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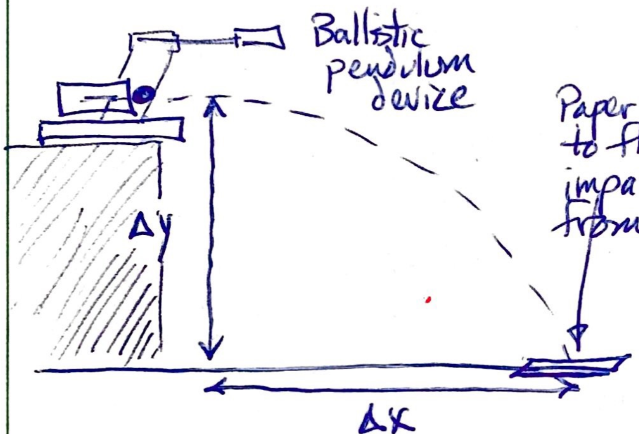
2018-11-12

AP Physics Lab: Conservation of Momentum, Energy

Objective: To determine the muzzle velocity of a projectile from a ballistic pendulum device, using both kinematics & conservation of momentum.

Setup:

Part I

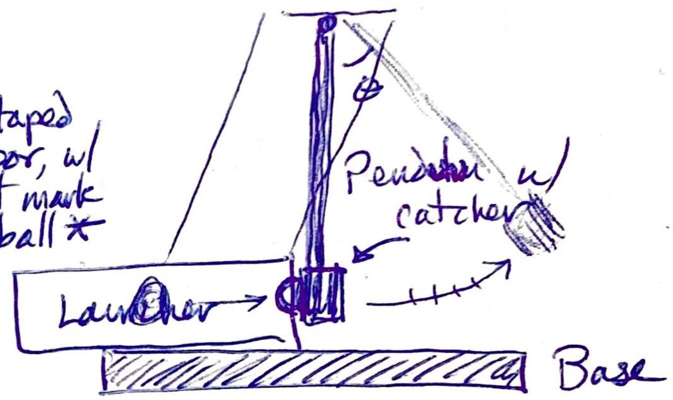


Classic projectile motion analysis

$$\Delta y = v_i t + \frac{1}{2}at^2$$

$$v_x = \frac{\Delta x}{\Delta t}$$

Part II



Ballistic pendulum analysis

$$U_{gi} + K_i = U_{gf} + K_f$$

$$p_1 + p_2 = p_{1\&2}$$

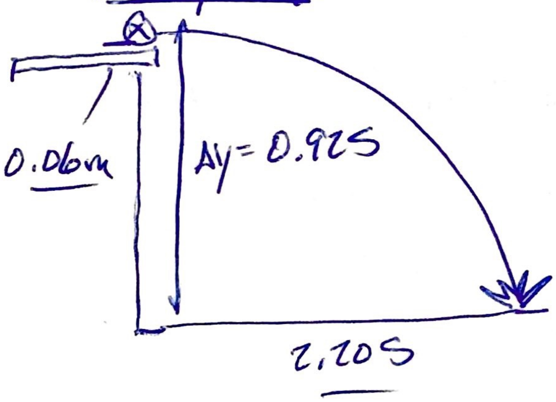
* We used multiple points of impact, & estimated an average position based on those points.

Data: Original data sheets attached on back.

Part I. Kinematics analysis

Distance Δy from floor to ball's center of mass, measured w/ meterstick	0.925m
Distance Δx, from release location to point of impact on floor, measured w/ metersticks	2.205 m + 0.06 m (base to release pt) = 2.265 m

Analysis:



Time to fall vertically:

$\Delta y = v_i t + \frac{1}{2}at^2$

$-0.925 = 0t + \frac{1}{2}(-9.8)t^2$

$\Delta t = 0.4345\,s$

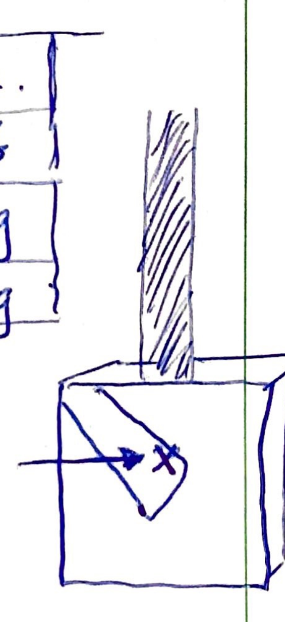
Velocity horizontally:

$V_x = \frac{\Delta x}{\Delta t} = \frac{2.265\,m}{0.4345\,s} = \boxed{5.21\,m/s}$

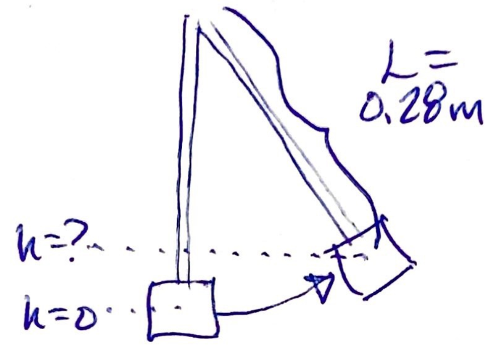
Part II Ballistic Pendulum analysis

Radius of arm to center of mass	0.28m.
θ of arm swing, relative to vertical	38°
Mass of ball & pendulum arm	310.03 g
Mass of ball alone	65.89 g

Note: Center of Mass measured at this point. (based on efforts to balance pendulum w/ ball in it.)



Analysis (of Ballistic Pendulum



<u>After</u> ball has hit pendulum, Conservation of Mechanical Energy indicates:

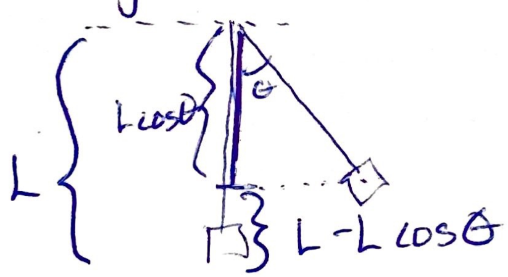
$$K_i = U_f$$

$$\frac{1}{2}mv^2 = mgh$$

$$v^2 = 2gh, \text{ so}$$

$$v = \sqrt{2gh}$$

Height $h = L - L\cos\theta$



So... $v = \sqrt{2g(L - L\cos\theta)}$

$= \sqrt{2 \cdot 9.8 \cdot (0.28 - 0.28\cos 38)}$

$= 1.0786$ m/s

<u>Before</u> ball hits pendulum (& during collision)

$$p_{ball} + p_{catcher} = p_{ball\ \&\ catcher}$$

$$m_{ball} v_{ball} + m_{catcher} v_{catcher} = m_{ball\ \&\ catcher} v_{ball\ \&\ catcher}$$

$$(0.06589)\, v_{ball} + 0 = (0.31003)(1.0786)$$

$$v_{ball} = \boxed{5.08 \text{ m/s}}$$

Discussion:

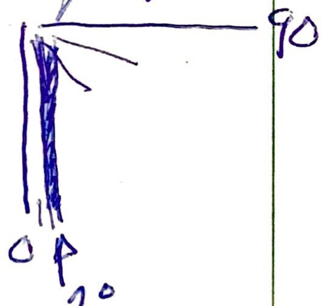
$$\% \text{ difference} = \frac{|5.08 - 5.21 \, m/s|}{\frac{5.08 + 5.21}{2}} \times 100$$

$$= 2.53\% \text{ difference}$$

Sources of Uncertainty:

Although the 2.53% error is a relatively low value for labs in this class, it's not surprising that our results were a bit off.

For the ballistic pendulum part of the lab, the center-of-mass was difficult to identify, making both angle & height calculations much more challenging. The plastic piece designed to aid in determining angle wasn't initially at the 0 position on the scale, meaning that either the scale or the plastic piece itself may have been off.



The original angle of 2°, if due to an incorrect orientation of the scale, would suggest an actual angle of 36°, but this would actually produce a smaller calculated velocity (even further from the kinematic result), so... it's unclear how this angle might have affected the result. Friction on the plastic piece, of course, might have played a part.

The kinematics analysis, while relatively straightforward to calculate, involved measurements over greater distances (2.265 meters horizontally). A difference of 5 or 6 centimeters is the calculated error here, if our results were to be the same for both parts of the lab.

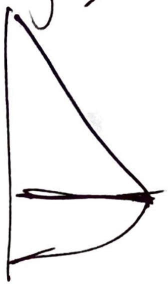
Summary:

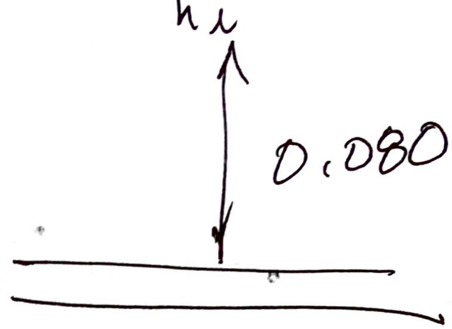
In this lab we took measurements that allowed us to calculate the "muzzle velocity" of a ball bearing launched from a spring-loaded firing mechanism. One analysis involved a "projectile motion" strategy, where the time to travel, vertical distance fallen, & horizontal distance traveled yielded a 5.21 m/s velocity. The second strategy involved a ballistic pendulum mechanism that required both conservation of momentum & conservation of energy analyses. Here we calculated a 5.08 m/s velocity, giving us a 2.53% difference between the two techniques. Possible sources of error included friction in the pendulum mechanism & inaccuracies in the measuring of the pendulum angle.

1,0238

$R = 0.28\,m$ ~~cm~~

l[j] < $\theta = 38°$





$h = L - L\cos\theta$

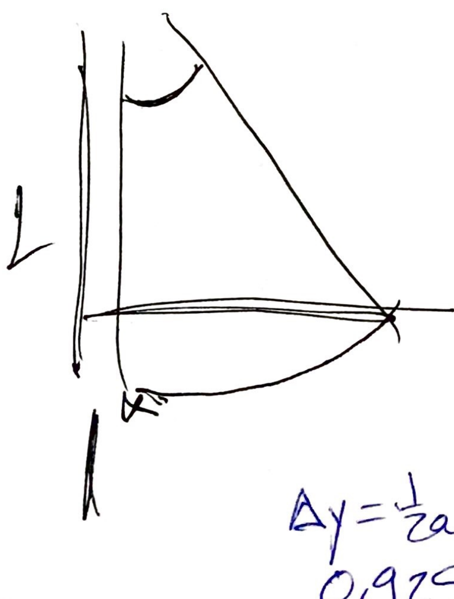
$\frac{1}{2}mv^2 = mg(L - L\cos\theta)$

$v = \sqrt{2g(0.28)(1-\cos 38)}$ 40

$= $ ~~6.772~~ m/s

~~1.106~~ 1.16

2,205 + 0,06
= 2.265



$mv + 0 = (m_1 + m_2)v$

$65.89\,v = 310.03$

1.16 ~~6.772~~
~~1.106~~
1,133

$v =$ ~~5.44~~ 5.20 m/s

5.22 m/s 5.33

$\Delta y = \frac{1}{2}at^2$

$0.925 = \frac{1}{2}(9.8)t^2$

$t = 0.434\,s$

2.13 m

0.925 m

$v = \frac{x}{t} = \frac{2.13}{0.434} = 4.91\,m/s$