Name _____ Section (Period) _____ Date _____

Lab Partner(s) _____

# 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.
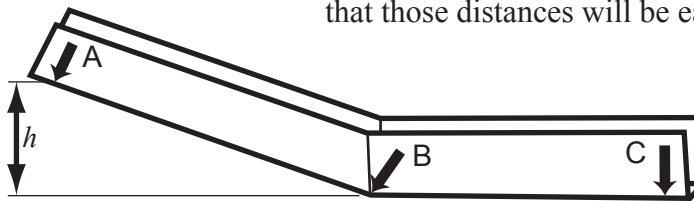


**II. The gravitational potential energy of the marble**

To simplify calculations, treat the height of point B as the reference point where gravitational potential energy equals zero. The gravitational potential energy of the marble depends on the height of the starting point compared to the ending point of the marble's path. Gravitational potential energy equals (mass)*(acceleration due to gravity)*(height). This can be written as $P.E. = mgh$.

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. Enter your result below.
Find point A's height above point B in meters.

| | |
|---|---|
| 1. Mass of the marble, $m$ (kg) | |
| 2. Acceleration due to gravity, $g$ (m/s$^2$) | |
| 3. Height of point A above point B, $h$ (m) | |
| 4. Gravitational potential energy at point A, $mgh$, (J) | |

## III. Calculating the kinetic energy of the marble

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 $K.E._l = 1/2mv^2$.

1. Find the mass of the marble. Enter all results below.
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 release the marble at point A. Divide the distance between points B and C by the time elapsed. Conduct three trials to determine the average velocity between points B and C.*
3. Calculate the average linear kinetic energy of the marble.

| Trial # | Linear Distance from B to C (m) | Time (s) |
|---------|---------------------------------|----------|
| 1       |                                 |          |
| 2       |                                 |          |
| 3       |                                 |          |
| Average |                                 |          |

| | |
|---|---|
| Average Velocity (m/s) | |
| Mass (Kg) | |
| Linear Kinetic Energy (J) $K.E._l = 1/2mv^2$ | |

## B. Kinetic energy due to rotation (optional)

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 $\omega$ is the marble's angular speed. The moment of inertia of a solid sphere is $2/5mr^2$, where $m$ is the mass and $r$ is the radius of the marble, so the kinetic energy of a rotating marble is $K.E._r = 1/2(2/5mr^2)\omega^2$. For a marble that is rolling without slipping, $\omega = v/r$, so $K.E._r = 1/2(2/5mr^2)(v/r)^2$, or

$$K.E._r = 1/5mv^2.$$

| | |
|---|---|
| Mass of marble (Kg) | |
| Velocity of marble (m/s) | |
| Rotational Kinetic Energy (J) $K.E._r = 1/5mv^2$ | |

## 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.

Total kinetic energy of the rolling marble = _____ (Kg)(m²)/s² = Joules.

## IV. Conclusion

1. What is the total Mechanical Energy of the marble at point A, before the marble starts to roll? _____
2. What is the total Mechanical Energy of the marble at point C? _____
3. Compare your answers to questions 1 and 2. Should these answers be the same? _____

why or why not? _____

_____

_____

*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.