WORK KINETIC ENERGY EXPERIMENT

Introduction

The work-energy theorem says that the net work done by the net force acting on an object is the change in kinetic energy of the object. That is

\[ W = \Delta K = \frac{1}{2} m \cdot v_f^2 - \frac{1}{2} m \cdot v_i^2 \]  

(1)

For a constant force in the direction of motion (taken to be along the x-axis),

\[ W = F \cdot x, \text{ where } x \text{ is the distance moved while the force is applied.} \]

(2)

If \( F \) is not constant, then

\[ W = \int F \, dx. \]  

(3)

This integral is mathematically equal to the area under the curve of \( F \) vs. \( x \), as shown by the shaded region in the graph on the next page.

Equipment

Track, motion sensor, force sensor, spring bumper, hook, black block mass, mass hanger, string, pulley

Preliminary Questions

1. You have two carts, one of mass \( m \), and a second loaded with weights so its mass is three times that of the mass \( m \). You push each of them (one at a time) with the same constant force, for the same distance, starting from rest. After you have pushed them through this distance, you remove the force. Which of the following statements will be true after the force is removed?

   a. The kinetic energy of the empty cart is less than the kinetic energy of the loaded cart.
   b. The kinetic energy of the empty cart is equal to the kinetic energy of the loaded cart.
   c. The kinetic energy of the empty cart is greater than the kinetic energy of the loaded cart.

2. In the same experiment as in the previous question, which of the following is true?

   a. The speed of the empty cart is less than the speed of the loaded cart.
   b. The speed of the empty cart is equal to the speed of the loaded cart.
   c. The speed of the empty cart is greater than the speed of the loaded cart.
**Experimental procedure**

![Graph showing force (F) vs position (x), velocity (v) vs time (t), and work (W) vs position (x(m)).]

**PART 1 – Force given by the hand**

In this experiment you will push a roller cart a short distance with a force sensor and monitor the velocity of the cart with a motion sensor. From your data, you will measure the work done during the push and the change in kinetic energy of the cart, and you will check the validity of the work-energy theorem.

Place the motion sensor on one end of the track with the roller cart near the other (pulley is used later in part II). Make sure the track is level by adding paper at the ends of it. If the track is level the cart should not move. Add the two black block masses (494g each) on top of the the cart and connect the force sensor and the motion sensor to the Pasco interface (if they are not connected already). The force sensor should be mounted with the rubber bumper instead of the hook (the hook is for part II). Open the data studio file “Work KE.dat” located in the ThawSpace T: drive. Data Studio will display two graphs: force vs position and velocity vs time.

Before taking a measurement, set the force sensor to zero by pressing the “tare” button. Hold the force sensor in one hand, start the measurement (hit Start icon on DataStudio), and push the cart with the force sensor in your hand toward the motion sensor. You want to push the cart for 10-20 cm. Make sure that you stop the cart by hand before it hits the motion sensor. Determine the work done on the cart by finding the area under the force versus position curve. To do so carefully select the appropriate data points on the graph. Next, determine the maximum value of the final velocity of the cart. Weigh the cart and masses, and calculate the change in the kinetic energy from the value of the velocity.

You only need one graph for a good run. Repeat several times your experiment until you are able to reproduce the two graphs above, and then take the data.

**Analysis**

1) What is the Work?

2) What is change in Kinetic Energy?

3) Within reasonable experimental error, is the Work equal the change in the Kinetic Energy?

4) In order to give a numerical meaning of the answer above, calculate the percent difference between the Work (W) and the Kinetic Energy (KE) using the equation below.

\[\%Diff = \left| \frac{W - KE}{(W + KE) / 2} \right| \times 100\]

If you obtain a percentage difference greater than 15%, repeat your measurement and check with the instructor.
5) Which measurement would have the most experimental error involved: the work or the change in kinetic energy? And why?

6) If you had to repeat the experiment on an incline plane instead of a horizontally leveled track, will the Work done by the applied force (your hand pushing) be equal to the change of change in the Kinetic Energy? Explain.

Print and turn in the plots obtained with DataStudio

**PART 2 – Force given by gravity**

For Part 2, the force applied on the cart will be due to gravity acting on the mass hanger.

7) Do you expect the experimental error to be less than in the case of Part 1? Why?

Mount the force sensor on top of the cart. Replace the spring bumper with the hook and using the string, connect the mass hanger to the force sensor. Remember to tare the force sensor before each measurement (be sure there is no tension in the string when you tare it).

Hold the cart, hit the Start icon on Datastudio and then let the cart go. Make sure the hanger hits the ground before the cart reaches the end of the track so that the cart travels about 15 cm with constant velocity. In this way the velocity graph should show the acceleration of the cart (while the hanger is falling) and then the motion at constant velocity of the cart (after the hanger hits the ground).

Determine the work and the final velocity of the cart.

8) What is the **Work**?

9) What is **change in Kinetic Energy**?

10) Within reasonable experimental error, is the Work equal the change in the Kinetic Energy?

11) In order to give a numerical meaning of the answer above, calculate the percent difference between the Work (W) and the Kinetic Energy (KE) using the equation below.

\[
\%\text{Diff} = \left|\frac{W - KE}{(W + KE)/2}\right| \times 100
\]

If you obtain a percentage difference greater than 15%, repeat your measurement and check with the instructor.

12) Compare your answer to question 11 with question 4 and describe the difference.

Print and turn in the plots obtained with DataStudio