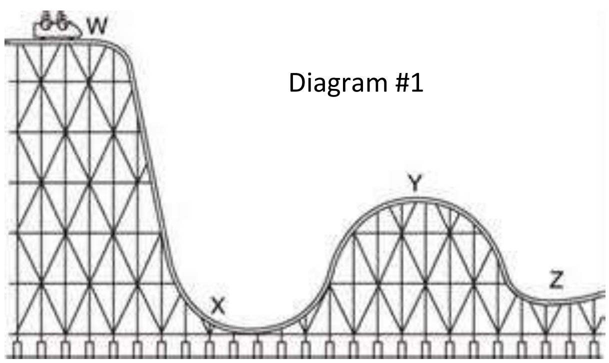
Roller Coaster Lab | Name: ___________________________
Law of Conservation of Energy / 75 | Period: _____________

Introduction:

The **law of conservation of energy**, first formulated in the nineteenth century, is a law of physics. It states that the total amount of energy in an isolated system remains constant over time. The total energy is said to be *conserved* over time. For an isolated system, this law means that energy can change its location within the system, and that it can change form within the system, for instance chemical energy can become kinetic energy, but that energy can be neither created nor destroyed.

In the twentieth century, the definition of energy was broadened. It was found that particles that have rest mass are equivalent to amounts of energy (see mass-energy equivalence). There particles were found subject to annihilation in which *matter* particles (such as electrons) can be converted to *non-matter* (such as photons of electromagnetic radiation), or even into potential energy or kinetic energy. Matter could also be created out of kinetic or other types of energy, in the process of matter creation. Thus, matter (defined as ponderable matter particles) was found not to be conserved.

We will apply this law to the real world phenomenon of Roller Coasters.



We will use Diagram #1 to the immediate left to simulate what will be attempted to replicate in lab.

Knowing the Law of Conservation of Energy, as stated above in the Introduction, we can represent this with the below formula, as it related to each point on the rollercoaster.

Energy at 1 = Energy at 2 = ………………. Energy at 7
OR this can be stated that the sum of PE (potential energy) + KE (kinetic energy) at each point is equal to every other point on the roller coaster, assuming friction is not considered a factor (negated). This is known as Mechanical Energy (ME) Below is the formula associated with this concept.

Energy at 1 = Energy at 2 = ……………….. = Energy at 7

$PE_1 + KE_1 = PE_2 + KE_2 = PE_{...} + KE_{....} = PE_7 + KE_7$

$Mgh_1 + 1/2\ mv_1^2 = mgh_2 + 1/2\ mv_2^2 = mgh_{....} + 1/2\ mv_{....}^2 = mgh_7 + 1/2\ mv_7^2$

OBJECTIVE:

The objective of this lab is to calculate energy at differing points on a rollercoaster, calculate the theoretical velocity and measure the actual velocity at differing points on a given rollercoaster track and determine conservation of energy values.

Pre-Lab Questions:

1. Examine the roller coaster track. At which points(s) on the track will the marble have the most gravitational potential energy (PE_g)? why?

2. At which point(s) on the track will the marble have the most kinetic energy (KE)? Why?

3. At which point(s) on the track will the PE_g and KE be equal? Why?

4. At which point on the track will the marble be moving the fastest? Why?

5. At which point on the track will the marble be moving the slowest? Why?

Setting up the Roller Coaster:

Items Needed:

-One Photogate timer apparatus
-One Ramp Stand
-One Rollercoaster track
- LabQuest interface
- Meterstick
- Steel Marble

Attach the roller coaster to the support pole with the pole clamps. Use the starting peg to start the marble in the same place each time you roll it down. It sometimes takes a few tries to roll it straight so that it stays on the track. Refer to Diagram #2 on the next page to learn where you will place each photogate. Record these positions in Table #1. These are the vertical heights (h) as measured from the lab table.

Configure the LabQuest interface:

You need to configure the LabQuest interface so the photogate will measure the velocity of the marble as the marble passes through it. As the marble passes through the photogate, it will block the infrared beam (and the red LED on the top of the photogate will turn on). Once the marble has passed through the photogate, the infrared beam will no longer be blocked.

To configure the LabQuest interface:

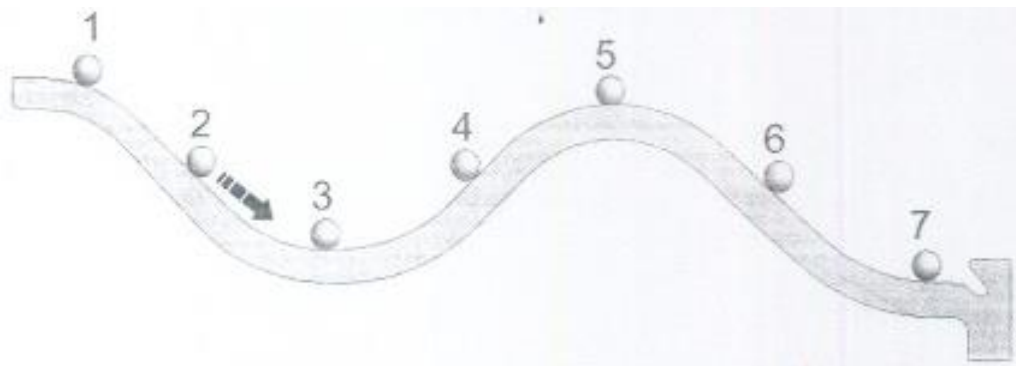
- Connect the photogate sensor to the LabQuest interface using the DIG1 port on the top of the interface. *Make sure the connector is oriented correctly. Do not force the connector into the port!*
- Turn the LabQuest on
- Press the home button
- Tap LabQuest App icon
- In the upper left hand corner, tap the meter icon 
- Tap “Sensors” → “Sensor Set Up”
- If DIG1 says “No Sensor”, tap the “No Sensor” tab and select “Photogate”.
- Tap “OK”
- Tap “Sensors” → “Data Collection”
- For Mode, select “Photogate Timing”
- For Photogate Mode, select “Gate”

- For length of object, enter the diameter (in meters) of the marble
- For End Data Collection, select “after 2 events”
- Tap “OK”

Your LabQuest is now ready to record the speed of the marble.

Diagram #2: Roller coaster track positions

Position 1: *0 cm*
Position 2: *25 cm*
Position 3: *43 cm*
Position 4: *60 cm*
Position 5: *80 cm*
Position 6: *105 cm*
Position 7: *125 cm*



To understand what is happening to the marble, you need to measure the speed (v) and the height(h) at the indicated positions.

You may realize that you don't need the mass of the marble, but for the time being, obtain the mass of the marble from the triple beam balance and record this in Data Table #1.

Speed is the distance traveled divided by time taken to travel that distance. During the time that the timer is counting, the marble moves one diameter. Therefore, the distance traveled is the diameter of the marble, and the time taken is the time from the photogate for the marble to enter and exit the light beam. Record the diameter of the marble in Data Table #1 and the time of the photogate in Data Table#1. Determine the speed of the marble at each point on the track. Record this speed in Data Table #1. Complete three trials at each position and calculate the average velocity.

When the marble is speeding up, it is gaining kinetic energy from falling down a hill. The kinetic energy is converted from potential energy the marble had at the top of the hill. As the marble goes along, it trades potential and kinetic energy back and forth.

To measure potential energy, we need to ensure that we have recorded the position on the track in which the height is measured (placed in Data Table #1) and then use the meter stick to measure the distance up from the lab table to this point. Calculate the potential energy (PE_g) by using the formula "mgh" and record this in Data Table #1. Use value of mass recorded in Data Table #1.

To measure kinetic energy, we need to use the photogate to find the speed of the marble. Use the formula $KE = 1/2\ mv^2$ to calculate the KE at each point on the roller coaster. Use value of mass recorded in Data Table #1. Record this KE in Data Table #1.

Now, these are the velocities, PE and KE, that we calculate using actual data from the lab situation. Because of friction and other variables, this information may be accurate to a limited amount. But we need to compare this to theoretical calculations, as done in typical homework problems to see how much they might differ in reality.

Procedure:

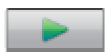
1. Measure the mass of the marble. Record the mass (in *kg*) in the data table.

2. Practice rolling the marble down the track. The marble should roll all the way to the end of the track without falling off. If the marble falls off of the track, adjust the height of the track so the marble will stay on.

3. For position 1 (*0 cm*), record the height above the lab table on the data sheet. Calculate PE_g of the marble at rest at position 1 and enter the value in the data sheet. Determine the KE and total mechanical energy $(ME = KE + PE_g)$ for position 1.

4. Measure the height above the lab table of position 2. Record the height in the data table.

5. Place the photogate at position 2 (*25 cm*). The photogate should be placed so the beam is above the track at a distance equal to the radius of the marble.

6. Tap the Collect button  on the LabQuest and release the marble from rest from the top of the track (*0 cm*). The LabQuest should stop recording once the marble passes through the photogate. Record the velocity of the marble in the data table.

7. Complete two more trials for position 2. Record the velocity for each trial in the data table.

8. Calculate the average velocity of the marble at position 2 from the three trials.

9. Calculate the $PE_g, KE, and\ ME$ for the marble at position 2. Enter the values in the data table.

10. Repeat steps 4-9 for the other positions indicated in Diagram 2.

Data Table #1:

Diameter of marble (m):			Mass of marble (kg):			
Position	Height (m)	Velocity (m/s)	Average Velocity (m/s)	Potential Energy $PE_g = mgh$ (J)	Kinetic Energy $KE = \frac{1}{2}mv^2$ (J)	Total Mechanical Energy $ME = PE_g + KE$ (J)
1						
2		Trial 1:				
		Trial 2:				
		Trial 3:				
3		Trial 1:				
		Trial 2:				
		Trial 3:				
4		Trial 1:				
		Trial 2:				
		Trial 3:				
5		Trial 1:				
		Trial 2:				
		Trial 3:				
6		Trial 1:				
		Trial 2:				
		Trial 3:				
7		Trial 1:				
		Trial 2:				
		Trial 3:				

Obtain Graph paper and:

1. Use the provided graph paper to show the PE_g , KE, and ME at each position. All three types of energy should be on one graph. Therefore use dots (●) for PE_g , “x” for KE, and squares (□) for ME at each position. Place the height on the “y-axis” and the Energy (J) on the “x-axis”. Draw a “line of best fit” for each type of energy. Title the Graph properly.

In Data Table #2, Use the space provided to calculate the theoretical velocity at each point identified on the roller coaster track. Show your work NEATLY! Place this information in Data Table #2. Transfer the velocity of the marble determined and recorded from Data Table #1 into the appropriate column in Data Table #2. Determine the % Error by finding the difference between the two values (theoretical and determined) and recording the absolute value (absolute error) into the error column. Divide the absolute error by the theoretical value and record this value as the relative error in the labeled column. Now find the % Error by multiplying the relative error value by 100%. Record in the column.

Data Table #2:

***Absolute error** is the magnitude of the difference between the exact value and the calculation.
*The **relative error** is the **absolute error** divided by the magnitude of the exact value.

Track position	Velocity Calculated at each position with formula	Velocity	Velocity	Absolute Error	Relative Error	% Error
	$mgh + 1/2mv^2 = mgh + 1/2mv^2$	Calculated	Table#1			
2						
3						
4						
5						
6						
7						

Post lab questions:

1. Describe the flow of energy between potential and kinetic along the roller coaster. Your answer should indicate where the potential energy is greatest and least, and also where the kinetic energy is greatest and least.

2. Describe the shapes of the graphs. What does the shape of each graph specifically tell you about the relationship between height and velocity and/or velocity squared?

3. How much work was required to move the marble between positions 3 and 5? Use the work-energy theorem, $W = (KE_f - KE_i) + (PE_{gf} - PE_{gi})$, to calculate your answer.

Score:
________ 20 Graph
________ 45 Data
________ 10 Postlab
________ 75 Total

4. Do the actual velocities and calculated velocities equal each other?
If not, why are they different?