ME 115(a): Final Exam

Instructions

1. Limit your total time to 5 hours. That is, it is okay to take a break in the middle of the exam if you need to ask me a question, or go to dinner, etc.
2. You may use any class notes, books, or other written material. You may not discuss this final with other students or other people except me or the T.A.s.
3. You may use mathematica or any software or computational tools to assist you. However, if you find that solution approach requires a lot of algebra or a lot of computation, then you are probably taking a less than optimal approach.
4. The final is due by 5:00 p.m. on the last day of finals.
5. The point values are listed for each problem to assist you in allocation of your time.

Problem 1: (35 Points)

The first three joints of the "armatron" manipulator that we used for demonstrations in class looks like Figure **??**

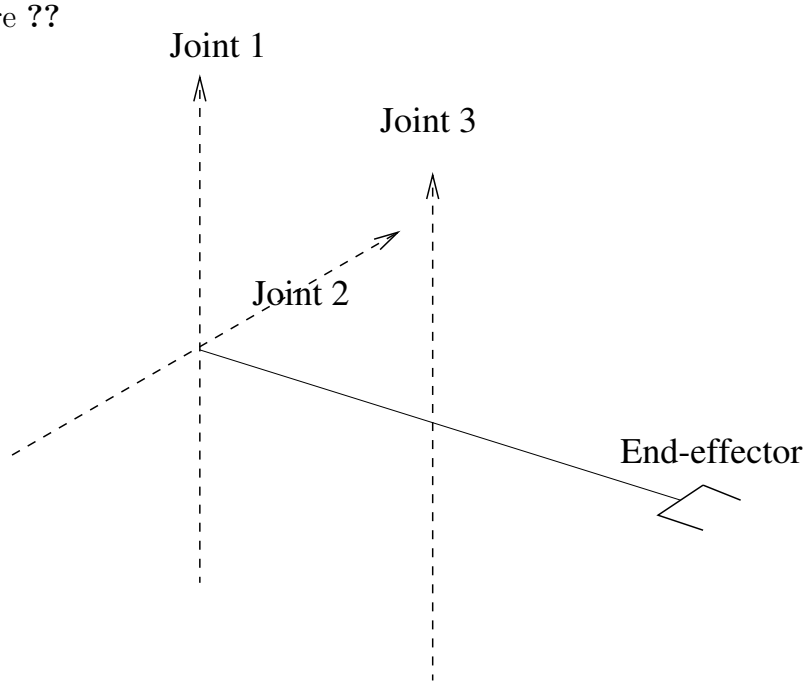

Figure 1: Schematic of Armatron Manipulator Geometry

Part (a): (5 points) Determine the Denavit-Hartenberg parameters.

Part (b): (7 points) Using either the Denavit-hartenberg approach or the product-of-exponentials approach, determine the forward kinematics.

Part (c): (8 points) Develop an expression for the spatial Jacobian matrix for this manipulator.

Part (d): (15 points) Solve the inverse kinematics of this manipulator, assuming that the goal is to position the origin of the tool frame.

Problem 2: (20 Points) Consider the two screws, S_1 and S_2, shown in Figure **??**. S_1 is perpendicular to the plane, P, and has zero pitch: $h_1 = 0$. The screw axis of S_2 lies in P, and S_2 some non-zero pitch, h_2. The distance between S_1 and S_2, as measured along a mutually perpendicular line, is denoted a. Describe the set of all screws whose axes lie in P and that are reciprocal to both S_1 and S_2.

Problem 3: (12 Points)

Recall our definition of a rigid body as a collection of points. Also recall the definition of "spherical motions" as those motion where one point in the rigid body remains fixed. Prove that a rigid body undergoing spherical motion has three degrees of freedom.

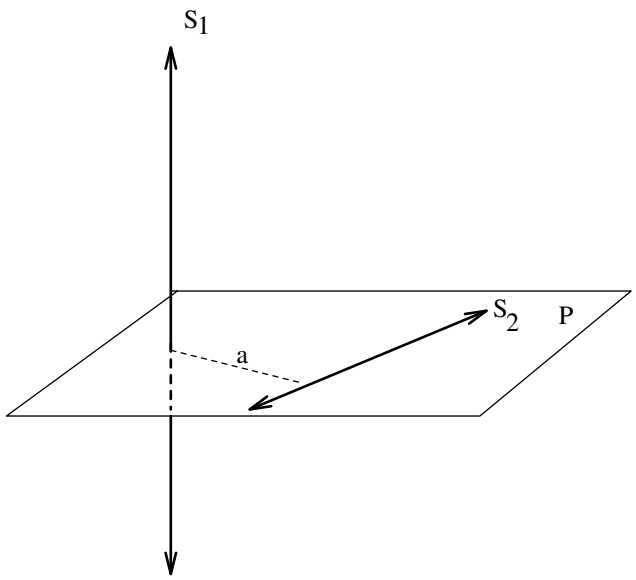

Figure 2: Two Screws

Problem 4: (16 Points) Do problem 11(d,e) in Chapter 2 of the MLS text. Recall that you have already done 11(a,b) in Homework #3. You need not rederive any results that were already developed in this homework solution.

Problem 5: (17 points)

For the rotation matrix given below

$$R = \begin{bmatrix} 0.833333 & -0.186887 & 0.52022 \\ 0.52022 & 0.583333 & -0.623773 \\ -0.186887 & 0.79044 & 0.583333 \end{bmatrix}$$

Part (a): (8 points) Compute the axis of rotation and angle of rotation.

Part (b): (4 points) Determine the unit quaternion that is equivalent to this rotation.

Part (c): (5 points) What are the z-y-z Euler angles of this rotation?