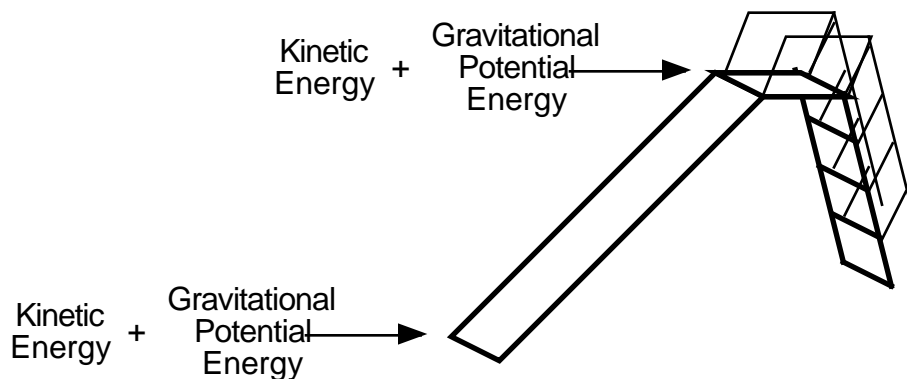


Roller Coaster's, Energy and Work

WORK

Background

The work of friction. If you were glide down a water slide you find that the speed at the bottom of the slide is less than calculated using conservation of energy techniques. If energy is completely conserved then the sum of the kinetic and potential energy due to gravity would be the same at the top and the bottom. But, if an actual experiment is done, the sum of the energies at the top is greater than the at the bottom. Their difference is due to the work of friction.

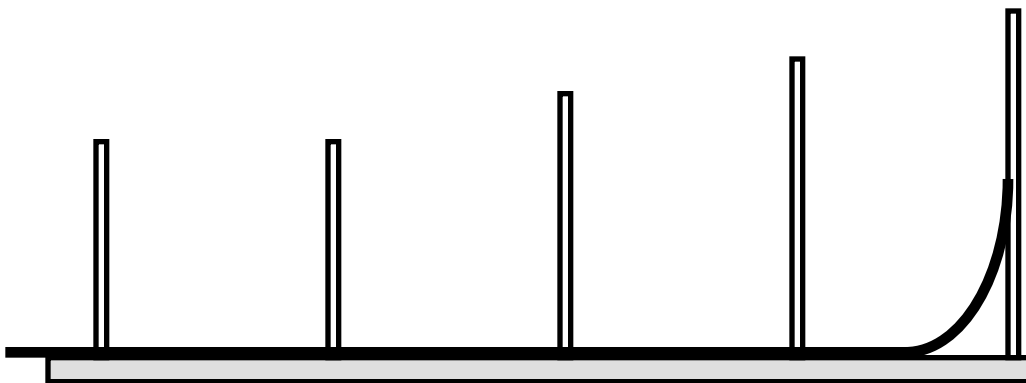


$$[\text{Kinetic Energy} + \text{Potential Energy}]_{\text{TOP}} - [\text{Kinetic Energy} + \text{Potential Energy}]_{\text{BOTTOM}} = \text{Work}_{\text{Friction}}$$

Before the advent of computer modeling techniques many successful roller coaster designers, such as John Miller, used a friction design ratio. John Miller used a ratio of 1:40. This meant for every 1 foot of height for the biggest hill meant the roller coaster track could run 40 feet. For example: A roller coaster whose biggest hill is 85 feet could contain approximately 3400 feet of track before coming to a rest without any brakes. ($3400 = 85 \times 40$) Of course, this was an estimate the shape of the track did affect actual results as you will discovery later in the lab.

Part 1a

Use your coaster track simulator to create the layout below.



Your hill does not need to look exactly like the one above. Pick an initial starting height of 3 cm above the flat section of the track. (Measure from the bottom of the channel the marble rolls in. Drop the marble along the track from this height. Measure how far it rolls. Repeat this trial 12 times. Calculate the average and \pm error. Do this for 6 cm, 9 cm and 12 cm. Use this data to come up with your own height to run distance ratio with a plus and minus error.

Roller Coaster's, Energy and Work

WORK

Part 1b

- Use the data from Part 1a to calculate the work of friction along the horizontal track and the magnitude of the frictional force stopping the ball for all 4 drop heights. Finally, come up with an average frictional stopping force.

Part 2

In this part you will investigate the effects of the dip after a hill on friction.

Procedure

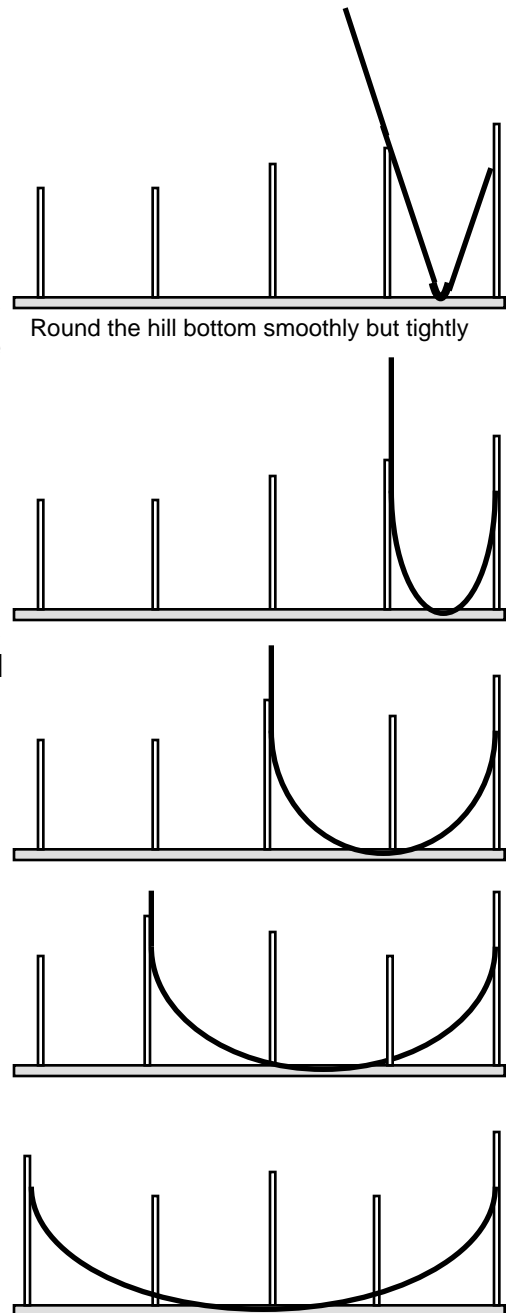
Set up the foam track as shown in the top right picture. You may attach a ruler to the bottom of the track to straighten it. At the bottom for the first run, make sure the track has some curve to it.

For each run, the marble should start at the exact same height.

Measure the maximum height the marble will roll up on the opposite side of the track. Repeat each trial 7 times (before throwing out the high and low values.)

Again, the work of friction is the difference in the sum of the mechanical energies at the top minus the sum of the mechanical energies at the highest rise after the dip.

- What are the different work magnitudes for the friction on each track?
- What do you think caused the differences?



Roller Coaster's, Energy and Work

ENERGY

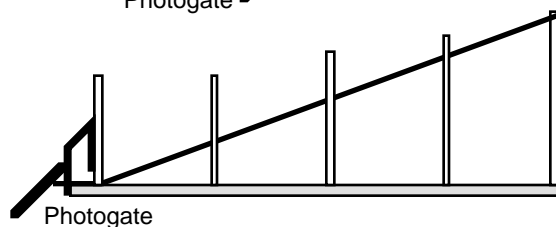
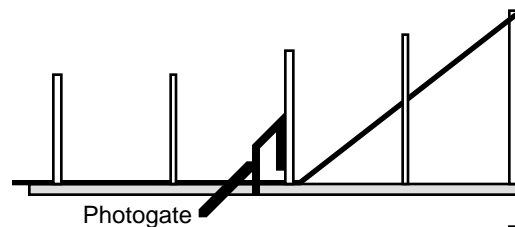
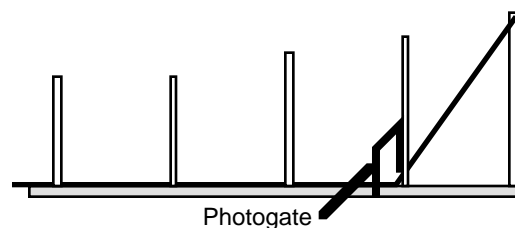
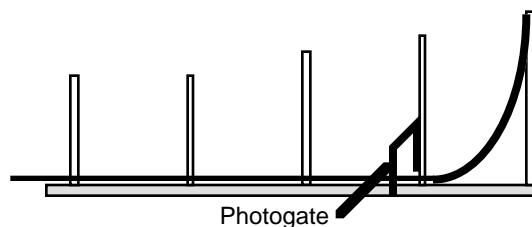
Part 3

This section will investigate the effects of hill shape on speed at the bottom. The data will be collected for 4 different set ups as shown to the right.

Note that each setup displays the location of the photogate. The photogate should be as close to when the hill has finished as possible.

Using the GATE method on the graphing calculators measure the time the marble rolls through the gate. Repeat each trial 7 times (before throwing out the high and low.)

- Use energy relationships to calculate the ideal total energy at the bottom of the hill.
- Calculate the percent error of each run when compared to the calculated total energy .
- Does the hill shape affect the total energy at the bottom?



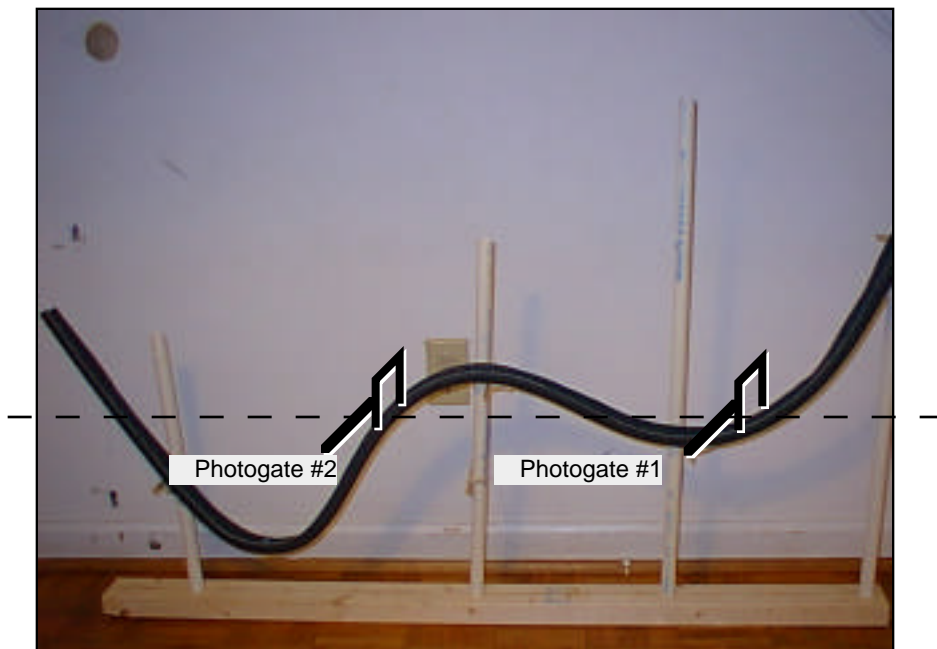
Roller Coaster's, Energy and Work

ENERGY

Part 4

This section will investigate the effects of hill shape on speed at different locations of the same height.

Make a track similar to the shape at the right. Use two probes and place them at the same height as shown below.



Use the GATE method on the graphing calculators measure the time for the marble to roll through the gates. Repeat this trial 12 times before throwing out the high and low values.

- Ideally the kinetic energy should be the same at both locations. Based on your numbers and considering errors is this reasonable? Use numbers to support you answer.

Roller Coaster's, Energy and Work

ANSWER SHEET

Show all work and answers on this page.

Part 1a

Use your in "Part 1" data to come up with your own height to run distance ratio with a plus and minus error.

Part 1b

- Use the data from Part 1a to calculate the work of friction along the horizontal track and the magnitude of the frictional force stopping the ball for all 4 drop heights. Finally, come up with an average frictional stopping force.

Part 2

- What are the different work magnitudes for friction on each track?

- What do you think caused the differences?

Roller Coaster's, Energy and Work

DATA TABLE

Show all work and answers on this page.

Part 1a Data Table

3 cm hill height	Roll distance (m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
Average=>	
+/-Error =>	
Height to Roll Ratio	
6 cm height	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
Average=>	
+/-Error =>	
Height to Roll Ratio	

9 cm hill height	Roll distance (m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
Average=>	
+/-Error =>	
Height to Roll Ratio	
12 cm height	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
Average=>	
+/-Error =>	
Height to Roll Ratio	

Roller Coaster's, Energy and Work

DATA TABLE

Show all work and answers on this page.

Part 1b Data Table

3 cm hill height	Roll distance (m)	Ball's Accel. (m/s ²)	Ball's Stopping Force (N)	Work to stop ball (J)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Average=>				
+/-Error =>				
Height to Roll Ratio				
6 cm height	Roll distance (m)	Ball's Accel. (m/s ²)	Ball's Stopping Force (N)	Work to stop ball (J)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Average=>				
+/-Error =>				
Height to Roll Ratio				

Roller Coaster's, Energy and Work

DATA TABLE

Show all work and answers on this page.

Part 1b Data Table

Continued

9 cm hill height	Roll distance (m)	Ball's Accel. (m/s ²)	Ball's Stopping Force (N)	Work to stop ball (J)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Average=>				
+/-Error =>				
Height to Roll Ratio				
12 cm height	Roll distance (m)	Ball's Accel. (m/s ²)	Ball's Stopping Force (N)	Work to stop ball (J)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Average=>				
+/-Error =>				
Height to Roll Ratio				

Roller Coaster's, Energy and Work

DATA TABLE

Show all work and answers on this page.

Part 2 Data Table

Run #1	Initial Kinetic Energy (J)	Initial Gravitational potential Energy (J)	Final Kinetic Energy (J)	Final Gravitational potential Energy (J)	Word done due to friction(J)
1					
2					
3					
4					
5					
6					
7					
Average=>					
+/- Error					
% Error					

Run #2	Initial Kinetic Energy (J)	Initial Gravitational potential Energy (J)	Final Kinetic Energy (J)	Final Gravitational potential Energy (J)	Word done due to friction(J)
1					
2					
3					
4					
5					
6					
7					
Average=>					
+/- Error					
% Error					

Run #3	Initial Kinetic Energy (J)	Initial Gravitational potential Energy (J)	Final Kinetic Energy (J)	Final Gravitational potential Energy (J)	Word done due to friction(J)
1					
2					
3					
4					
5					
6					
7					
Average=>					
+/- Error					
% Error					

Roller Coaster's, Energy and Work

DATA TABLE

Show all work and answers on this page.

Part 2 Data Table

Continued

Run #4	Initial Kinetic Energy (J)	Initial Gravitational potential Energy (J)	Final Kinetic Energy (J)	Final Gravitational potential Energy (J)	Word done due to friction(J)
1					
2					
3					
4					
5					
6					
7					
Average=>					
+/- Error					
% Error					

Run #5	Initial Kinetic Energy (J)	Initial Gravitational potential Energy (J)	Final Kinetic Energy (J)	Final Gravitational potential Energy (J)	Word done due to friction(J)
1					
2					
3					
4					
5					
6					
7					
Average=>					
+/- Error					
% Error					

Roller Coaster's, Energy and Work

DATA TABLE

Show all work and answers on this page.

Part 3 Data Table

	Time Through Photogate (s)	Velocity through the Photogate (m/s)	Kinetic Energy (J)
1			
2			
3			
4			
5			
6			
7			
Average=>			
+/- Error			
% Error			

Part 4 Data Table

	Time Through Photogate #1 (s)	Velocity through the Photogate (m/s)	Kinetic Energy (J)	Time Through Photogate #2 (s)	Velocity through the Photogate (m/s)	Kinetic Energy (J)	Difference Between the Kinetic Energies (J)
1							
2							
3							
4							
5							
6							
7							
Average=>							
+/- Error							
% Error							