Conservation of Energy Lab Report

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Contents

1 Data/Result Tables

Table 1: Measured Values

Variable	Measured Value
m_{cart}	$(513 \pm 2)g$
h_i	$(25.4 \pm 0.05)cm$
h_f	$(2.00 \pm 0.05)cm$
Δs	$(121.00 \pm 0.05)cm$

Table 2: Experimental Values

Variable & Trial Number	Measured Value
$v_{f,1}$	$1.901\frac{m}{s}$
$v_{f,2}$	$1.965\frac{m}{s}$
$v_{f,3}$	$1.978\frac{m}{s}$

Table 3: Other Values

Variable	Value
v_i	$0\frac{m}{s}$
g	$9.8\frac{m}{s^2}$

Table 4: Calculated Values

Variable	Calculated Value
v_f with uncertainties	$(2.14 \pm 0.02)\frac{m}{s}$
$v_{f,avg}$ (average of measurements)	$1.948\frac{m}{s}$
f (friction)	$(0.168 \pm 0.005)N$

2 Analysis

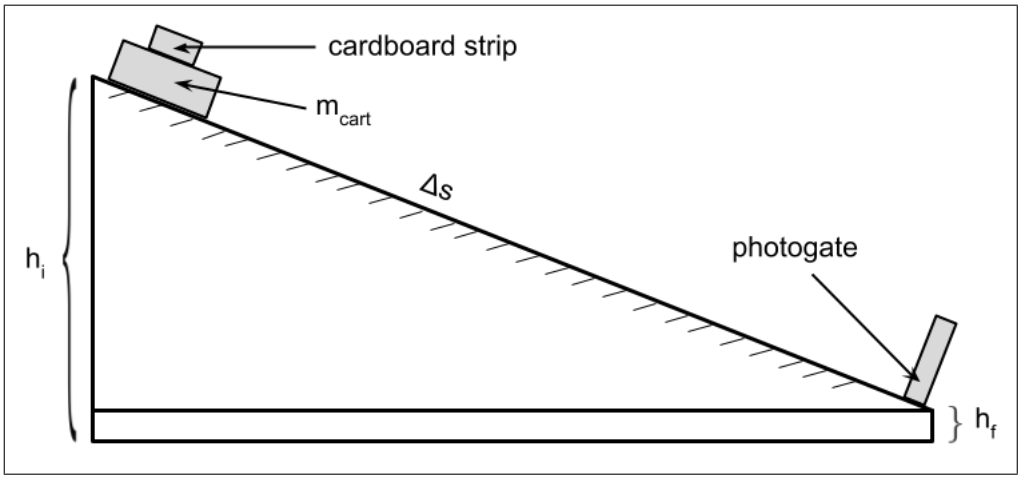

Figure 1: Diagram of ramp setup

2.1 Question 1

Assuming no friction, $W_{nc} = 0$. There are only conservative forces.

$$
\begin{aligned}
\Delta M &= W_{nc} \\
\Delta M &= 0 \\
M_f - M_i &= 0 \\
M_i &= M_f \\
U_i^g + \cancelto{0 \text{ b/c } v_i = 0}{K_i} &= U_f^g + K_f \\
mgh_i &= mgh_f + \frac{mv_f^2}{2} \\
gh_i &= gh_f + \frac{v_f^2}{2} \\
gh_i - gh_f &= \frac{v_f^2}{2} \\
\frac{v_f^2}{2} &= g(h_i - h_f) \\
&= 9.8\frac{m}{s^2} \cdot ((25.4 \pm 0.05)cm - (2 \pm 0.05)cm) \\
&= 9.8\frac{m}{s^2} \cdot ((25.4 - 2)cm \pm (0.05 + 0.05)cm) \\
\frac{v_f^2}{2} &= 9.8\frac{m}{s^2} \cdot (23.4 \pm 0.1)cm \\
v_f^2 &= 2 \cdot 980\frac{cm}{s^2} \cdot (23.4 \pm 0.1)cm \\
&= (45864 \pm 392)\frac{cm^2}{s^2} \\
v_f^2 &= (4.5864 \pm 0.0392)\frac{m^2}{s^2} \\
v_f &= \sqrt{(4.5864 \pm 0.0392)\frac{m^2}{s^2}} \\
&= \left(4.5864^{0.5} \pm 0.5 \cdot \left(\frac{0.0392}{4.5864}\right) \cdot 100\%\right)\frac{m}{s} \\
&= 2.14\frac{m}{s} \pm 0.85\% \\
&\boxed{v_f = (2.14 \pm 0.02)\frac{m}{s}}
\end{aligned}
$$

2.2 Question 2

$$\begin{aligned} v_{f,avg} &= \frac{v_{f,1} + v_{f,2} + v_{f,3}}{3} \\ &= \left(\frac{1.901 + 1.965 + 1.978}{3}\right)\frac{m}{s} \\ v_{f,avg} &= 1.948\frac{m}{s} \end{aligned}$$

From question 1,

$$v_f = (2.14 \pm 0.02)\frac{m}{s}$$
$$v_f \in [2.12,\ 2.16]\frac{m}{s}$$
$$2.12 > 1.948$$

Therefore the two values are not within experimental error.

2.3 Question 3

$$
\begin{aligned}
\Delta M &= W_{nc} \\
M_f - M_i &= W_f \\
W_f &= K_f + U_f^g - (\cancel{K_i}^{0 \text{ b/c } v_i = 0} + U_i^g) \\
-f\Delta s &= \frac{mv_f^2}{2} + mgh_f - mgh_i \\
&= m\left(\frac{v_f^2}{2} + gh_f - gh_i\right) \\
&= m\left(\frac{v_f^2}{2} + g(h_f - h_i)\right)
\end{aligned}
$$

$$
\begin{aligned}
\frac{v_f^2}{2} &= \frac{\left((1.948 \pm 0.001)\frac{m}{s}\right)^2}{2} \\
&= \frac{1.948^2 \pm 2 \cdot \left(\frac{0.001}{1.948}\right) \cdot 100\% \ \frac{m^2}{s^2}}{2} \\
&= \frac{3.796 \pm 0.103\% \ \frac{m^2}{s^2}}{2} \\
&= 1.897\frac{m^2}{s^2} \pm 0.103\% \\
\boxed{\frac{v_f^2}{2} = (1.897 \pm 0.002)\frac{m^2}{s^2}}
\end{aligned}
$$

$$
\begin{aligned}
h_f - h_i &= (2 \pm 0.05)cm - (25.4 \pm 0.05)cm \\
&= ((2 - 25.4) \pm (0.05 + 0.05))\, cm \\
&= (-23.4 \pm 0.1)cm \\
\boxed{h_f - h_i = (-0.234 \pm 0.001)m}
\end{aligned}
$$

$$-f\Delta s = m\left(\frac{v_f^2}{2} + g(h_f - h_i)\right)$$

$$f = -\frac{m\left(\frac{v_f^2}{2} + g(h_f - h_i)\right)}{\Delta s}$$

$$= -\frac{(513 \pm 2)g \cdot \left((1.897 \pm 0.001)\frac{m^2}{s^2} + 9.8\frac{m}{s^2} \cdot (-0.234 \pm 0.001)m\right)}{(121 \pm 0.05)cm}$$

$$= -\frac{(0.513 \pm 0.002)kg \cdot \left((1.897 \pm 0.001)\frac{m^2}{s^2} + 9.8\frac{m}{s^2} \cdot (-0.234 \pm 0.001)m\right)}{(1.21 \pm 0.0005)cm}$$

$$= -\frac{(0.513 \pm 0.002)\left((1.897 \pm 0.001) + (-2.293 \pm 0.0098)\right)}{1.21 \pm 0.0005}N$$

$$= -\frac{(0.513 \pm 0.002)\left((1.897 - 2.293) \pm (0.001 + 0.0098)\right)}{1.21 \pm 0.0005}N$$

$$= -\frac{(0.513 \pm 0.002)(-0.396 \pm 0.011)}{1.21 \pm 0.0005}N$$

$$= -\frac{\left((0.513 \cdot -0.396) \pm \left(\frac{0.002}{0.513} + \frac{0.011}{0.396}\right) \cdot 100\%\right)}{1.21 \pm 0.0005}N$$

$$= \frac{0.203 \pm 3.168\%}{1.21 \pm 0.0005}N$$

$$= \frac{0.203 \pm 0.006}{1.21 \pm 0.0005}N$$

$$= \left(\left(\frac{0.203}{1.21}\right) \pm \left(\frac{0.006}{0.203} + \frac{0.0005}{1.21}\right) \cdot 100\%\right)N$$

$$= (0.168 \pm 2.997\%)N$$

$$\boxed{f = (0.168 \pm 0.005)N}$$

3 Error Discussion

3.1 Random Errors

1. There could have been random shakes or vibrations on the track, from people bumping on the table or from footsteps of people walking nearby.

2. There may have been slight fluctuations in the slant of the cardboard strip on the cart with each trial caused by the handling of the cart after each trial.

3.2 Systematic Errors

1. The slant of the table which the apparatus rested on could have been slightly slanted, thus affecting h_i and h_f values relative to a flat plane like the floor.

2. The paper taped onto the cart may not have been perfectly perpendicular to the path of the cart. This may have resulted in more air friction. Furthermore, it may have affected the reading on the photogate as it was unable to read the full length of the cardboard.

3. Placing the photogate so close to the end of the track could have resulted in inaccurate readings. The front of the cart left the track first, causing the cart to tilt slightly forward. This may have lowered the height of the cardboard on the cart and brought it out of line of the photogate, prematurely ending the reading.

4. The placement of the cardboard strip on the cart was in a way that the start of the strip travelled less than Δs when it was picked up by the photogate. Δs was measured to the back of the cart. The measurements would have been more accurate if the cardboard strip was placed at the very end of the cart or Δs was measured to the start of the cardboard.