Name _____ Section (Period) _____ Date _____

Lab Partner(s) _____

PAPER ROLLER COASTER LAB

Calculating Potential Energy and Kinetic Energy of a Rolling Marble

INTRODUCTION AND OBJECTIVES

The Law of Conservation of Energy states that energy can be neither created nor destroyed. However, energy can change from one form to another. In the case of a marble on a paper roller coaster, a marble starts at the top of the roller coaster with a relatively large amount of potential energy and no kinetic energy. As the marble starts rolling down the roller coaster, the amount of potential energy stored in the marble decreases while its kinetic energy increases. Potential energy is also converted into heat energy due to friction. In this experiment, you will be calculating the change in potential energy of a marble traveling between two points on a paper roller coaster and compare that to the kinetic energy that was gained by the marble during that same time.

EQUIPMENT NEEDED

- completed Paper Roller Coaster
- ruler
- pencil
- calculator
- stopwatch (optional)
- video camera (optional)
- photogate timer (optional)

PROCEDURE

I. Selecting the starting and ending points.

Choose a portion of the roller coaster in which the marble accelerates and then keeps a fairly constant speed. Ideally, this would mean a gentle downhill section followed by a level section. The marble does not need a steep hill to accelerate.

Place three marks on the roller coaster. Label the beginning of the hill "A", the end of the hill "B", and the end of the level section "C". You will be measuring the distance between each of these points so make sure that those distances will be easy to measure.

II. The gravitational potential energy of the marble

The change in gravitational potential energy of a marble on a paper roller coaster depends on the difference in height from the starting point to the ending point of the marble's path. Gravitational potential energy equals mass x acceleration due to gravity x change in height. This can be written as $\Delta P.E. = mg\Delta h$.

1. Find the mass of the marble. Measure the mass of ten marbles and divide that by ten. Convert the mass of the marble to kilograms. mass of marble = 0.0053 Kg. (my sample marble)
2. acceleration due to gravity = 9.8 m/s^2. (accepted value near sea level)
3. Find the change in height from point "A" on your roller coaster to point "B" in meters.
   Height above the table (or floor) for point "A" = .62 m. (my sample coaster)
   Height of point "B" = .41 m. (my sample coaster)

The change in height = height of "B" - height of "A." Δh = -.21 m. (the difference between B and A)

Why is this a negative number? height of marble is decreasing as the marble goes from B to A

4. $\Delta P.E. = mg\Delta h$ = -.0109 $(Kg)(m^2)/s^2$ = Joules.

Is this a positive or negative number? negative Why? The amount of potential energy decreases since the height of the marble has gone down.

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III. Calculating the kinetic energy of the marble

As the marble travels down the hill from point "A" to point "B," the potential energy in the marble will decrease. On the previous page, you calculated how much potential energy is lost. Here, you will determine how much of that potential energy was converted into kinetic energy.

The total kinetic energy of the marble is made of two parts, the kinetic energy due to its linear motion and the kinetic energy due to its rotation. A marble that is rolling has more kinetic energy than a marble that is sliding along at the same speed. You will calculate those two amounts separately before adding them together.

A. Kinetic energy of the linear motion

The marble's kinetic energy due to the its linear motion is one half its mass times its velocity squared. It can be written as $K.E._l = {}^1/_2 mv^2$.

1. Find the mass of the marble. Measure the mass of ten marbles and divide that by ten. Convert the mass of the marble to kilograms. mass of marble = 0.0053 Kg.
2. Find the velocity of the marble between points "B" and "C." There are many ways to do this. The simplest way (although the least precise) is to use a stopwatch to determine how long it takes to get from point "B" to point "C" after you start the marble at point "A." Divide the distance between points "B" and "C" by the time elapsed.*

Distance from "B" to "C" = .38 m.

Release the marble at point "A." How long does it take for the marble to travel from "B" to "C?"

Time from "B" to "C" = .28 s.

Velocity of marble between "B" and "C" = distance/time = 1.36 m/s.

3. The linear kinetic energy of the marble = ${}^1/_2 mv^2$ = 0.0049 J.

B. Kinetic energy of the rotational motion

The marble's kinetic energy due to its rotational speed is $1/2I\omega^2$, where I is the moment of inertia of the marble and ω is the marble's angular speed. The moment of inertia of a solid sphere is ${}^2/_5 mr^2$, where m is the mass and r is the radius of the marble, so the kinetic energy of a rotating marble is $K.E._r = {}^1/_2({}^2/_5 mr^2)\omega^2$.

For a marble that is rolling without slipping, $\omega = v/r$, so $K.E._r = {}^1/_2({}^2/_5 mr^2)(v/r)^2$, or

$$K.E._r = {}^1/_5 mv^2.$$

1. mass of marble = 0.0053 Kg. (same number as above)
2. velocity of marble = 1.36 m/s. (same number calculated above)
3. The rotational kinetic energy of the marble = ${}^1/_5 mv^2$ = 0.0020 $(Kg)(m^2)/s^2$ = Joules.

C. Total kinetic energy of the rolling marble

The marble's total kinetic energy is the sum of its linear kinetic energy and its rotational kinetic energy. Add your results from sections A and B above.

Total kinetic energy of the rolling marble = 0.0069 $(Kg)(m^2)/s^2$ = Joules.

How does that compare to the change in potential energy of the marble between point "A" and point "B?"

The loss of potential energy was greater than the increase in kinetic energy.

Explain why the potential energy that the marble lost might not equal the kinetic energy that the marble gained while rolling down the hill. Friction between the marble and the track will usually result in some energy being lost and some of the potential energy not being converted to kinetic energy. Also, errors in measurements could cause a difference between the two values.

*For more precise measurement of the marble's velocity, use either a photogate timer or a video camera. A video camera can be used if it allows for frame by frame advance and an on-screen display showing elapsed fractions of a second.