Energy

Name:	Teammates:

Introduction

In this week's lab, we are going to investigate the motion of objects from an energy perspective. We will relate the position and velocities of objects to their energies and not to the forces acting on them. In the absence of external forces to the system, no net work will be done on the objects, which means that the total energy of the system will remain constant.

Two Types of Energy

All forms of energy can be classified into either kinetic energy or potential energy. The energy of an object is equal to its ability to do work. It has the ability to do work on other objects by applying a force to those objects and change their velocity.

Kinetic energy is the energy that an object has because of its motion relative to its surroundings. Potential energy is the energy that is stored in a system by virtue of forces between objects that are separated by some distance. If the objects are allowed to move under the influence of the force between them, then work is done as the force displaces the objects from their initial positions, and energy is transferred. A prime example of this is gravitational potential energy.

Kinetic Energy

If an object is moving, it has kinetic energy. For example, a cue ball that is rolling across the table has kinetic energy relative to the other static billiard balls on the table. If the cue ball hits another ball, it applies a force to the second ball over a very small distance. This force changes the cue ball's velocity while it transfers energy to the static ball, and thus, it does work. We define the kinetic energy of an object as

$$K.E. = \frac{1}{2} mv^2$$

Gravitational Potential Energy

One of the more important forms of potential energy in our lives is gravitational potential energy. This is the energy that comes about because of gravitational forces between objects, such as yourself and the Earth. A ball that is dropped from rest at some height above the Earth's surface will begin to accelerate downward as gravity pulls it. As the ball accelerates, gravity works on it to convert its potential energy into kinetic energy (the ball's height decreases as its velocity increases). If the ball is dropped from a higher altitude, then gravity operates over a greater distance, thereby generating more kinetic energy. The gravitational potential energy of an object thus depends upon the height through which an object is allowed to fall. If we call H, the height through the object will fall, the gravitational potential energy of the object is:

Fig 1: Parachutist jumping from an MV-22 Osprey (*DOD*)

$$G.P.E. = \text{mass} \times g \times H$$

An example of a device that takes advantage of gravitational potential energy is a hydroelectric dam (Figure 2). This device uses the potential energy of water "stacked up" behind a dam to move a turbine that is located at some height below the water. The turbine is connected to a generator, which creates electricity as it turns. Hydroelectric plants do not result in carbon emissions. Yet, they have a serious environmental impact, as the placement of the dam converts a river ecosystem to a lake ecosystem. This can have a large effect on the movement of sediments that are necessary for sustained agriculture, as well as aquatic life forms which need to be able to move freely along the length of the river.

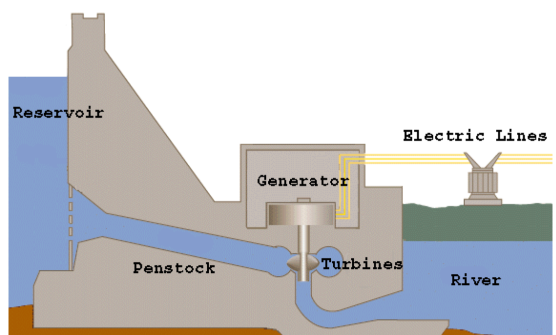

Fig 2: Diagram of a hydroelectric facility.

Energy Transfer

In the absence of outside forces, the total amount of potential and kinetic energy in a system will remain the same. This is due to the law of conservation of energy, which states that "Energy can neither be created nor destroyed; it can only be transferred from one form to another." This can be written as

$$\mathbf{E = KE_{initial} + G.P.E_{initial} = KE_{anytime} + G.P.E_{anytime} = KE_{final} + G.P.E_{final} = Constant}$$

Model

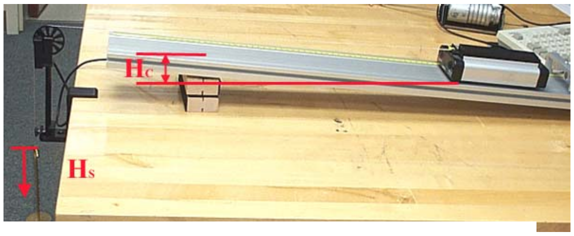

Fig. 3: Picture of experiment setup

This week's activity will test the conservation of mechanical energy using a suspended mass that is attached via a thin string to a dynamic carts that is free to move along a tilted track (see Figure 3). If the suspended mass, the cart's mass, and the slope of the track are appropriately chosen, the mass will be pulled downward by gravity with a constant net force. This, in turn, will pull the cart up the track with a constant acceleration. In the initial configuration, the suspended mass has gravitational potential relative to the floor, the cart has gravitational potential energy relative to the table. Since neither is moving, there is no kinetic energy. Thus, the system has a total mechanical energy initially given by

$$E_i = m_s\, g\, H_{si} + m_c\, g\, H_{ci}$$

where m_s is the suspended mass, H_{si} is the initial height above ground of the mass, and H_{ci} is the initial height above the table of the cart. When the suspended mass has gotten to its bottom position (H_{sf}), its gravitational potential energy is $m_s\, g\, H_{sf}$. Additionally; the mass has a kinetic energy ($\frac{1}{2}\, m_s\, v_f^2$). On the other hand, the cart now has potential energy due to its elevated position ($m_c g H_{cf}$). The kinetic energy of the cart is ($\frac{1}{2}\, m_c\, v_f^2$). Note that we use the same velocity for both cart and mass. The final mechanical energy is thus:

$$E_f = m_s\, g\, H_{sf} + m_c g H_{cf} + \tfrac{1}{2}\, m_s\, v_f^2 + \tfrac{1}{2}\, m_c\, v_f^2$$

Activity

Figure 3 shows the set up for this activity. The dynamics cart is initially leveled on the table before the 2" block is placed under the feet on the free end of the track. The Smart Pulley needs to be raised such that the string that connects the suspended mass to the cart is level to the track. If the 2" block is placed properly, then the 50 gram mass holder on the end of the string should still be able to accelerate the cart up the track. With this setup, do the following steps:

1. Measure the mass of the dynamics cart.

Mass of the Cart = m_c = ________ g　　　　Mass of bar weight = ________ g

2. Connect one end of the string to the dynamics cart and the other to a mass hanger. Place the cart on the track and run the string over the pulley. Pull the cart as far back along the track so that the mass hanger almost touches the bottom of the pulley. Hold the hanger in place above the ground to prevent the system from moving. Measure the location of the cart on the track (using scale on track).
3. Measure the height of the cart mass above the table and the height of the suspended mass above the floor.

Initial Height of the hanger: H_{si} = ________ cm　　　　Initial Height of cart: H_{ci} = ________ cm
(measure it from the bottom of the mass)

Final Height of the hanger: H_{sf} = ________ cm　　　　Final Height of cart: H_{cf} = ________ cm

4. Turn on the DataStudio software and load the program "P05_energy".
5. Turn the pulley so that the photogate beam of the Smart Pulley is "unblocked" (the light-emitting diode (LED) on the photogate is off).
6. Click the "Start" button to begin data recording.
7. Release the cart so it can be pulled by the falling mass hanger. Data recording will begin when the Smart Pulley photogate is first blocked.
8. Stop the data recording just before the mass hanger reaches the floor by clicking the "STOP" button. Alternatively, edit the data table by deleting rows that correspond the hanging mass touching the floor.
9. From the table of position versus time, determine the final position of the cart on the track.
10. Position the cart on the cart at that same final position and measure the height of the cart above the table at that position and the height of the hanging mass above floor.

Initial GPE of cart: GPE_{ci} = ________ Joules　　　　Final GPE of cart: GPE_{cf} = ________ Joules

11. Use the data from DataStudio software to determine the final velocity of the cart.
12. Repeat this process 4 more times and average the measured velocities. You are encouraged to do the suggested calculations with Excel and print the resulting table.

Hanging Mass	Final Velocity					Avg v_f	$KE_{cf}=½\ m_c\ v_f^2$	$KE_{sf}=½\ m_s\ v_f^2$
	Run 1	Run 2	Run 3	Run 4	Run 5			
50 g								
100 g								
150 g								
200 g								
250 g								

13. Repeat the data acquisition procedures above for total masses in 50 gram increments up to 250 grams.
14. Complete the following table. You are encouraged to do the suggested calculations with Excel and print the resulting table. (**Remember, the subscript ”s” refers to the hanging mass, ”c” to the cart, ”i” to initial, ”f” to final. A subscript ”i” without an ”s” or a ”c” means that we are interested in the overall – for both cart and hanging mass- energy**.)

Hanging Mass	KE_i(J)= KE_{ci}+ KE_{si}	KE_f(J)= KE_{cf}+ KE_{sf}	GPE_{si} (J)	GPE_i (J)	GPE_{sf} (J)	GPE_f (J)	E_i(J)= KE_i+GPE_i	E_f(J)= KE_f+GPE_f	% Diff.
50 g									
100 g									
150 g									
200 g									
250 g									

1. Did the results confirm that the mechanical energy of the cart-hanging mass was conserved?

2. What were the factors that might have affected the results?

3. Would the results of the lab been different if measured the H_c values relative to the floor instead of the table?

4. Would the results of the lab been different if measured the H_s values relative to the table instead of the floor?

5. What are the possible sources of random errors in this experiment? How have you attempted to account for them?

6. What are the possible sources of systematic errors in this experiment? Are their effects noticeable? If so, is the error large?