Scott Nomura

Lab: Cons. of Momentum, Energy: The Ballistic Pendulum

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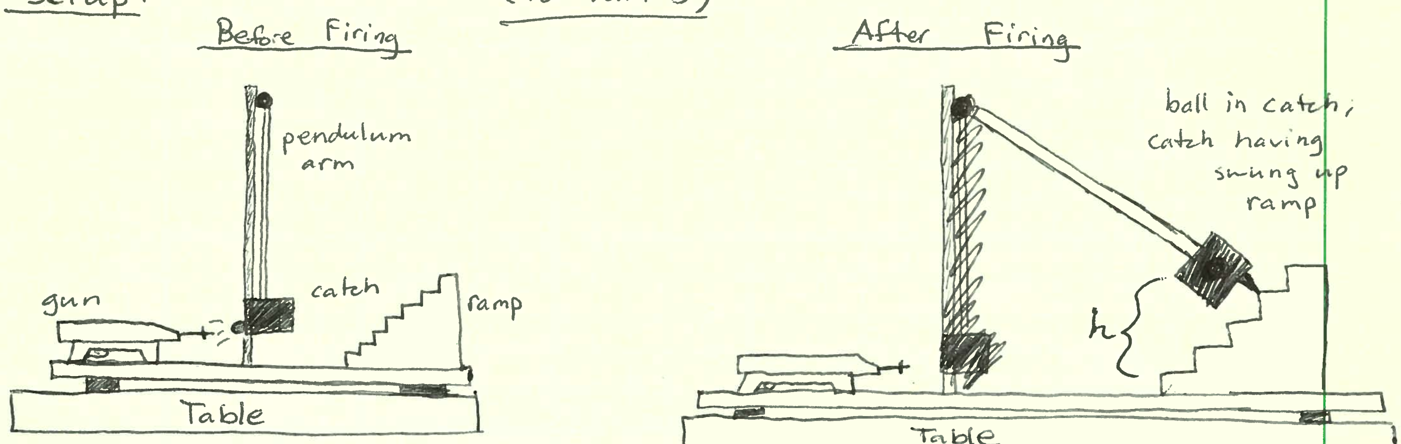
Objective: To experimentally determine, in 2 different ways, the "muzzle velocity" of a bullet leaving a gun. The first approach will be to use a classic projectile-based, kinematics approach to finding v_{bullet}. The second approach will involve using a "ballistic pendulum."

Theory: Conservation of momentum and conservation of energy are 2 fundamentally important Physics laws, and many common problems require the appropriate application of both.

Equipment: Ballistic pendulum unit, w/steel ball (bullet)
Meter stick
Balance

Setup: (For Part B)



Procedure:

Part A — V_{muzzle} of the ball using Kinematics

1. Carefully remove the pendulum arm from the ballistic pendulum base and set it aside.

2. Make sure the gun is oriented horizontally, with ≥4 m of clear space in front of it. The gun should <u>NEVER</u> be loaded and cocked if there are people in front of it.

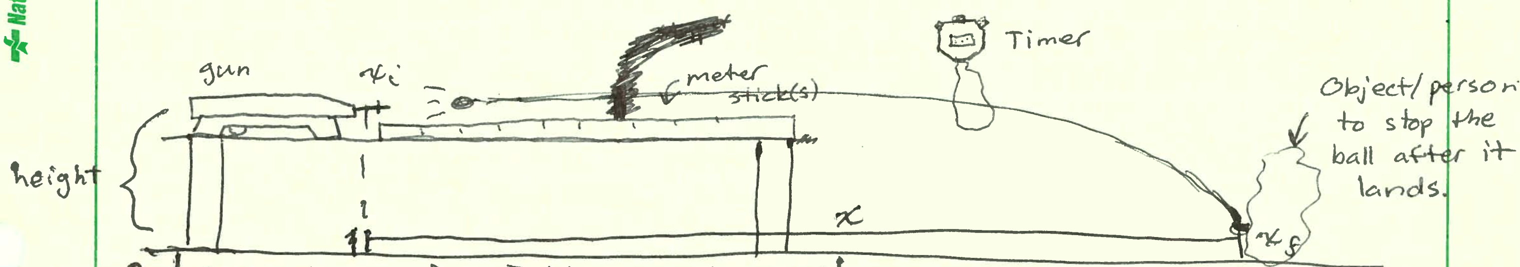
3. Take measurements to calculate V_{ball} as it leaves the gun. Take multiple trials.

Part B — V_{muzzle} of ball using Conservations of Momentum & Energy

1. Reattach the pendulum arm; DO NOT OVERTIGHTEN THE BLACK PIVOT SCREWS! Align the catcher horizontally & vertically with the ball. Receive confirmation to start from instructor.

2. Fire the ball into the catcher. Run 3 trials, collecting data to determine the V_{muzzle} of the ball.

• Setup: (For Part A)



• Observations, Data Tables, & Graphs:

Table 1

Height (m)	1.015 m (from floor to table = 95.5cm, table to ball = 6.0 cm)
Avg. Horiz. Distance (m)	3.02 m
Mass of ball (g)	69.0 g = 0.069 kg
(g) Mass of Pendulum Arm	271.1 g = 0.2711 kg
CM of Catcher (cm)	7.0 cm = 0.07 m

Table 2

Trial #	Horiz. Distance (m)
1	2.98 m
2	3.08 m
3	2.99 m
Avg.	3.02 m

Table 3

Trial #	Vertical height (cm)
1	16.0 cm
2	16.0 cm
3	16.0 cm
Avg.	16.0 cm (0.16 m)

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For Part A:

$y_f = y_i + v_i t + \frac{1}{2}at^2$ ← Solve for time it took ball to fall

$y_f = 0 + 0 + \frac{1}{2}at^2$

$t^2 = \frac{2y_f}{a}$

$t = \sqrt{\frac{2y_f}{a}}$ ← Plug in the negative height for y_f (since $y_i = 0$) ↗ From Table 1

so, $t = \sqrt{\frac{2(-1.015m)}{-9.8m/s^2}}$

$t = 0.455s$

Now, solve for v_{x_i} using $v = \frac{d}{t}$:

$v = \frac{d}{t}$ ← substitute $t = \sqrt{\frac{2y_f}{a}}$

$= \frac{d}{0.455s}$ ← Use Avg. Horiz. Distance from Table 1

$= \frac{3.02m}{0.455s}$

$= \boxed{6.64\ m/s}$

For Part B:

Start with Conservation of Energy:

$K_i = U_f$

$\frac{1}{2}\cancel{m}v^2 = \cancel{m}g(h_f - h_i)$ ← Masses cancel

$\frac{v^2}{2} = g(h_f - h_i)$

$v^2 = g2(h_f - h_i)$

$v = \sqrt{2g(h_f - h_i)}$

Next, use Conservation of Momentum:

$\underset{(ball)}{m_1 v_1} + \underset{(catcher)}{m_2 v_2} = \underbrace{(m_1 + m_2)}v'$

Added together, b/c after the collision, the ball and catcher are combined.

Re-arrange eqn. to solve for v_1 (velocity$_i$ of ball):

$$v_1 = \frac{(m_1+m_2)}{m_1} \cdot v'$$

⟵ $m_2 v_2$ term cancels, b/c the catcher started at rest ($v_2 = 0$).

or,

$$v_1 = \frac{(m_1+m_2)}{m_1} \cdot \sqrt{2g(h_f - h_i)}$$

⟵ Plug in the v value we got in the first part of Part B (Cons. of Energy)

$$= \frac{(0.069 + 0.2711)}{0.069\ kg} \cdot \sqrt{2(9.8)(0.16 - 0.07)}$$

Have to remember to subtract the ball's original height (measured from its initial center of mass).

$$= 4.93 \cdot 1.33$$

$$= \boxed{6.55\ m/s}$$

Discussion:

- % diff.: $\frac{|Value2 - Value1|}{|Value2 + Value1|/2} \times 100$

$$= \frac{6.64 - 6.55}{(6.64 + 6.55)/2} \times 100 = \frac{0.09}{6.595} \times 100 = 1.36\ \%$$

Yay!

- In this lab, there were a few sources of error: Though it was probably very small, air resistance could have affected the velocity of the ball. Also, although the pendulum swings with low friction, there is still some friction that could affect the velocity. Lastly, the level of the floor and or table might not have been completely flat, and this could have created errors for part A, when we had to find the velocity with a projection method. And actually, the pendulum never started from exact rest, so the velocity (initial) was slightly off due to the tiny oscillations.

Summary of Results:

This week in lab, we found the velocity of a ball (shot by a gun) by using kinematics and conservation of momentum. For the kinematics part, we measured the horizontal distance traveled, the vertical height from which the ball was shot, used these values to derive the time it took the ball to fall then finally calculated the v_i. For the momentum part, we measured initial and final masses and the final height in order to figure out the v_i. To help us figure out v_i in Part B, we used the Law of Conservation of Energy as well as the Conservation of Momentum.

Through the kinematic approach, we got a v value of 6.64 m/s, and through the ballistic pendulum approach, we got a v value of 6.55 m/s. ~~With~~ The % difference was only 1.36%, so we can conclude that bothe methods give us a v value.

This lab was soo good, Scott, that I couldn't bring myself to write on it until the very end. Nicely done!

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