Roller Coaster Construction

SPH4C

Objectives:

Students will demonstrate the relationship between gravitational potential, kinetic energy, and energy loss by building a working model of a roller coaster where a marble will represent the cart and by performing calculations relating to their roller coaster.

Materials:

3 lengths of pipe insulation, cut in half (provided)
tape and tables, lab stools, or other materials to support design
marble (or marble-sized ball bearing)
metre stick and measuring tape

Procedure Part 1 (Calculating Friction):

Determine the mass of the marble or marble-sized ball bearing (in kg):

m = ______________________

We can estimate the frictional force acting on the marble as it rolls along a the track by finding the work done by friction as the marble travels along the track.

Take a single length of track. Measure the length of the track (in metres):

Length = Δd = _________________________

Raise one end of the track to a height of 0.50 m (h_1). Release the marble from rest at this height and let it roll along the length of the track. Raise the other end of the track until you find the maximum height the marble can reach after travelling the entire length of the track (h_2).

The work done by friction is equal to the change in potential energy of the marble (in Joules):

$W = mg\Delta h = mg(h_2 - h_1)$

= (_____________)(_____________)(___________________________)

= ____________________

So the frictional force acting on the marble (in Newtons) is:

$F = \frac{W}{\Delta d}$ = ____

(The work and the force are both negative because the frictional force is backwards, opposite the direction of motion.)

Procedure Part 2 (Construction):

Only the pipe insulation above may be used to construct the track of the roller coaster itself. The full length of the pipe insulation must be used. Students may not cut their pipe insulation.

Students may use other materials to construct “decorative” elements. The marble should not come in contact with any decorative elements over the length of the track.

The roller coaster shall have at least one steep hill (the initial drop) and one low hill. It should also contain at least one single loop-the-loop or other inversion.

Only the force of gravity can be used to move the marble or ball bearing. Once the marbe or ball bearing is moving on its own, no one may touch it or the coaster.

You must demonstrate to your teacher that the marble or ball bearing can complete the track completely on multiple trials.

Teacher's initials: ____________

Procedure Part 3 (Calculating the Speed):

What is the height of the starting position of the marble (in metres)?

h = ________________________

What is the gravitational potential energy of the marble at its starting position?

$E_g = mgh =$ ____

What is the kinetic energy of the marble at its starting position?

$E_k = \frac{1}{2}mv^2 =$ ____

What is the total mechanical energy of the marble at its starting position?

$E_T = E_g + E_k =$ ____

What is the ideal mechanical energy of the marble at the bottom of the first hill?

E_T (ideal) = _________________________

What is the length of track from the starting position of the marble to the bottom of the first hill?

Δd = _________________________

What is the work done by friction on the marble as it rolls to the bottom of the first hill?

$W = F\Delta d =$ ____

(remember that the work is negative!)

What is the actual mechanical energy of the marble at the bottom of the first hill?

E_T (actual) = E_T (ideal) + W = ______________________________

What is the height of the track at the bottom of the first hill?

h = ______________________

What is the gravitational potential energy of the marble at the bottom of the first hill?

E_g = mgh = ______________________________

What is the kinetic energy of the marble at the bottom of the first hill?

E_k = E_T (actual) – E_g = ______________________________

What is the speed of the marble at the bottom of the first hill?

$v=\sqrt{\frac{2E_k}{m}}$ = ______________________________

Discussion Questions:

How does the height of the second hill compare to the height of the first hill? Explain why.

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What happens if the marble is not travelling quickly enough to complete the loop? Explain why.

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What happens if the marble is travelling too quickly at the top of the second hill? Explain why.

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