2.007 Design and Manufacturing I
Spring 2009

2.007 – Design and Manufacturing I
Draft Exam on Drawing, CAD, Motors, Pneumatics, and Mechanisms

You have 1.5 hours to answer the following 9 questions. Please show your work to the extent possible given the allotted time. Point allocations (out of 100 total) are listed for each question.

1. (10 points) What tension, T, must be applied to <u>raise</u> the 4 N weight at a constant rate?
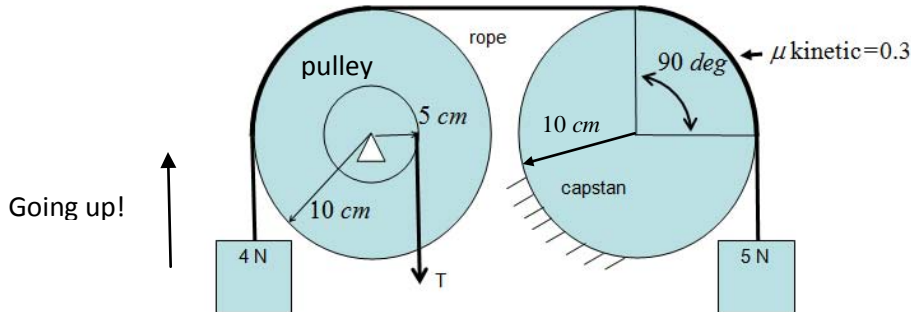
First, I deal with the right side which is a capstan and NOT a pulley
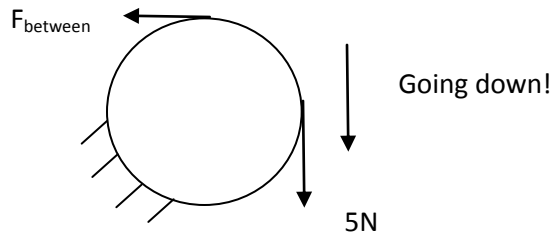
By the capstan equation $F_{between}$=5N*e^(-µ*Θ)=5N*e^(-0.3*π/2)=3.12N

NOTE the sign in the exponent. It is nagative because the 5N weight is going down and the frictional forces oppose the motion resulting in a lower tensile force in the rope in between the capstan and the pulley than was applied by gravity.

Next, I deal with the left side which is a pulley and NOT a capstan

Sum of moments about the pivot SM=4N*10cm-$F_{between}$*10cm-T*5cm=0

T=1.76N
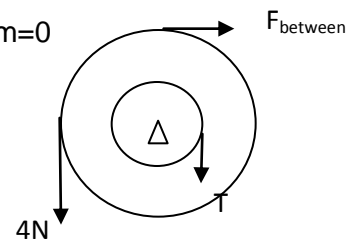
2. (5 points) How many degrees of freedom does this mechanism possess?

4 Bodies each with 3 DOF = 12 DOF
5 full pin joints eacg remove 2 DOF = -10 DOF

Leaving **2 DOF** of the mechanism

One of the DOF is associated with the parallelogram linkage
Comprised of the base, two links extending from the base, and
the triangular piece near the top of the lamp.
The other degree of freedom is associated with the lamp head itself which
Is free to rotate about its pivot.

Some students thought perhps some of the elements of the mechanism were
Redundant, but none of them are.

Base is fixed to the
table
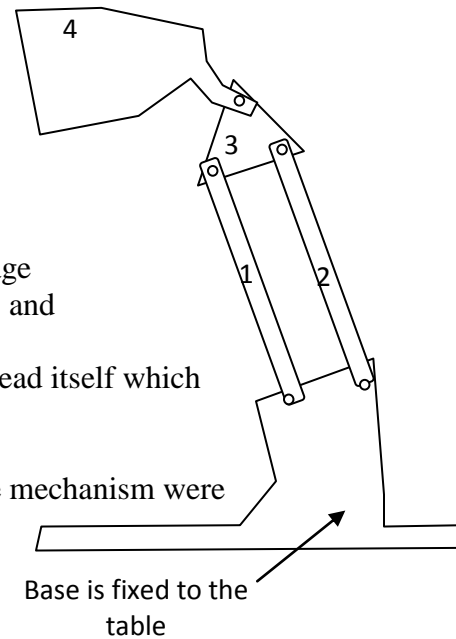
3. (5 points) The components shown here (resistor,
   LED, capacitor, battery, and switch) are connected in
   series. The switch is closed for 5 seconds. During
   that time, the LED lights and then gradually dims.
   The capacitor is then removed from the circuit and
   reconnected as shown. The switch is then closed.
   Which statement best describes what happens after
   the switch is closed again:

a) The LED lights up and then slowly dims over the
   course of 5 seconds
b) The LED starts dim then slowly brightens over the
   course of 5 seconds
c) The LED lights up steadily
d) LED does not light

Switch is closed for 5 seconds

5 V   2 kΩ

470 μF

Switch is closed again

2 kΩ

Circuit is
re-arranged

470 μF

The capacitor is charged during the first 5 sec
interval. It is discharged in the next interval. Note
that the capacitor is placed in the circuit facing the
opposite direction which is necessary to put the
higher voltage at the correct side of the diode. Note
also that the time constant RC has not changed so the
dimming should occur at the same rate as before.
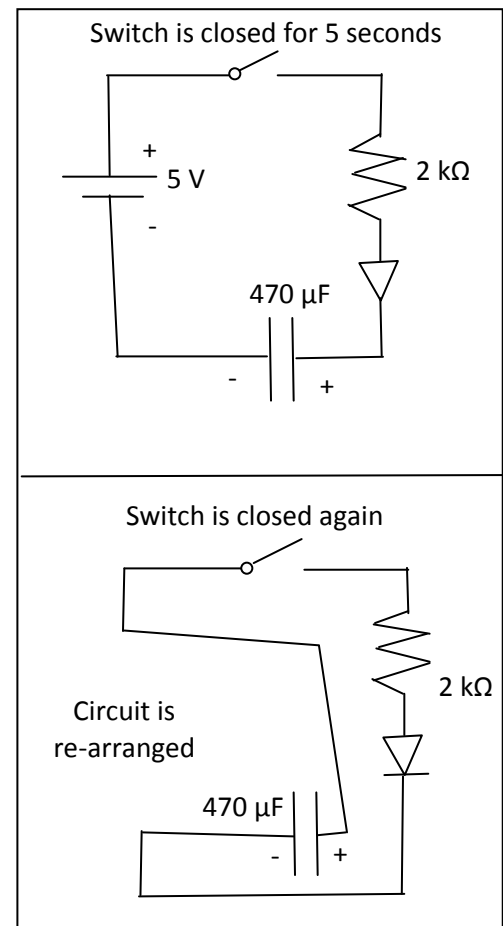
4. (15 points) Sketch a four bar mechansim that could guide the trash barrel and the frame supporting it through the three positions indicated here so that compost can be deposited automatically in the hopper to the right. Please use the attachment points on the frame indicated by arrows.

Attach links here
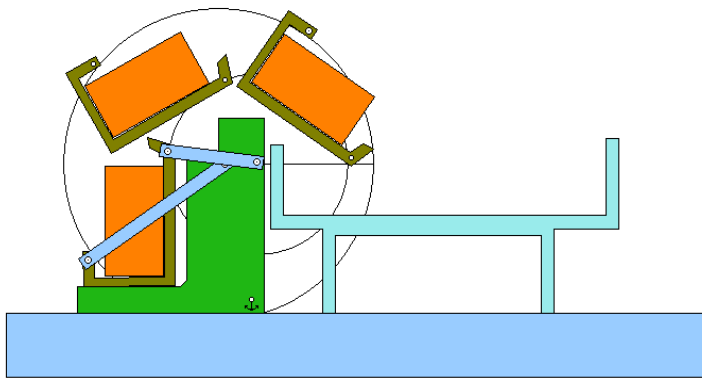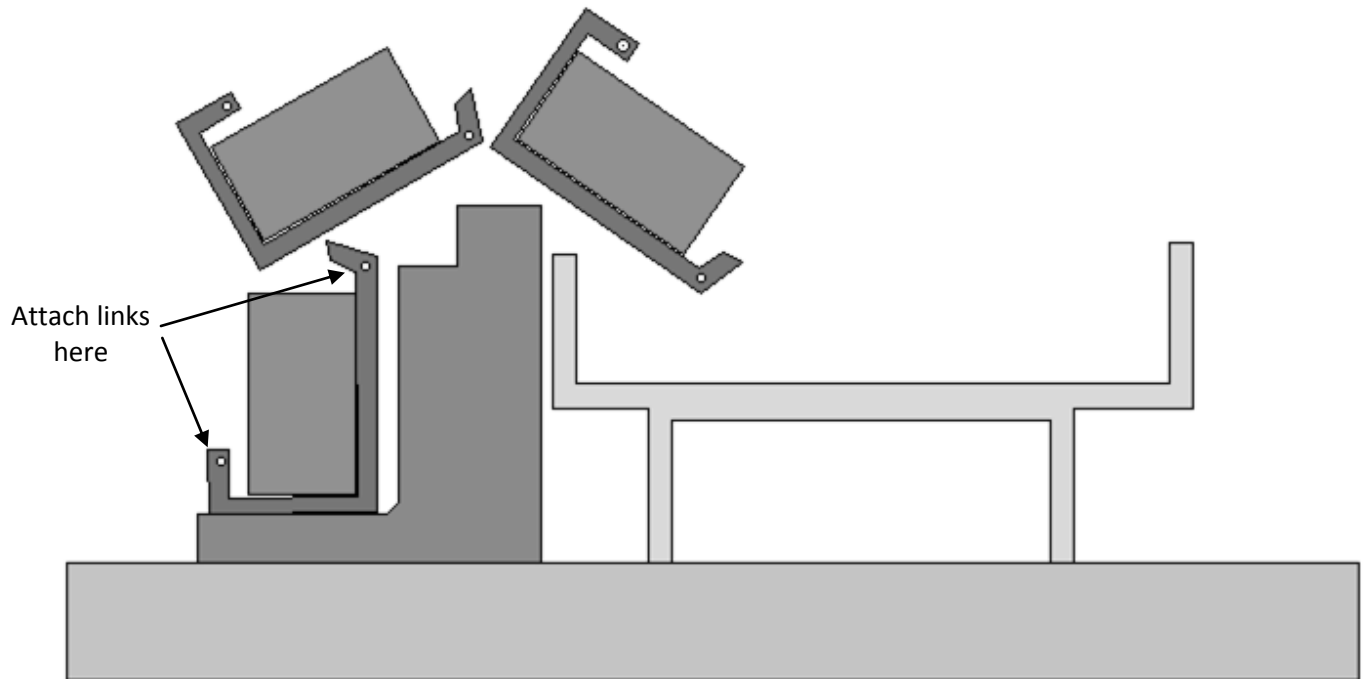
See the working model file online – composter1

5. (20pts total) Make three views (top, front, and side) of the part that is shown in an isometric view below. Please retain the proportions and show hidden lines and center lines as appropriate. Please align the three views with respect to one another.
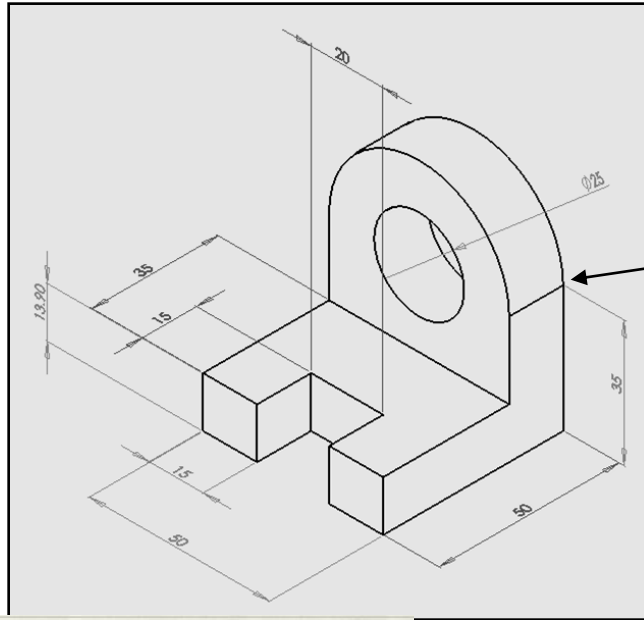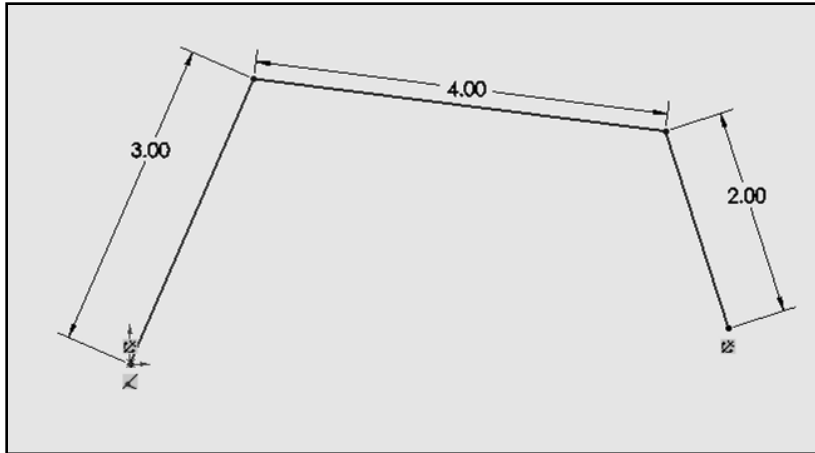

This line should not be there.

My mistake (well, Solidworks puts it there and I forgot to get rid of it).

NOTE: I had to make the figure in the
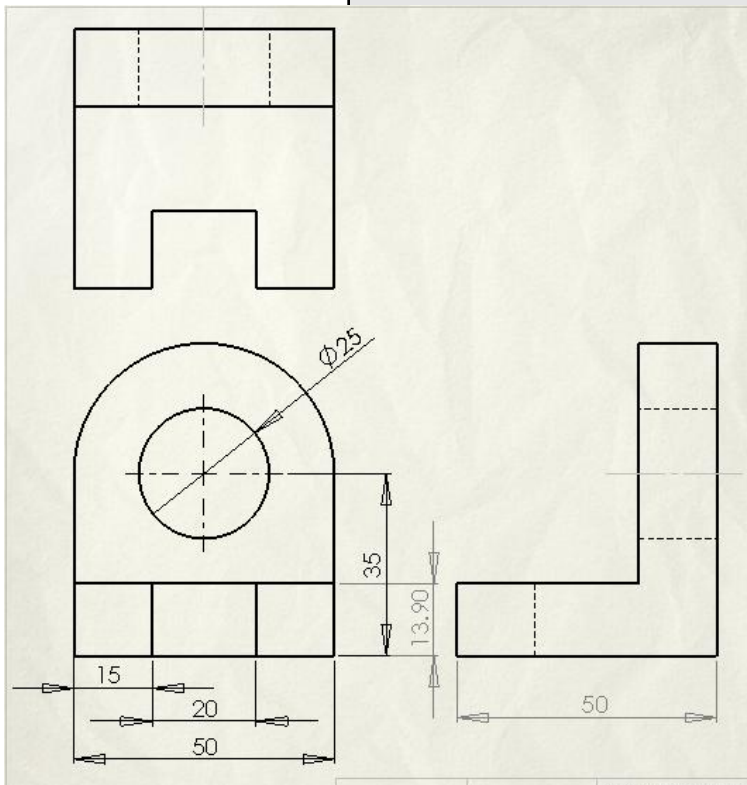
6. (5 points) Describe a step you might take in Solidworks to fully constrain the sketch below.

You can place an angular dimension between any pair lines. Similarly, you can place some other constraint that removes a single degree of freedom. Any action that removes two or more degrees of freedom (such as fixing a point or dimensioning two angles) will OVER dimension the sketch.

7. (10 points) A bike is travelling straight and at a constant speed up a 30 degree hill. The bike and rider together weight 200N. Estimate the tension in the part of the chain indicated by the arrow.

NOTE: The wheels are about 3 times the diameter of the front sprocket and about 7 times the diameter of the rear sprocket.


What is the tension in the chain at this location?

30 *deg*

Sum the forces in the direction along the surface. That will show the frictional force needed to keep the bike moving at a constant speed is 200N*sin(30*deg)=100N.

Note that only the rear wheel will apply a substantial frictional force pushing the rider up the hill. The front wheel should roll along applying the needed reaction force and maybe some rolling resistance which we can neglect for the purpose of this problem.

Note that a 200N bike and rider is awfully light. Might be a 4-year-old girl.

Sum the monents about the rear wheel. There is only the 100N frictional force applied at the bottom edge and tangent to it and the chain tension which is applied at the top of the rear sprocket and tangent to it. The ratio of the two radii is 7, so the solution is 700N.

8. (10 points) A designer proposes to change the dimensions of an electric motor by increasing the radius of the armature significantly (e.g., by 50%) (see the figure below). All other parameters of the motor are preserved as they were (number of windings, strength of the magnetic field, and so on). Which statement is most accurate:

a) (5 points) State the effect on the stall torque. **Increases by 50%**
b) (5 points) State the effect on the no load speed. **Decreases proportionally to 1/1.5 which is a 33% decrease**
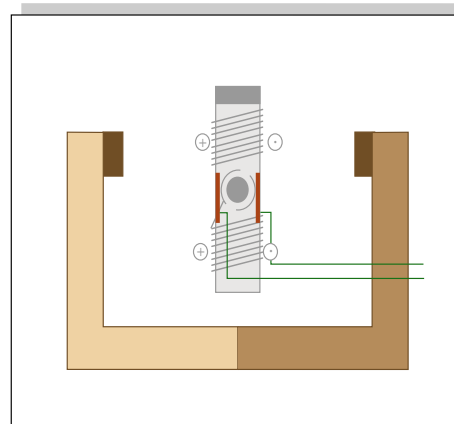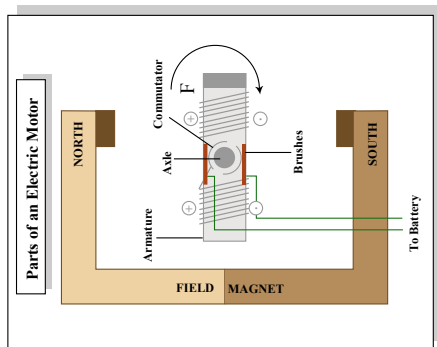
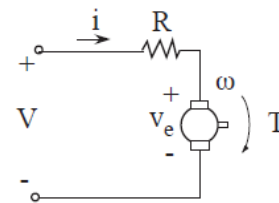Figures by MIT OpenCourseWare.

Motor before changes

Motor with longer armature radius

NOTE: The equations below have been proposed to model the behavior of a permanent magnet DC motor.
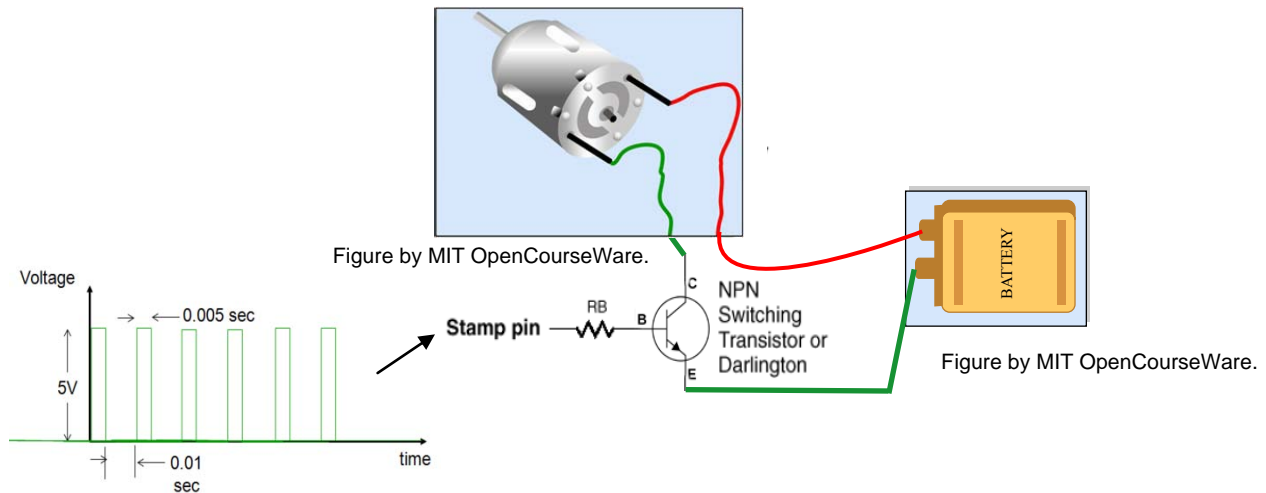
$$V_{in} = Ri + V_e$$

$$V_e = K_t \omega$$

$$T = K_t i$$

$K_t = 2nLrB$ where n is the number of windings, L is the length of each winding, r is the radius of the armature, and B is the magnetic field strength

9. (10 points) A circuit is arranged with a switching transistor as shown below. The supply is a 9V battery. The terminal labeled "Stamp pin" is at 5V for 0.005 sec, 0V for 0.01 sec and then repeats that pattern over and over. A DC motor is connected between the battery and the transistor. Its specification sheet indicates a no load speed of 10,000 rpm at 5V DC. Estimate the rpm of the motor when run within this circuit with no load applied to its output shaft.

Figure by MIT OpenCourseWare.

Voltage

→ ←0.005 sec

5V

→ ←0.01
sec

time

Stamp pin

RB

B

C

E

NPN
Switching
Transistor or
Darlington

BATTERY

Figure by MIT OpenCourseWare.

The Stamp in will, when raised to 5V, create a connection path for the current to flow through the motor to the ground (- terminal of the battery). The pin is at 5V for only 1/3 of the duty cycle, so the effective voltage seen by the load is 1/3 of the supply voltage which is 9V, not 5V. The voltage is effectively 3V applied to the motor (see the wikipedia entry on pulse width modulation). The no load speed at 5V is 10,000 rpm. The motor's no load speed at 3V is proportially less -- 6000 rpm with no load at 3V.