Name: _____

ID: _____

MIDTERM EXAMINATION

Introduction to Robotics

Instructions:

1. **Do not** start this test until the proctors say you can begin.
2. The exam contains 6 pages, please check to see if you have all of them.
3. Place all class materials under your desk. This is a **CLOSED** book exam.
4. Quickly browse each problem before beginning the test. Note that some questions are worth more points than others.
5. You may use the reverse side of each sheet if you need more room.
6. If you have any questions about any problems, raise your hand until a proctor can help you.
7. Be brief in your answers.

The exam consists of the following parts:

- **Part A**: 3 multiple choice
- **Part B:** 5 short answer questions worth
- The time limit for the exam is **1 hour 30** minutes.

PART	MAX POINTS	SCORE
A	3	
B	17	

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Part A: Choose the correct answer (3 points)

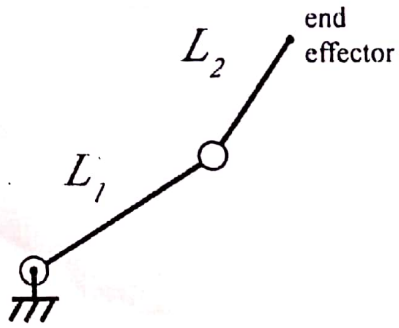
1. Forward kinematics determines the position and orientation of the end effector from which of the following
   a. forces on links
   b. joint angles
   c. joint torques
   d. link length
   e. a and d
   f. b and d

2. Which one of the following sequence of rotations is not Eulerian?
   a. XYX
   b. ZXY
   c. YXY
   d. XZZ

3. Which of the following vectors can be coordinate frames for a 3D space?
   a. $[0, 0, 2]^T$, $[1, 0, 1]^T$, $[4, 0, 6]^T$
   b. $[0, 1, 5]^T$, $[1, 0, 1]^T$
   c. $[1, 1, 1]^T$, $[1, 0, 1]^T$, $[3, 3, 3]^T$
   d. $[1, 1, 1]^T$, $[1, 0, 1]^T$, $[0, 3, 0]^T$

Part B: Short answers

4. (2 points) Concisely describe the set of points that the end effector can reach for the two-link robot where L1 > L2



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5. (3 points) Given a homogeneous matrix A_i:

$$A_i = \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

a. the axis of rotation? _____

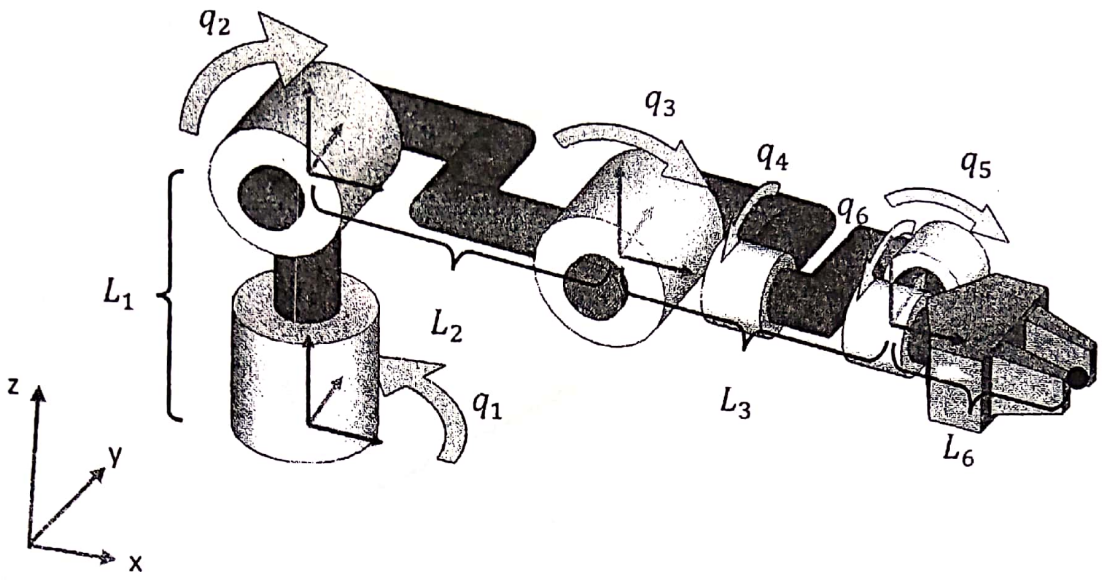
b. angle of rotation _____

c. translation in each axis _____

6. (4 points) Find the H matrix corresponding to the following transformation: First rotate by π/2 about the fixed y-axis. Then translate 7 units along the current y-axis. Then rotate by π/4 about the current z-axis. Finally translate 5 units along the current z-axis. (You don't need to evaluate the whole expression. I just expect you to clearly show the metrices)

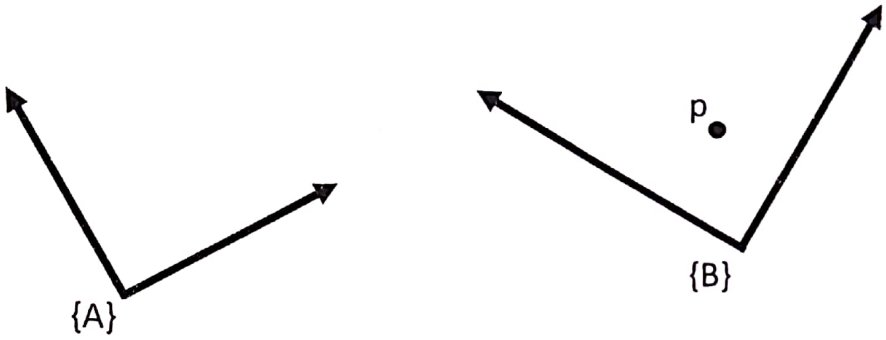
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7. (4 points) What is the pose of the end effector of the robot printed below?



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8. (4 points) The pose of coordinate system A is given by a rotation angle of 30° and a translation of 2 units in the x direction and 4 units in the y direction from the world coordinate system. And the pose of coordinate system B is given by a rotation angle of 30° and a translation of 1 unit in the x direction and 2 units in the y direction from coordinate system A. Given the position p is $[1, 1]^T$
   a. what is the position of p with respect to A?
   b. what is the pose of B with respect to the world coordinate system?



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Cheat sheet

$$R_x^{3D}(\omega) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\omega) & -\sin(\omega) \\ 0 & \sin(\omega) & \cos(\omega) \end{bmatrix} \quad R_y^{3D}(\phi) = \begin{bmatrix} \cos(\phi) & 0 & \sin(\phi) \\ 0 & 1 & 0 \\ -\sin(\phi) & 0 & \cos(\phi) \end{bmatrix}$$

$$R_z^{3D}(\kappa) = \begin{bmatrix} \cos(\kappa) & -\sin(\kappa) & 0 \\ \sin(\kappa) & \cos(\kappa) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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