Experiment 6

WORK and ENERGY (10/2/23 version)

EQUIPMENT	
BeeSpi™ photogate	*1 Hotwheels™ race car*
Energy program	*1 triple beam balance*
inclined track w/ cork	*Graphical Analysis program*
	1 Table clamp
	1 c-clamp

INTRODUCTION

The purpose of this experiment is to give an object (a toy car) a specific amount of potential energy and determine the velocity and kinetic energy associated with this energy as well as the stopping distance of the car. The relationship between velocity, work, and energy will then be explored. These concepts are summarized below.

Work

Work is defined as force times distance. Thus

$$Work = Force \times distance$$

or

$$W = Fd$$

For example, you do work when you exert a force on a box that you slide across the floor for some distance. You also do work on a box when you lift it some height above the floor. Frictional forces also do work on both you and the box.

Potential Energy

Energy is the capacity to do work. Energy that is a property of position is called *potential energy*. Potential energy due to elevated position is called gravitational potential energy. The gravitational potential energy of a mass at height h is given by

$$Gravitaional\ potential\ energy = weight \times height$$

or

$$PE_{gravity} = mgh$$

where the force of weight is defined as mass times the acceleration due to gravity.

Kinetic Energy

The kinetic energy of a moving body is equal to one half its mass times its velocity squared, or

$$Kinetic\ energy = \frac{1}{2} mass \times velocity^2$$

or

$$KE = \frac{1}{2} mv^2$$

If it is assumed that all of the gravitational potential energy is converted to kinetic energy, we see that the change in Kinetic energy = work done in bringing object to rest.

Since work is equal to force times the distance through which it is applied, and if friction provides the force, the relationship above becomes:

$$Change\ in\ KE = Frictional\ force \times stopping\ distance$$

or

$$\Delta KE = \frac{1}{2} mv^2 = Fd.$$

This equation relates the energy of a moving car to the stopping distance once brakes are applied. Notice that v is squared. Consequently, *the stopping distance is proportional to the square of the velocity*. **For example, if the velocity is increased by a factor of 2, then the stopping distance increases by a factor of 4!**

This lab utilizes a toy car, an inclined racetrack, a section of track to stop the car, and a computer. You will measure the mass of the car, give it a certain potential energy by placing it at some height above the table, release it, and measure the distance it slides before coming to rest. A photogate will measure the velocity of the car.

By graphing the data obtained, you can find out whether the *stopping distance and height* are proportional to the velocity or to the square of the velocity. You will relate the work done in stopping the car to its original velocity and potential and kinetic energies. The primary energy relations examined will be:

$$\Delta PE\ converted\ to\ KE \quad then \quad \Delta KE = work\ to\ stop$$

or

$$mgh = \frac{1}{2} mv^2 \quad then \quad \frac{1}{2} mv^2 = Fd$$

In other words,

$$\Delta PE = \Delta KE = Work\ to\ stop$$

or

$$mgh = \frac{1}{2} mv^2 = Fd$$

PROCEDURE

1. Measure the mass of your car using the digital or triple beam balance. Record this measurement on the data sheet in kilograms.
2. Note the distance scale along the track. Use this for measuring stopping distance.
3. Set a photogate at the bottom of the track before the cork portion begins to measure the velocity of the car after it has fallen down incline but before it begins to stop
4. Note the three distances marked on the inclined section of the track. These correspond to the measured height column in the data table.
5. Press the "Start" button on the photogate
6. Line up the center of mass mark on the car with the 0.15m (15cm) height and release the car.
7. Record the velocity and stopping distance in the data table. Repeat two more times and record in the data table.
8. Repeat step 6 and step 7 for **0.3m** and **0.6m**.
9. Calculate the **average** velocity and **average** stopping distance for each of the three heights. Record in the data table.
10. Use the ENERGY program to complete the data table.
11. Plot a graph of average stopping distance (on the y-axis) vs. height (on the x-axis) using GRAHICAL ANALYSIS. **Copy your graphs on next page.**
12. Plot a graph of velocity vs. height.
13. Plot a graph of and velocity squared vs. *height*.

PLEASE NOTE THAT (0,0) MUST BE INCLUDED ON PLOTS.

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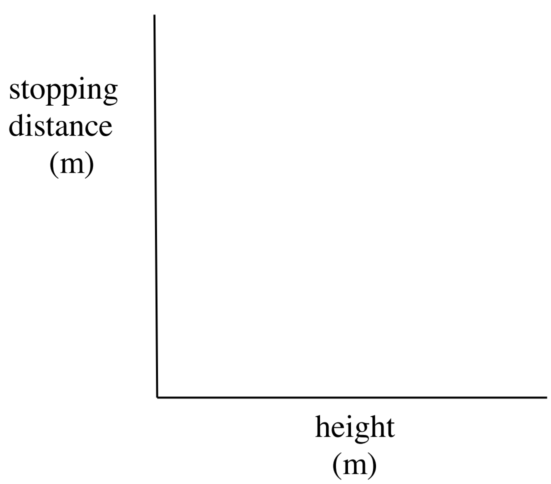
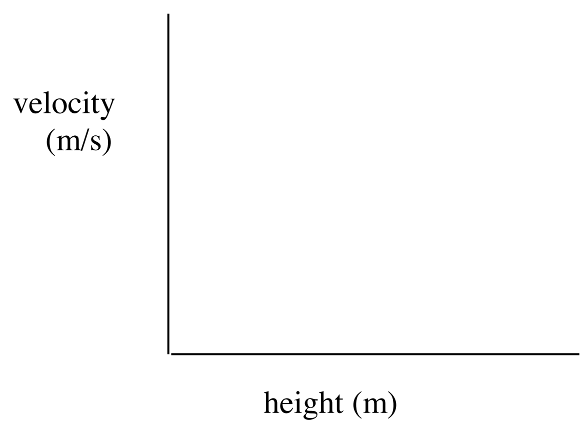
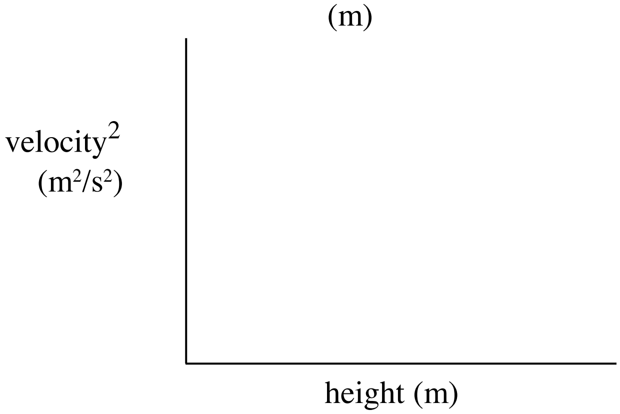
DATA SHEET

Mass of car = ________________ kg

Height (meters)	Velocity (m/sec)	Stopping distance (m)	Potential Energy (Joules)	Avg. Velocity (m/sec)	Avg. Velocity Squared (m^2/sec^2)	Avg. stopping distance (m)	Avg. Kinetic Energy (Joules)
0.15							
0.15							
0.15							
0.3							
0.3							
0.3							
0.6							
.06							
0.6							







QUESTIONS

1. Look at your plots. Two of them should be linear and one should be nonlinear. Which plots are linear and which is nonlinear? Discuss if this is what you observed (i.e., measured) and why this is the case. See equations in introduction for hints.

2. Compare and discuss the potential and kinetic energies found during this experiment. Are they the same? Should they realistically be the same? Discuss what you observed.

3. Is it a good idea to touch the brakes (i.e., the discs of the brakes) of a car immediately after the driver has made a large number of hard stops? Explain in the context of conservation of energy.

4. A car traveling 50 mph takes 100 feet to stop. How much distance is required to stop it at 100 mph? Show work or explain your answer.

5. If you had plotted stopping distance vs. potential energy & kinetic energy vs. height, would these plots be linear or nonlinear plots? Explain your answer. See your plots above for guidance.