motions of a double pendulum system as shown in the figure below, where $l_1$and l_2 are the length of the pendulums. Provide a step-by-step derivation.


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<td>CO5</td>
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