Pulleys, Work, and Energy

In this laboratory, we use pulleys to study work and mechanical energy. Make sure that you have the following pieces of equipment.

- two triple-pulley assemblies
- apparatus from which to hang your pulleys
- weights
- Vernier LabPro computer interface box
- Dual-Range Force Sensor

1 Preparation

Make sure that the force sensor is plugged into the Vernier LabPro computer interface box, and that the interface box is plugged into the computer. The interface box has a power cable that also needs to be plugged in. The force sensor has two settings: ± 10 N and ± 50 N. Use the ± 10 N setting.

Start Logger Pro on the computer. You may have to click OK to a few dialog boxes that are setting things up. On the main menu of Logger Pro, choose Experiment - Zero. This will properly zero out the force sensor.

Now, try a little test. On the main menu of Logger Pro, choose Experiment - Start Collection. The computer will start collecting data from the force sensor and continue for 10 seconds. If the force sensor is not being pushed or pulled, it should read very close to zero. If you pull gently on the hook of the force sensor, you should get a positive reading. If you push (again, gently) on the hook, you should get a negative reading. If you stop pushing or pulling, you should get zero again. Confirm that all of this works before going on.

2 Setup A

Use your pulleys to produce Setup A in Figure 1. Use a mass of 0.8 kg as the hanging mass (include the mass of the weight hanger as part of the 0.8 kg). Hook the force sensor onto the pulley string and record the force required to hold the system in equilibrium. The reading of the force sensor tells you how much tension is in the string.

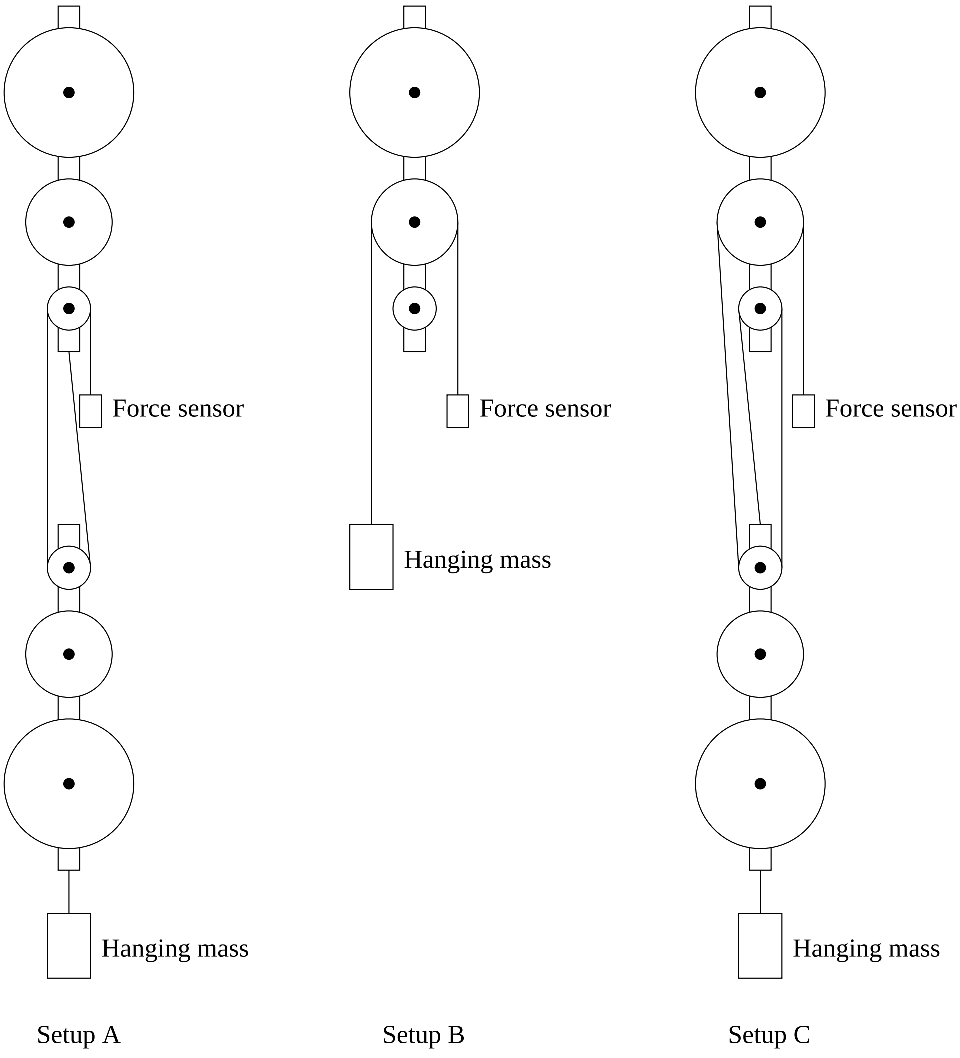
Measured tension for setup A	

Draw a free-body diagram for the triple-pulley assembly that is attached to the hanging mass. Label each force with its cause (tension, for example), and its value.

Now, slowly and gently pull the force sensor downward, so that the hanging mass moves up. Record how far you pull the force sensor downward (let's call this distance L) and how far the hanging mass moves upward (let's call this distance l).

L	
l	

Figure 1: Some pulley setups.



Calculate the change in mechanical energy for the hanging mass. (This is the same as the change in potential energy, because the hanging mass is not moving at the beginning, and is not moving at the end.)

Main Data Table

Setup	Tension T (N)	L (m)	l (m)	ΔME (J)
A				
B				
C				
D				
E				
F				

3 Setup B

Use a pulley to produce Setup B in Figure 1. Again, use a mass of 0.8 kg as the hanging mass. Hook the force sensor onto the pulley string and record the force required to hold the system in equilibrium. Record this tension in the main data table.

Now, slowly and gently pull the force sensor downward, so that the hanging mass moves up. Record how far you pull the force sensor downward, and how far the hanging mass moves upward. Complete the second row of the main data table.

4 Setup C

Look at setup C in Figure 1. Suppose a hanging mass of 0.8 kg. Before setting it up, try to predict the tension that you will measure in the string.

Tension prediction for setup C	

Use your pulleys to produce Setup C in Figure 1. Continue to use a mass of 0.8 kg as the hanging mass. Hook the force sensor onto the pulley string and measure the tension.

Draw a free-body diagram for the triple-pulley assembly that is attached to the hanging mass. Label each force with its cause (tension, for example), and its value.

Now, slowly and gently pull the force sensor downward, so that the hanging mass moves up. Complete the third row of the main data table.

5 Setups D, E, and F

Look at setups D, E, and F in Figure 2. Suppose a hanging mass of 0.8 kg. Before setting them up, try to predict the tension that you will measure in the string.

Tension prediction for setup D	
Tension prediction for setup E	
Tension prediction for setup F	

Use your pulleys to produce Setup D in Figure 2. Complete the items in the main data table. Then repeat for setups E and F.

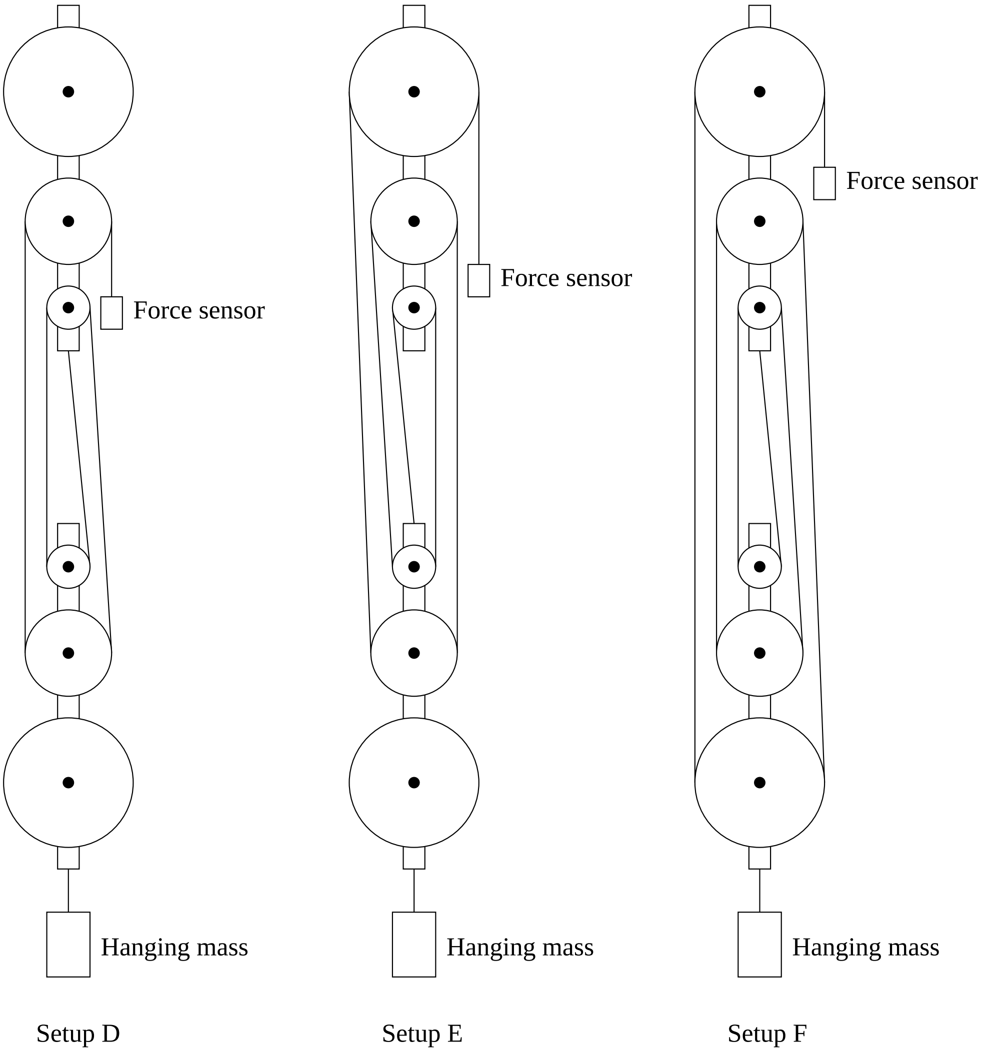
6 Questions

1. How can it be, in Setup A, that you are able to lift an approximately 8-N weight with less than 8 N of tension in the string?

2. Looking at your measurements for all six setups, what pattern do you see in the relationship between L, l, and the measured tension?

3. When the hanging mass is raised to a higher level, its potential energy (and hence its mechanical energy) is increased. Where did this energy come from?

Figure 2: Some more pulley setups.



4. Can you account, in a quantitative way, for the change in mechanical energy of the hanging mass?

5. Can you give a rule for how to predict the relationship between L and l by looking at a picture of the pulley setup?

7 Acknowledgments

This laboratory exercise is strongly influenced by similar laboratory exercises written by J. R. O'Donnell and B. L. Hurst.