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2.007 Design and Manufacturing I  
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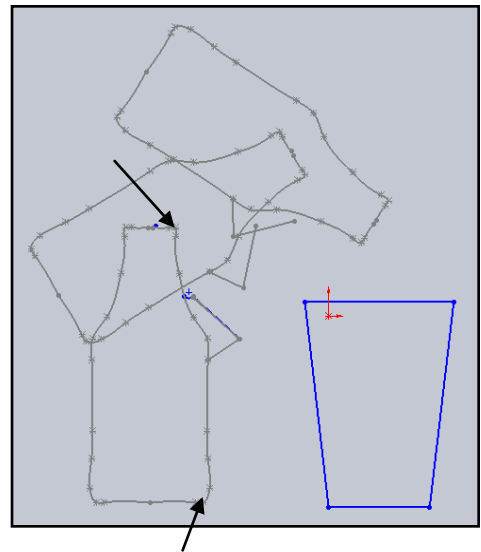
## 2.007 – Design and Manufacturing I

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

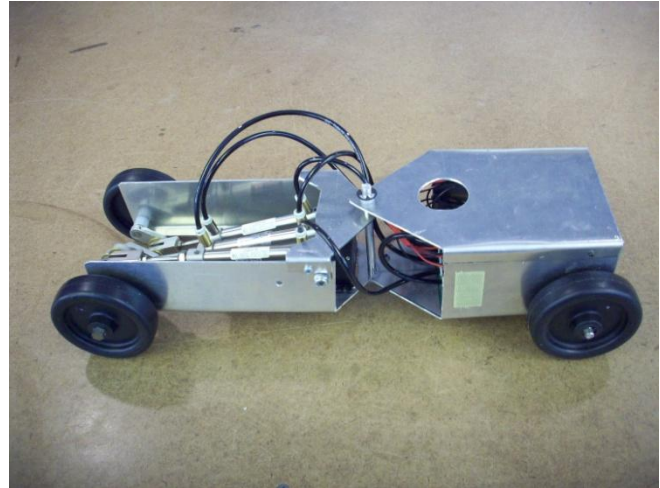
This practice exam is intended for a 1.5 hour period. It has 8 problems and 100 points total.

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 is 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.
  - 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.
  
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 a 4 bar mechanism that attaches to the locations indicated by the arrows.
  - a) Synthesize the mechanism.
  - b) Sketch the mechanism in the first position where the bottle is still on the table.
  - c) Describe your steps.



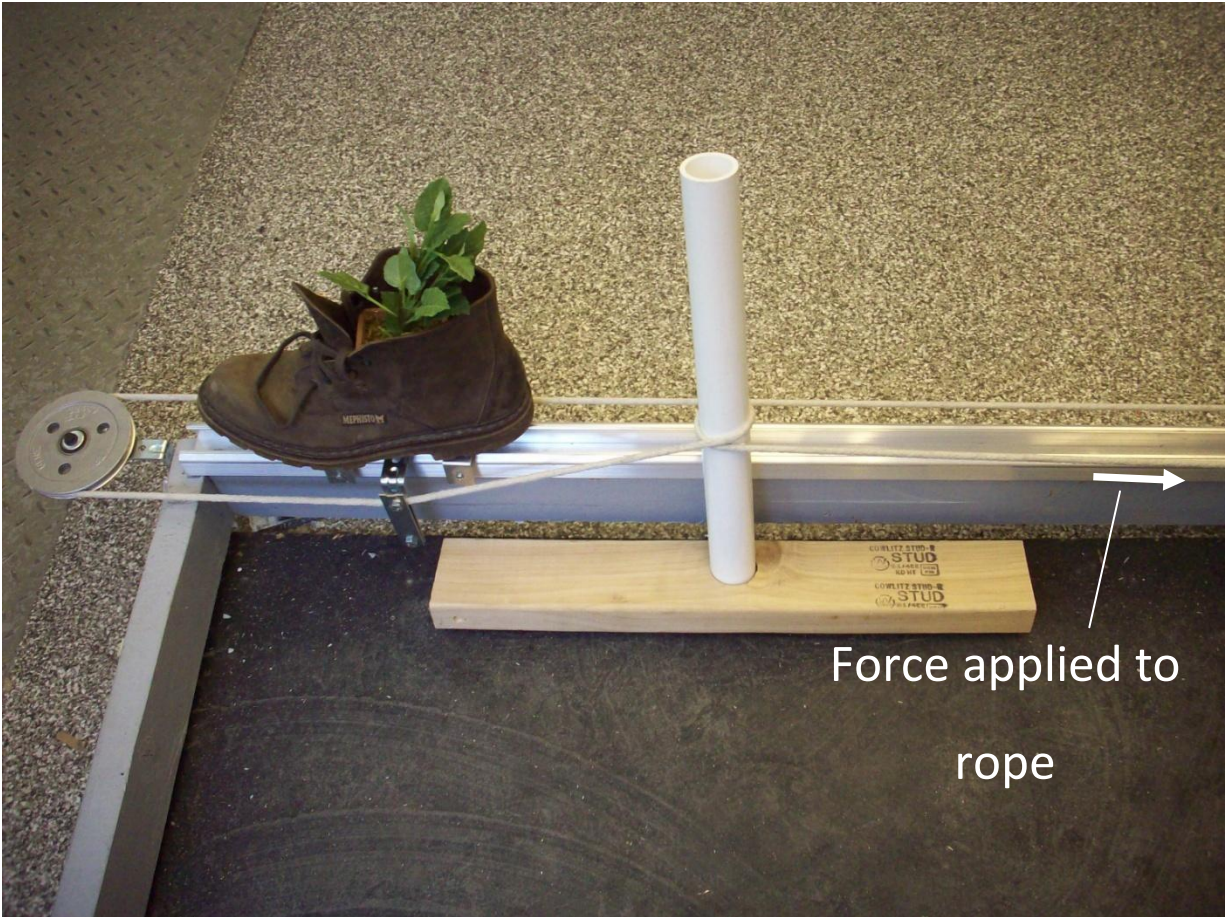
3. (10 points) A vehicle is composed of 3 pneumatic pistons attached to a straight shaft at one end and a crankshaft at the other. Each piston is attached to two compressed air lines, one for extension and one for retraction. Each air line is attached to a supply of high pressure air through a solenoid 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?



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.

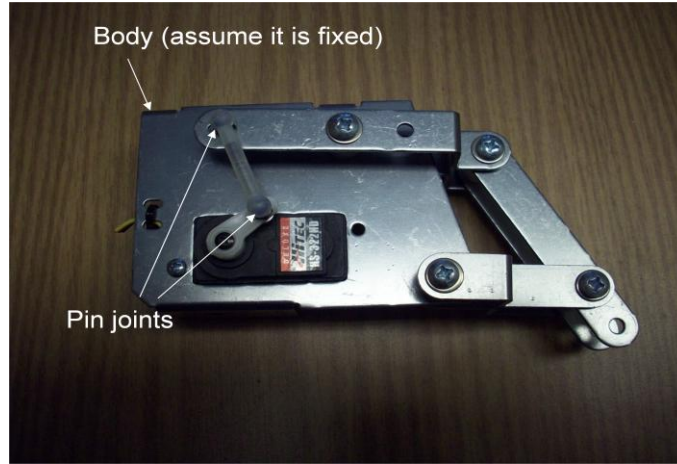


- Make a free body diagram of the vehicle and its front and rear segments. Assume the car was proceeding straight when, at that moment, a torque of  $0.3 \text{ N}\cdot\text{m}$  is applied by the servo.
- Explain what will happen in words and graphics. Will the vehicle be able to turn with a servo connected in this manner? Will the front or rear wheels slide laterally?



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).
- Make a free body diagram of the PVC pipe.
  - 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.

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



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

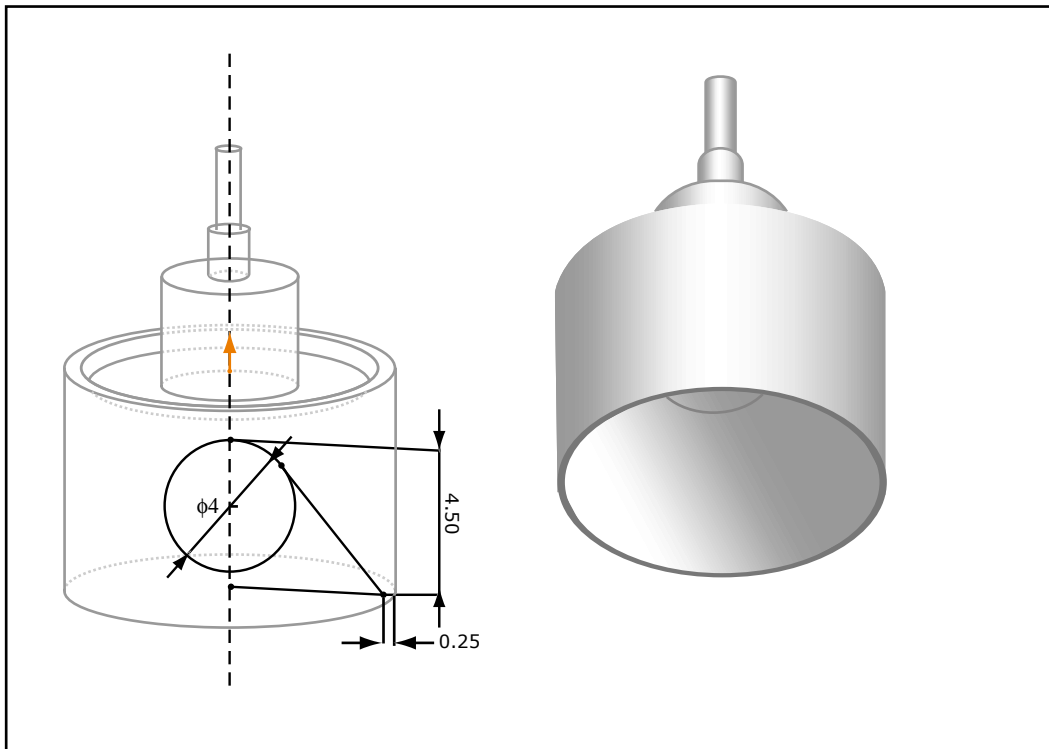


Figure by MIT OpenCourseWare.

Part geometry from SpinMaster Toys, Inc.

- (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.
- (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 4.50mm). How will the angle subtended by the arc and the angle of the tangent line vary?
- (5pts) Make a sketch of the part with the cavity depth decreased to 2.00mm.
- (5pts) Describe what engineering concerns may arise if the cavity depth is increased to, for example, 9mm.

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

