Name__________________________ Section _______ Date_____________

Pre-Lab Preparation Sheet for Lab 6:

Energy, Work, and Power

(Due at the Beginning of Lab)

1. Power is defined as the time derivative of work.

$$P \equiv \frac{dW}{dt}$$

Given this and the definition of Work, derive an expression for Power as a function of velocity. Show your algebra.

2. A fricative block slides first up, then down a ramp with accelerations a_{up} and a_{down}. The ramp is tilted at an angle θ. The force of friction is f.

a. Apply the 2nd law to these two cases: sliding up and sliding down the ramp.

b. Write an expression for $\sin(\theta)$ in terms of a_{up} and a_{down}.

c. Write an expression for f in terms of a_{up} and a_{down}.

Note: Make a copy of your solutions. You will need this for the lab.

Name ______________________ Date __________ Partners________________

TA ________________ Section ______________________

Lab 6: Energy, Work, and Power

"Capital isn't this pile of money sitting somewhere, it's an accounting construct."

--*Bethany McLean (The same can be said of energy.)*

Equipment

2.2 meter track	Force sensor
Motion sensor	Friction cart
Cart spring	One ½ kg cart mass

Introduction

Energy is like money. An energy problem is essentially an accounting problem

- A system starts with some initial energy.
- Energy can then be added to the system. (That is, a force can do positive work on the system.)
- Energy can be removed from a system. (That is, a force can do negative work on the system.)
- Energy can be transformed from one form into another. (Such as kinetic into potential energy.)

Your job in this lab is to do the accounting: verify that your assets, earnings, and losses add up. Let's say that the total energy of a system is its mechanical energy *ME*.*

$$\begin{aligned} ME &\equiv \textit{kinetic energy} + \textit{potential energy} \\ &= K + U \end{aligned} \tag{1}$$

Then, the accounting equation is simply

$$ME_f = ME_i + \left(\textit{positive work on the system}\right) - \left(\textit{negative work on the system}\right) \tag{2}$$

Work is the change in energy on an object due to an applied force. For a tiny step $d\vec{s}$,

$$\begin{aligned} dW &= \vec{F} \bullet d\vec{s} \\ &= F_x\ dx + F_y\ dy + F_z\ dz \end{aligned} \tag{3}$$

* We could also include the thermal energy, chemical energy, electro-magnetic energy, magical energy, or monolith energy, but let's keep it simple for now.

Integrating over the path of motion, we have

$$
\begin{aligned}
W &= \int_{\vec{s}_i}^{\vec{s}_f} \vec{F} \bullet d\vec{s} \\
&= \int_{x_i}^{x_f} F_x \, dx + \int_{y_i}^{y_f} F_y \, dy + \int_{z_i}^{z_f} F_z \, dz
\end{aligned} \tag{4}
$$

The sign of the work is determined by relative directions of the applied force and the motion.

> **Note:** the sign conventions of your several measuring devices have no respect for each other or Equation (4). Do not naively accept what the computer is telling you. Instead, figure out the sign of the work yourself.

Exercise 1

Note the design of the friction cart. Here, the normal force on the frictive pad is from a spring force and *not* the weight. Hence, the friction *f* will be nearly constant for all of your measurements.

Combine the friction cart and force sensor.

1. Level the track.
2. Measure the friction force on the system

f = ____________________________________

3. Level the track and tare the force meter.
4. Select the Velocity and Force tab on the Capstone program.
5. Then gently pull the cart about a meter away from the motion detector. Slowly vary the applied force so that the force vs. position curve is a little messy.

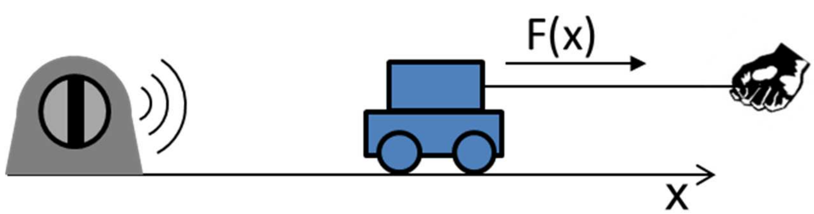


Fig. 1

6. Using the integration tool , measure the work of your hand pulling the cart.

W_h = ____________________________________

7. Calculate the work of friction on the cart. (Show your calculation.)

W_f = ____

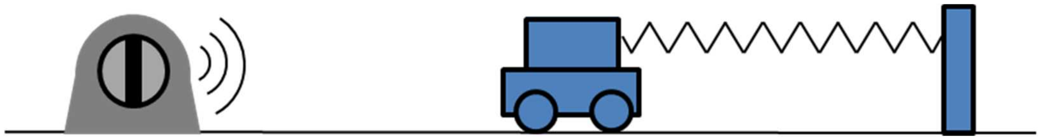
8. Verify Equation (2). Calculate the percent difference between the left and right hand sides of the equation.

Exercise 2

Now, we'll do much the same experiment, but using a spring instead of our fingers.

1. Attach one end of a spring to the force sensor and the other to the end-stop. With the spring fully relaxed, tare the force sensor.
2. Stretch the spring by ~0.5 m.
3. Start recording, and then release the cart.

Catch the cart before it crashes!!

Fig. 2 

Now, we need to define exactly what our system is. We can say either

- The system is just the cart, and the spring is an external force doing work on the cart.

or

- The system is (the cart + the spring), and have the spring contribute to the potential energy of the system.

It does not really matter, but let's go with the first option. That way it looks more like Exercise 1.

4. Defining the initial condition as the point of release, verify Equation (2) for the point of maximum velocity. Calculate the percent difference between the left and right hand sides of the equation.

Power is the time derivative of work:

$$P = \frac{dW}{dt} \tag{5}$$

5. Given the definition of work, write the expression for power in terms of velocity.

6. What is the maximum power of the spring on the cart?

Exercise 3

1. Remove the spring and force sensors. Insert one ½ kg mass in the bed of the cart.
2. Tilt the ramp to about 5˚.
3. After a brief push, observe the cart as is rolls up, then down the ramp. Record the relevant parameters and associated uncertainties. Justify each of these uncertainties. Define t_0 as the moment after the initial push has ended.

NOTE: For this apparatus, accurately measuring the angle of the ramp and the friction is relatively difficult. However, measuring acceleration is relatively easy.

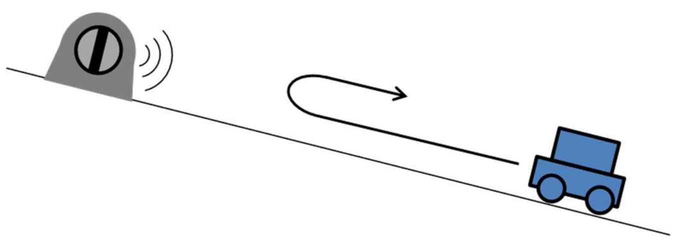


Fig. 4

4. Write an algebraic expression describing the conservation of energy for this system including all relevant terms.
5. Within the uncertainty of your measurements, verify that energy is (or is not) conserved in this system.