2.007 Design and Manufacturing I
Spring 2009

2.007 – Design and Manufacturing I

Practice Exam on Drawing, CAD, Motors, Pneumatics, and Mechanisms

This practice exam is intended for a 1.5 hour period. It has 8 problems and 100 points total. NOTE: These are problems we made up and decided not to use on the exam in this form. We thought maybe they were not as clear as we wanted or didn't match our objectives perfectly. So, this practice exam is not quite representative, but practicing on imperfect problems is better than not practicing.

1. (20 points) A vehicle is composed of a box shaped structure with permanent magnet DC motors placed at all four corners and driving all four wheels (each through a gear train). All these motors are attached to a 5V NiCad battery pack. The coefficient of static friction between the wheels and the surface is 0.5. The vehicle starts from a stand still on level ground. The stall torque is 0.3Nm and the no load speed os 50rpm. The vehicle weight is 1N and the wheels are fairly hard.

   a) (5 pts) Draw a torque speed curve for the motor.
   b) (10 pts) Describe the situation when the voltage is first applied to the motors. Indicate the operating point on the torque speed curve.

   When the voltage is first applied, the motor is at it stall condition since the shaft speed is zero and so the torque is that the stall torque.

   c) (5 pts) Describe the situation when the vehicle reaches its steady state velocity on level ground. Indicate the operating point on the torque speed curve.

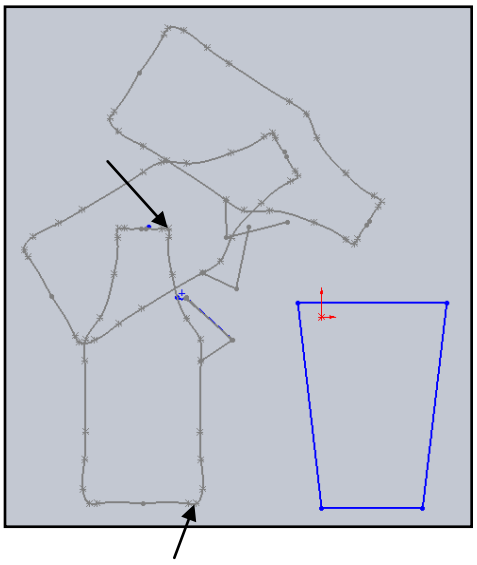
   When the vehicle is at its top speed, the motor may be very close to its no load speed. If the rolling resistance and drag are low, the top speed might be set at nearly the no load speed times the wheel radius.

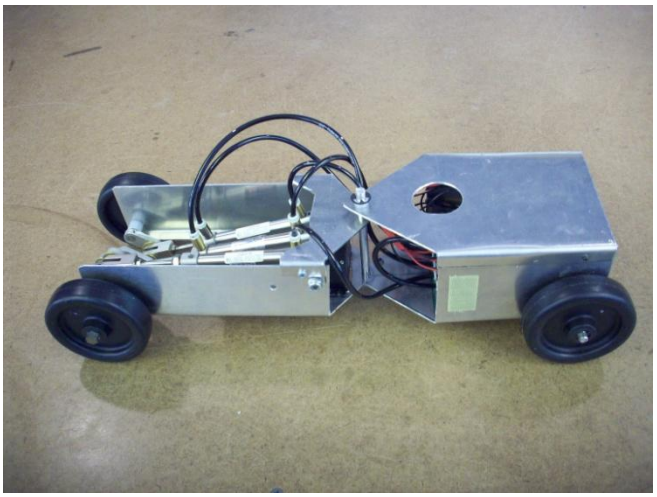
2. (10 points) A bottle of soda is to be poured by a machine. Three positions desired are depicted here to the right. We want to make 4 bar mechanism that attaches to the locations indicated by the arrows.

   a) Synthesize the mechanism. **By "synthesize the mechanism", I just mean sketch out the three points the end of the coupler curve must occupy and draw the circle defined by that set of 3 points indicating it center.**
   b) Sketch the mechanism in the first position where the bottle is still on the table.

   Draw a link from the center of the cirle to the point on the first position of the bottle.

   c) Describe your steps.

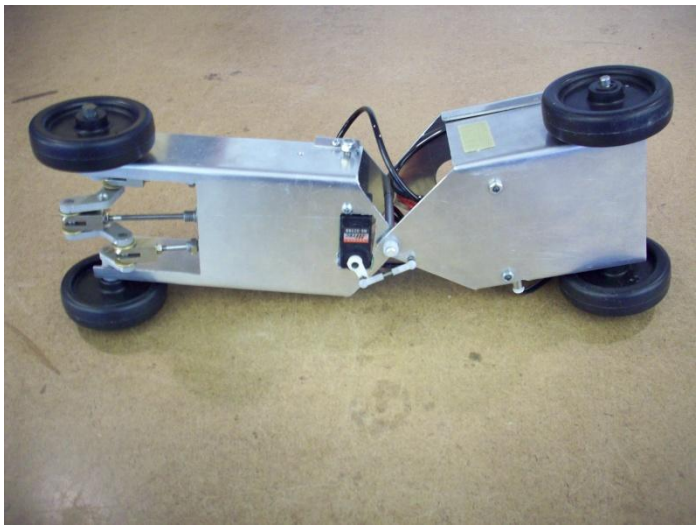




3. (10 points) A vehicle is composed of 3 pneumatic pistons attached to a straight shaft at one end and a crankshaft at the other. Each piston is atatched to two compressed air lines, one for extension and one for retraction. Each air line is attached to a spply of high pressure air through a solenoid actuated valve. The crankshaft has three pins displaced from the main bearings by one inch and separated from each other pin by 120 degrees. Describe using words and graphics, a process by which solenoid actuated valves can be used to drive the rear wheel clockwise and therefore propel the vehicle forward. What specifically is the sequence of "firing" of the pneumatic actuators you propose for propelling the vehicle?

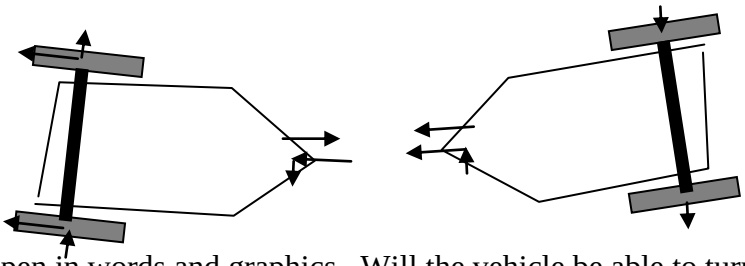
The valves can be use to extend two of the pistons and retract the other. Then one can be extended while the other two are retracted. This scheme can be repeated through six different states. A firing sequence I propose is.

Piston
1 2 3
+ + -
+ - -
+ - +
- - +
- + +
- + -



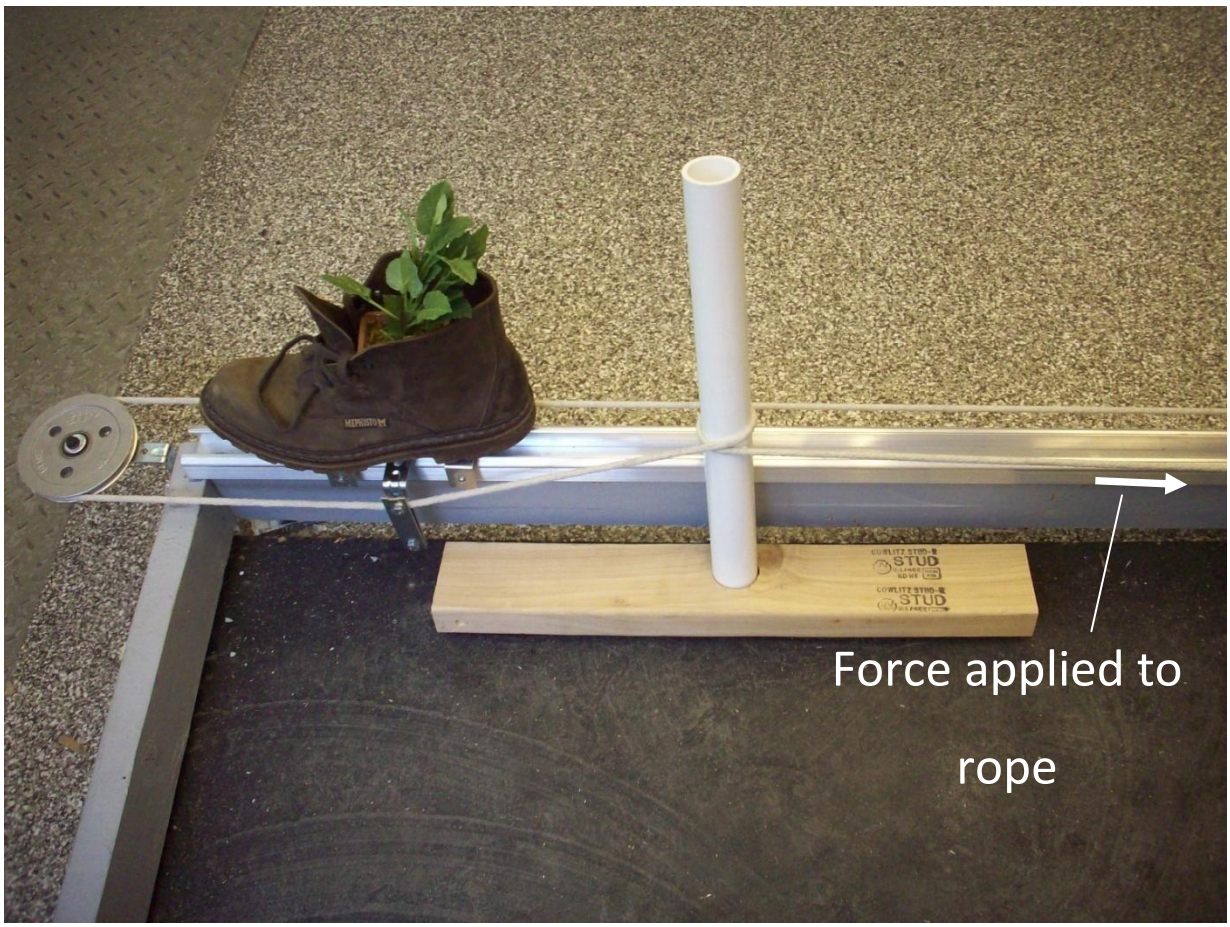
4. (10 points) Consider the same vehicle as in problem 5. It is proposed to steer the vehicle using a standard hobby servomotor. The vehicle is segmented into a front and aft part and a pin joint is arranged in the middle to connect them. The body of the servomotor is rigidly attached to the rear segment of the vehicle. The end of the servo horn is connected to a link and the other end of that link is pinned to the rear segment of the vehicle.

a. Make a free body diagram of the vehicle and its front and rear segements. Assume the car was proceeding straight when, at that moment, a torque of 0.3 N*m is applied by the servo.



b. Explain what will happen in words and graphics. Will the vehicle be able to turn with a servo connected in this manner? Will the front or rear wheels slide laterally?

The vehicle will turn using this scheme. The middle of the vehicle will displace while the wheels stay relatively stationary. The wheels will not displace laterally very much unless the weight distribution is far from even.

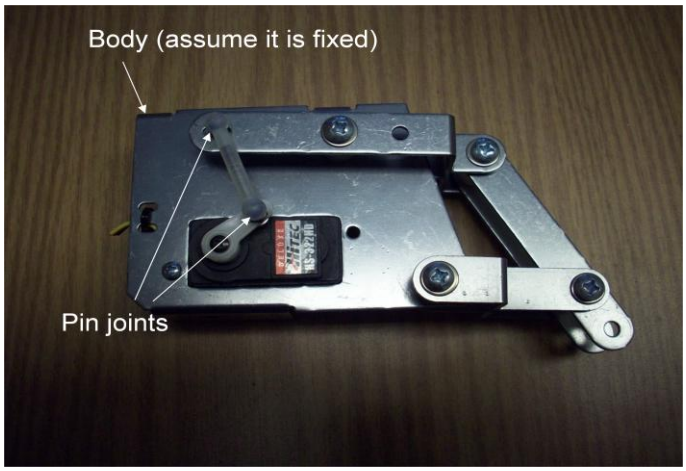


5. (10 points) A person wishes to keep a rope in a fixed location despite a force applied to the rope by another person seeking to move it. They propose to wrap the rope once around a PVC pipe (as shown above). The end of the PVC pipe is placed within a hole in a 2 in by 4 in piece of lumber which is then pinned in place (the pin is not shown above) .

    a. Make a free body diagram of the PVC pipe.
    b. Estimate the force that will result in moving the rope. You may assume the tension in the left side of the rope is initially 20N and that the coefficient of friction between the rope and PVC pipe is 0.3.

T=W*e^(mu*theta)=20N*e^(0.3*2*pi)~130N

6. (5 points) How many degrees of fredom does this mechanism possess? Describe your solution process.



3*5 = 15 DOF for the 5 bodies.

7*2=14 DOF for the 7 full pin joints

Leaving 1DOF

7. (15 pts total) This question and its several parts (a-d) are based on the two images of a piston below.

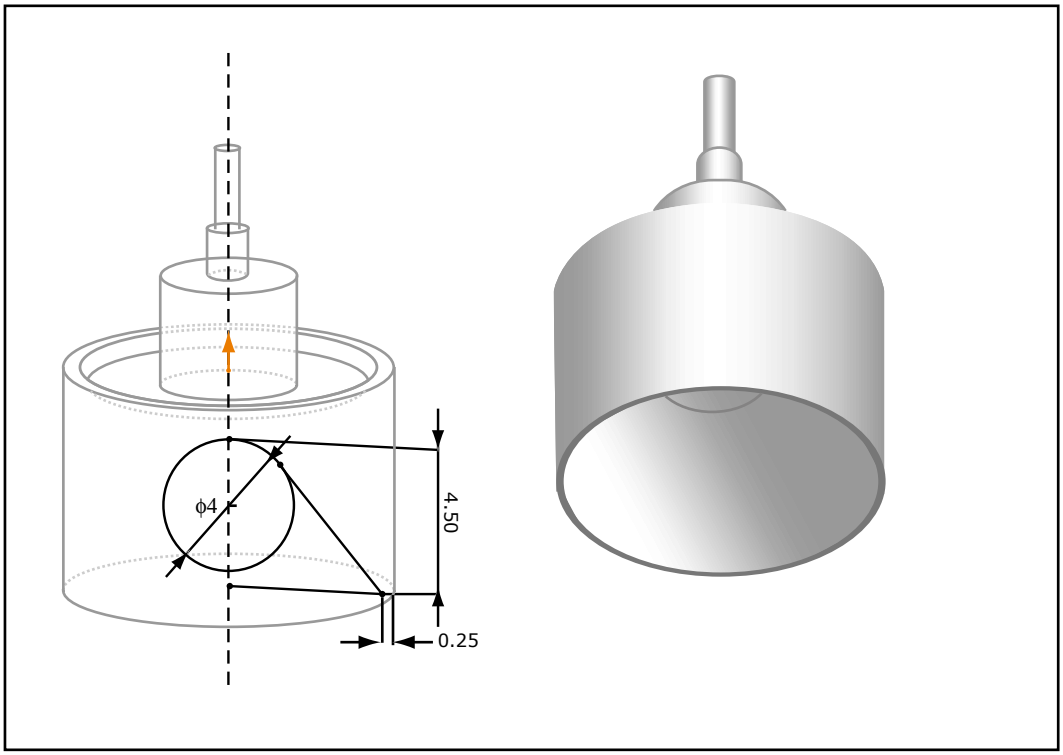


Figure by MIT OpenCourseWare.

Part geometry from SpinMaster Toys, Inc.

a) (3pts) The interior surface at the bottom of the piston is defined by the sketch geometry in the graphic. What operation do you think transformed the sketch into the 3D feature? Briefly explain why.

CUT REVOLVE

b) (2pts) Given the way that the sketch is dimensioned and constrained including the tangency of the line and the circle, describe briefly in words how the resulting cavity be affected by changes in its overall depth (which is currently 4.50*mm*). How will the angle subtended by the arc and the angle of the tangent line vary?

If the depth is reduced, the cone in the bottom will become shallow. The arc subtended by the circle will be reduced.

c) (5pts) Make a sketch of the part with the cavity depth decreased to 2.00*mm*.

d) (5pts) Describe what engineering concerns may arise if the cavity depth is increased to, for example, 9*mm*.

At 9mm cavity depth, the cavity will extend out above the surface above it. This will rend the part into two separate pieces.

8. (20 pts total) Make three view drawing from the isometric drawing shown here.