Conservation of Energy Lab

Author: Hanke Chen
Experimental Group: Scout Crooke, Elena Engler, and Seth Gorton
Date of lab: 2/15/19-2/22/19
Due Date: 3/1/19

***Abstract*— Our research objective is to use our knowledge of Conservation of Energy and Projectile Motion Kinematics to predict how far a marble will travel away from the table before hitting the ground after rolling down a slope and off the edge of a table. We compare the theoretical value to the experimental value to verify the theory of Conservation of Energy using statistics.**

I. Theory

- Conservation of Energy
- Potential Energy on Earth: $U = mgh$
- Rotational Kinetic Energy: $KE = \frac{1}{2}Iw^2$
- Linear Kinetic Energy: $KE = \frac{1}{2}mv^2$
- Kinematics: $\delta x = v_x t$
- Rotational Inertia of a Ball: $\frac{2}{5}mr^2$

II. Procedure

1) We propped the clear tube up using multiple textbooks, serving as a ramp without any slope greater than 45 degrees angle to the leveled desktop.
2) We used duct tape to secure the tube to the table and the books on the table.
3) We measured the height from the surface of the textbooks to the surface of the desk and from the surface of the textbooks to the highest inside surface of the ramp.
4) We measured the height of the tub from the table and to the floor using a measuring tape.
5) We placed a meter stick against the edge of the table so that it is parallel to the table and perpendicular to the floor in order to find the location on the ground directly below the edge of the table. Place a piece of electrical tape on the floor to mark the distance.
6) We made sure all the measurements are precise: the ruler is perfectly straight and perpendicular to the edge of the desk or the floor; all measurements are done by having eyes aligned perpendicularly to the mark. We made sure all measurement errors come from the precision of the ruler.
7) We released the marble from the edge of the top of the tube.
8) We took a video in slow motion of where the marble hits the floor with a meter stick on the ground and recorded the distance from the landing point of the marble to the tape.

TABLE I
Data collected by measurements and experiments

Trail	Distance (cm)
Ball traveled 1	76.3 ± 0.5
Ball traveled 2	75.7 ± 0.5
Ball traveled 3	76.7 ± 0.5
Ball traveled 4	76.8 ± 0.5
Ball traveled 5	76.3 ± 0.5
Ball traveled 6	76.2 ± 0.5
Ball traveled 7	77.5 ± 0.5
Ball traveled 8	77.0 ± 0.5
Ball traveled 9	77.0 ± 0.5
10	76.4 ± 0.5
Average	76.59
STD.P	0.49
STD.S	0.51
Height of ramp_{1}	21.85 ± 0.05
Height of ramp_{2}	3.00 ± 0.05
Height of ramp_{total}	24.85 ± 0.10
Height of drop	91.28 ± 0.05

III. Data

Height of ramp: 21.85 + 3.00 = 24.85cm
Height of drop: 91.28cm

IV. Analysis

A. Experimental Calculation

$$\delta\bar{x} = 76.59 \pm 0.51cm \approx 76.6 \pm 0.5cm$$

B. Theoretical Calculation

$h = 21.85cm + 3.00cm = 24.85 \pm 0.10cm$ $\delta y = 91.28 \pm 0.05cm$ $\delta h = 0.10cm$ $\delta\delta y = 0.05cm$

Conservation of Energy
$mgh = \frac{1}{2}mv^2 + \frac{1}{2}\frac{2}{5}mr^2\frac{v^2}{r^2}$
$v = \sqrt{\frac{10gh}{7}}$
$mgh = \frac{1}{2}mv^2$
$v_x = \sqrt{2gh}$
$\delta y = \frac{1}{2}gt^2$
$t = \sqrt{\frac{2\delta y}{g}}$
$\delta x = vt = \sqrt{\frac{10gh}{7}}\sqrt{\frac{2\delta y}{g}} = \sqrt{\frac{20\delta yh}{7}}$
Propagating the Error
$\sigma_h = \frac{d\delta x}{dh}\delta h = \sqrt{\frac{5\delta y}{7h}}\delta h = \sqrt{\frac{5*0.10}{7*24.85}} * 0.10 = 0.005361333 \approx 0.0054cm$
$\sigma_{\delta y} = \frac{d\delta x}{d\delta y}\delta\delta y = \sqrt{\frac{5*24.85}{7*91.28}} * 0.05 = 0.0220486177 \approx 0.022cm$

$\sigma_{\delta x} = \sqrt{\sigma_h^2 + \sigma_{\delta y}^2} = 0.0226910871 \approx 0.023cm$

$\delta\bar{x} = \sqrt{\frac{20\delta yh}{7}} = \sqrt{\frac{20*91.28*24.85}{7}} = 80.50391295 \approx 80.50 \pm 0.023cm$

C. Calculation Conclusion

If energy is conserved: $min(big) < max(small)$. For our experiment $(80.50 - 0.023)cm < (76.6 + 0.5)cm$. Thus the energy is conserved!

V. Source of Error

There are some sources of error in our experiment:

- There are some marble's potential energy converted to heat and sound due to the kinetic friction with the surface of the ramp and air resistance. Therefore, the experimental result would be smaller than the theoretical result. Our experimental design minimizes the error by limiting the maximum angle to 45 degree so that the kinetic friction can be reduced.
- The ramp may be tilted due to the nature of the material. That way, the experimental value of delta x would be larger than the theoretical. We taped the end of the ramp carefully to minimize this error.
- The random error may be introduced by moving the desk, book, measuring stick, and ramp slightly, that we did not notice, leading to a bigger uncertainty in collecting the height of the ramp and the height of the drop. We taped the the textbooks carefully and have tapes to mark the position of the desk to minimize this error.

VI. Conclusion

In this experiment, we accomplished our research objective by using our knowledge of Conservation of Energy and Projectile Motion Kinematics to predict how far a marble will travel away from the table before hitting the ground after rolling down a slope and off the edge of a table.

We compare the theoretical value to the experimental value to verify the theory of Conservation of Energy using statistics. Our difference of experimental value $(76.5cm)$ and theoretical value $(80.50cm)$ are less than $5cm$, suggesting that the energy loss is negligible if it ever exist. Because our error range of experimental value ($\delta\bar{x} \approx 76.5 \pm 0.5cm$) and our theoretical value ($\delta\bar{x} \approx 80.50 \pm 0.023cm$) overlaps, the energy is conserved between the ball released and hit to the ground. The theory of Conservation of Mechanical Energy is verified to be true. Our experiment was considered successful because we verified the theory.