ME 115(b): Final Exam, Spring 2015-16

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. Also, don't include the time it takes to download and watch the videos as part of the 5 hours.
2. You may use any class notes, books, or other written material.
3. You may use any material on the course website (in fact, for some problems you will need to access videos on the course web site), but not other internet sites.
4. You may use mathematica or any software or computational tools to assist you.
5. Feel free to ask me or the T.A.s questions about the exam.
6. The final is due by 5:00 p.m. on the last day of the final period. If you need your grade turned in to the registrar for purposes of graduation, then the final is due at 5:00 p.m. on Friday, June 3.
7. The point values are listed for each problem to assist you in allocation of your time.
8. Please put all of your answers in a blue book, or carefully staple the pages of your work together in the proper order (adding page numbers and/or problem numbers to the pages will help me).

Problem #1 (45 points): Parallel Mechanisms–Mobility and Kinematics

Part (a): (10 points) Consider the video of the "Spider Mechanism" milling machine on the course web site. What is the mobility of the body which holds the milling tool relative to the object being milled? How do you prove your answer?

Part (b): (35 Points) Consider the "Rostock" Delta mechanism seen in the "Rostock Mechanism" video on the course web site. Instead of 3 revolute joints driving the mechanism like the classical Claval Delta mechanism that we studied in class, this variant is driven by three vertically oriented prismatic actuators.

- (5 points) What is the mobility of this mechanism? Back up your result with a calculation.
- (10 points) Can this mechanism have an actuator or kinematic singularity?
- (20 points) Find the inverse kinematics to position the origin of the tool frame, (x_T, y_T, z_T), at a desired location.

Problem #2 (20 Points): Special Configurations of "Slider-Crank" linkages.

Consider the "slider-crank" four bar linkage shown Fig. 1. This mechanism, which is commonly used as the piston mechanism in an internal combustion engine, consists of three revolute joints and one prismatic joint. The joints are numbered successively, with the first joint being at the left of the figure, and the fourth joint being the prismatic joint.

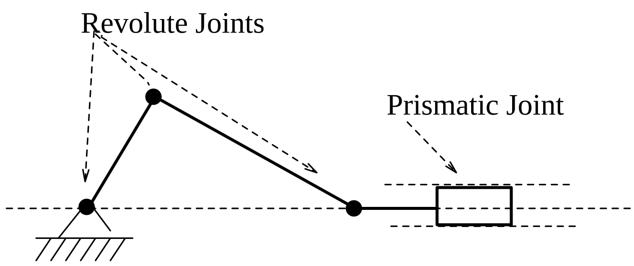

Figure 1: Slider Crank Mechanism

Part (a): (7 points) One of the special configurations is obvious: the piston (or prismatic joint) is at "top dead center," and the cylinder comes momentarily to rest in this position. Show that this configuration is indeed a special configuration. In particular, show that joint 4 has a stationary configuration when $\theta_1 = 0$ and $\theta_2 = 0$.

Part (b): (13 points) Develop an expression for the stationary configurations of joint 1. What are the necessary conditions for joint 1 to have a stationary configuration?

Problem #3 (25 Points): (force closure)

This problem will consider the issue of force closure for the two grasps shown in Figure 2.

Part (a) (10 Points): Consider the an equilateral triangle grasped by three point contact fingers, as shown in Figure 2(a). Each finger contact ies at the midpoint of each triangle edge. Assume that finger contacts #1 and #2 are frictionless. Assume that there is friction at contact #3.

- Sketch the structure of the grasp map for this grasp
- Is this grasp force closure? Justify your answer using one of the force closure definitions.

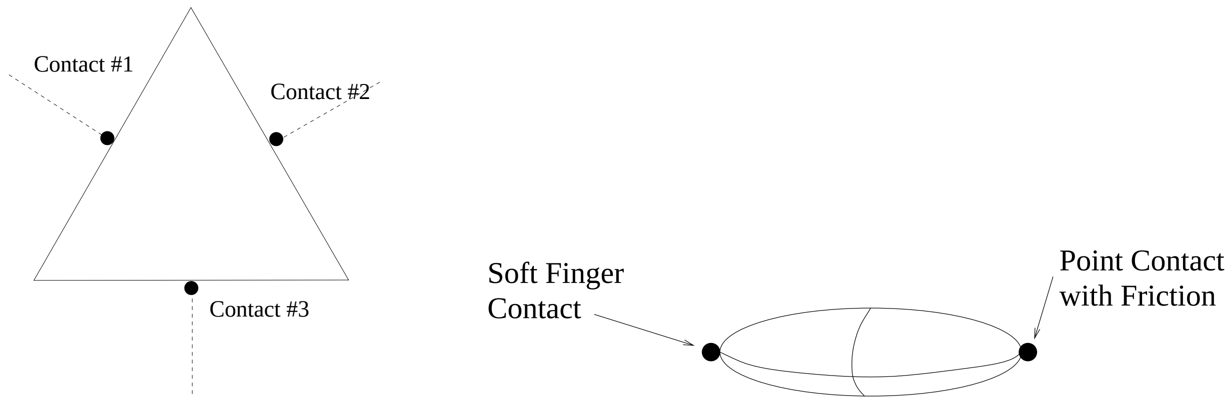

Figure 2: (a) 3-fingered grasp of a planar triangle; (b) 2-fingered grasp of an ellipsoidal Object

Part (b) (15 points): A 3-dimensional ellipsoidal body is grasped by two fingers in an antipodal point grasp (Figure 2(b)). Let one of the contacts be modelled by the point contact with friction model. Let the other contact be modelled by a soft finger contact.

- Construct the grasp map for this grasp
- Is this grasp force closure? Justify your answer using one of the force closure definitions.

Problem #4 (15 Points): (grasping kinematics) For the grasp pictured below, assume a point contact with friction model, where $\mu = \tan 30^o$.

1. Is this grasp Force Closure?
2. What is the structure of the grasp constraints?
3. Is this grasp manipulable?

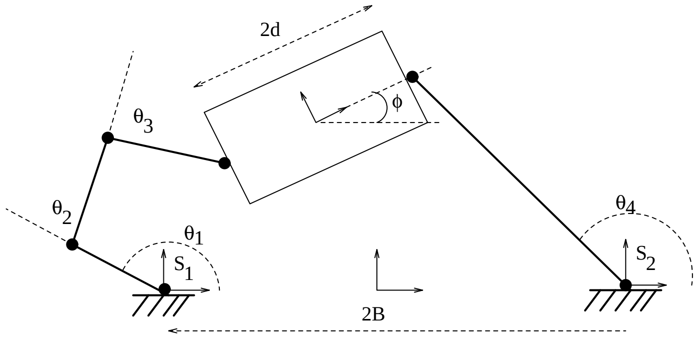

Figure 3: Two Fingered Grasp

Extra Credit (10 Points): (curvature of a planar hyperbola)

A planar hyperbola can be parametrized by the equation:

$$x(t) = a\sec(t) = \frac{a}{\cos(t)}; \qquad y(t) = b\tan(t) \tag{1}$$

where a and b are constants, and t is a curve parameters (not necessarily arc-length).

- What is the curvature of the hyperbola curve at a given point t'?
- What are the contact equations for a hyperbola roll-sliding on a flat plane?