Name: ____

RBE 3001: Unified Robotics III

Final Exam

Instructions:

1. **This is a 120 minute exam. Budget your time effectively!**
2. Print your name legibly in the space provided at the top of each page.
3. **You must show all your work to justify your answers. Partial credit will be assigned if you demonstrate your understanding of the material.**
4. The exam is open-notes. A formula sheet is attached.
5. The MCP3204 ADC spec sheet will be available online in Canvas as well as the formula sheet you were provided previously.
6. There are 10 questions printed on 8 pages (including the cover page).

Question	:	**1a**	**1b**	**1c**	**2**	**3a**	**3b**	**3c**	**4**	**5**	**6**	**∑**
Possible Max	:	20	15	10	10	5	5	5	5	5	20	100
Your Score	:											

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1. Figure 1 shows the diagram of a planar, 3-DOF PRR robot arm. The x and z axes of the F_0 coordinate system are shown.

   a. (20 pts.) Annotate the figure with all of the relevant link parameters – then use those link parameters to generate the D-H table for this robot. Clearly state all of your assumptions. Make sure you also clearly indicate the joint variables.

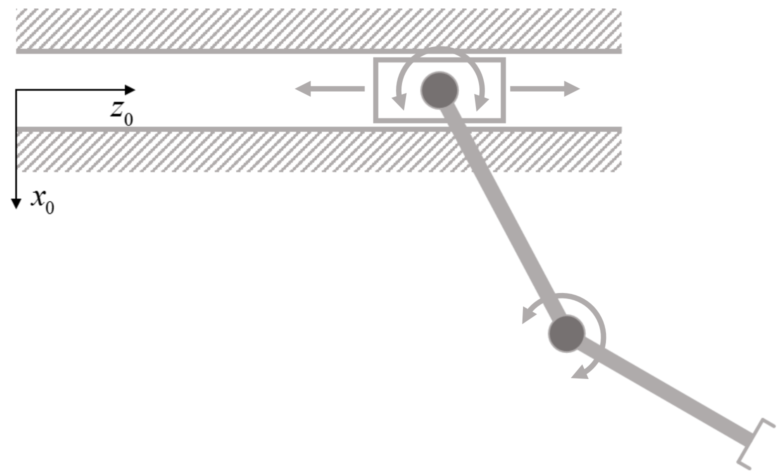
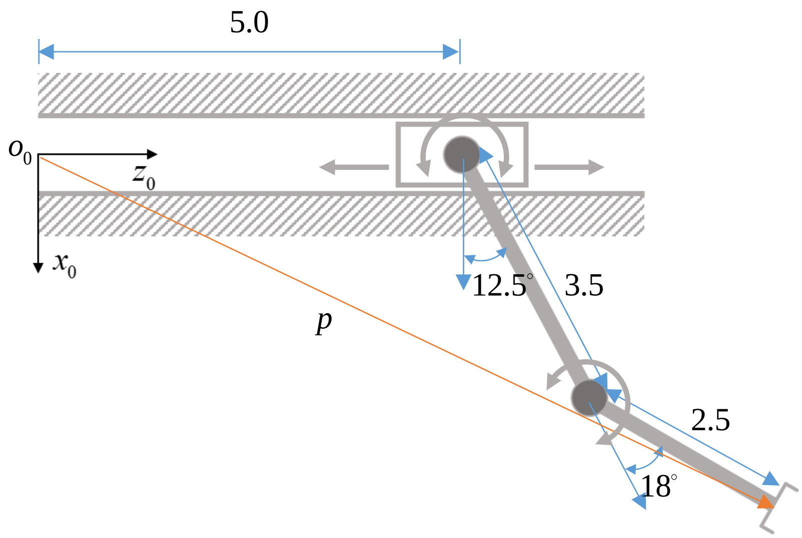


Figure 1: 3-DOF planar robot manipulator with a PRR configuration.

b. (15 pts.) Calculate the link-specific homogeneous transform matrices, $A_{i-1}^{i},\ i = 1, 2, 3$ for the PRR manipulator.

c. (10 pts.) Assume the dimensions (in decimeters) and angles shown below. Show how you can easily use the three HTMs you derived in part b to determine the location of the EOAT w.r.t. o_0 (the origin of the F_0 coordinate system). In other words, determine the vector p.



2. (10 pts.) It is desired to have the third joint of a 6R industrial robot go from an initial joint angle of 42° at time $t = 0$ seconds to a final angle of 76° at time $t = 4$ seconds. The joint must have a zero velocity at the beginning and end of the movement.

   Using a third-order polynomial, determine the joint angle at time $t = 2.5$ seconds.

3. Provide short answers (5 pts. each).

(a) When converting an analog signal to digital, there is always the issue of limited resolution. If you are measuring a signal which can vary from 0 to 5.0 volts, and you use a 12-bit ADC (which also measures from 0 to 5.0 volts), what is the smallest voltage difference you can detect? Be sure to show your work. Please calculate your answer to three significant digits.

(b) The MCP3204 ADC chip in the Hitachi accelerometer module you used in lab has an SPI interface. According to the data sheet, there is a maximum speed (2 MHz) at which you can drive the SPI clock; this is common for chips. But there is also a minimum clock speed (10 kHz), which is unusual. Explain why this particular chip has a minimum clock speed.

(c) Suppose you have an ultrasonic sensor which emits a very short pulse every 100 milliseconds. What is the maximum distance this sensor can detect without having to worry about aliasing? Be sure to show your work. List any approximations you use.

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4. (5 pts.) A Jacobian always has 6 rows. What determines the number of columns in a Jacobian?

5. (5 pts.) Suppose you want to go in the other direction, e.g., $\dot{q} = J^{-1}(q)v$. For this to work, the Jacobian must be invertible. What does it mean if the Jacobian is <u>not</u> invertible?

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6. (20 pts.) In the mid-term exam, you developed a path to fly the drone from the landing pad (D_0) to an intercept with the suspect at point B (D_6). One possible path is shown in the following figure. The HTM from the starting pose to the ending pose of the depicted path is given by:

$$T_0^6 = \begin{bmatrix} -0.988 & -0.152 & 0 & -6.5 \\ 0.152 & -0.988 & 0 & 7 \\ 0 & 0 & 1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

This tells us, for example, that the drone, when located at point B, is located at $X = -6.5$, $Y = 7$, and $Z = 5$ w.r.t. the coordinate system associated with the landing pad.

Using the supplied HTM, calculate the location of the landing pad w.r.t. the drone's local coordinate system as it hovers over point B as shown (i.e., having flown the indicated path).