PHY 1331 Lab Report 3 - Conservation of Energy and Momentum

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Part 1:

Calculation 1a: Using the data from Table 1 in the experimental details, find the average value of the time it takes for the bocce and lead balls to hit the water for each of the four given heights. These values will be put into your Table 1 below.

Sample Calculation:

- Bocce ball, height of 3.0m

$$\frac{0.77+0.78+0.76}{3} = 0.77s$$

Calculation 1b: For each time you obtain in Calc. 1a, find the maximum speed of each ball just before it hits the water for each of the four initial heights. This value can be called the "average maximum speed" of a ball for a given height. These values will be put into your Table 1 below.

Sample Calculation:

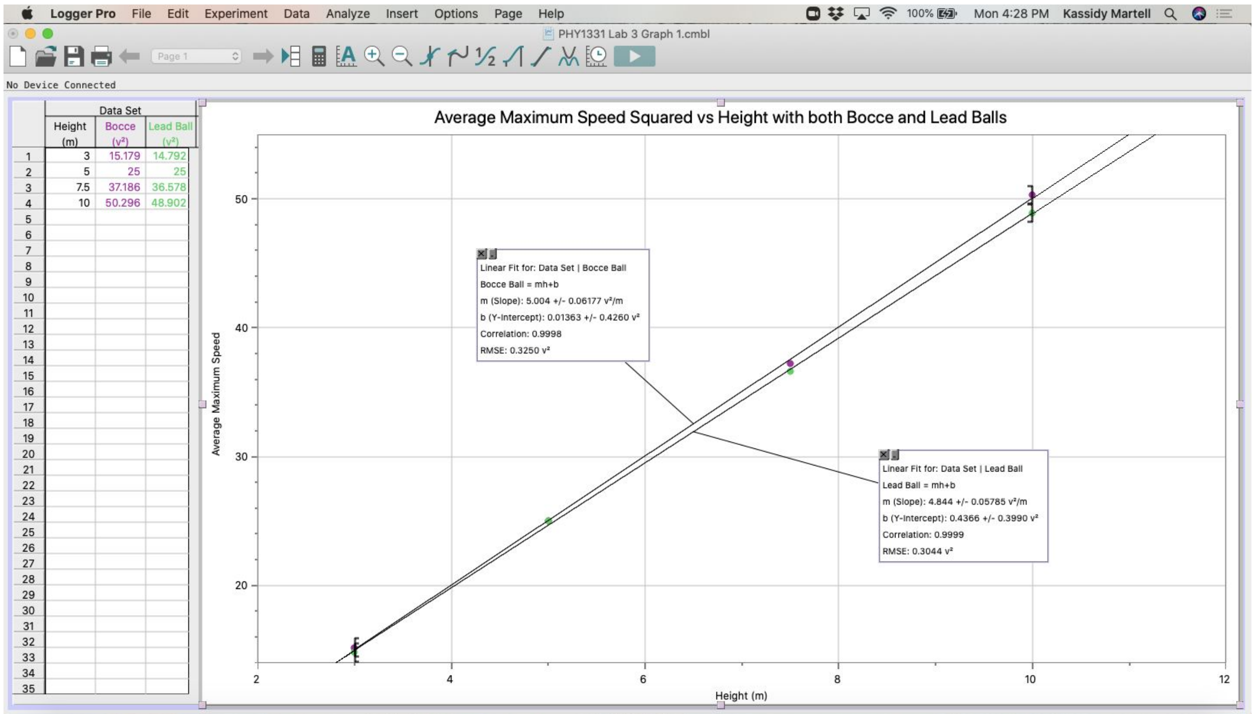
- Lead ball, height of 7.5m

$$\frac{7.5m}{1.24s} = 6.05m/s \pm 0.81$$

Table 1: Create a table that includes the type of ball and its mass, the initial height of the ball, the average value of the time it takes to hit the water, and the average maximum speed of the ball. You don't need to include any uncertainties in your table. You may leave three decimal places for your average time and average speed values.

Item and its Mass (kg)	**Height (m)** $\pm$ **0.1 m**	**Average Time (s)**	**Average Speed (m/s)**
Bocce Ball (0.95 $\pm$ 0.05) kg	3.0	0.770	3.896
Bocce Ball	5.0	1.000	5.000
Bocce Ball	7.5	1.230	6.098
Bocce Ball	10.0	1.410	7.092
Lead Ball (5.40 $\pm$ 0.10) kg	3.0	0.780	3.846
Lead Ball	5.0	1.000	5.000
Lead Ball	7.5	1.240	6.048
Lead Ball	10.0	1.430	6.993

Graph 1: Using the data from Table 1 you just created, plot a graph of the "average maximum speed" squared (v^2) as a function of the initial height (h) for both the bocce ball and lead ball. You should show both plots on the same graph. Use the linear regression tool to fit your data and be sure to show the uncertainty of both linear fits as well as the data table. Be sure to give your graph an appropriate title that describes the data shown.



Calculation 1c: Using the slope of the linear regressions for Graph 1, calculate the experimental value for the acceleration due to gravity $g$exp (and its uncertainty) for both the bocce ball and lead ball data.

Bocce ball:
Average time total: 1.10s
Average height total: 6.375m
Average velocity: $v = gt$

Calculation for average velocity:
$v = 9.8(1.10) = 10.78 m/s$

$g$exp: $\frac{v^2}{h} = 2a = \frac{(10.78)^2}{6.375} = \frac{18.229}{2} = 9.11 m/s^2$

Lead ball:
Average time total: 1.11s
Average height total: 6.375m

Average velocity: $v = 9.8(1.11) = 10.88 m/s$

$g$exp: $\frac{v^2}{h} = 2a = \frac{(10.88)^2}{6.375} = \frac{18.569}{2} = 9.28 m/s^2$

Average $g$exp: $9.195 m/s^2 \pm 0.0598$

Question 1a: Compare the $g$exp values obtained in Calc. 1c to g = 9.8 m/s 2 . Which ball's data provides a more accurate value? NB. You have used different methods in the past to compare experimental values to accepted/ theoretical values so we expect you to perform a similar analysis as you've done before.

Percent Error:

$$1 - \frac{actual}{theoretical}\ x\ 100\%$$
$$1 - \frac{9.195}{9.8}\ x\ 100\% = 6.17\%$$

There is about a 6% difference between the known value for gravity and the calculated value for gravity. The lead ball provides a more accurate value for acceleration due to gravity, as 9.28 is closer to the known value of 9.8 in comparison to the bocce ball's value of 9.11.

Calculation 1d: Calculate the average maximum kinetic energy (and its uncertainty) for the lead ball when it is dropped from a height of 7.5 m. You should use the average maximum speed of the ball you obtained in Calc. 1b. NB. You will need to use the uncertainty of the average time (found using the statistical method) as well as the uncertainty on the initial height to calculate the uncertainty of the average maximum speed. Then you should use the uncertainty of the average max speed as well as the uncertainty on the mass of the ball to calculate the uncertainty on the average max kinetic energy.

Average maximum speed: 6.05m/s

$$E_{kin} = \frac{mv^2}{2}$$
$$\frac{5.40 \pm 0.10(6.05^2)}{2} = 98.83 \pm 0.46\ J$$

Calculation 1e: Calculate the initial potential energy (and its uncertainty) of the lead ball dropped from an initial height of 7.5 m. You may use the theoretical value of g = 9.8 m/s 2 for this calculation. You must consider both the uncertainty on the initial height and mass of the ball for this calculation.

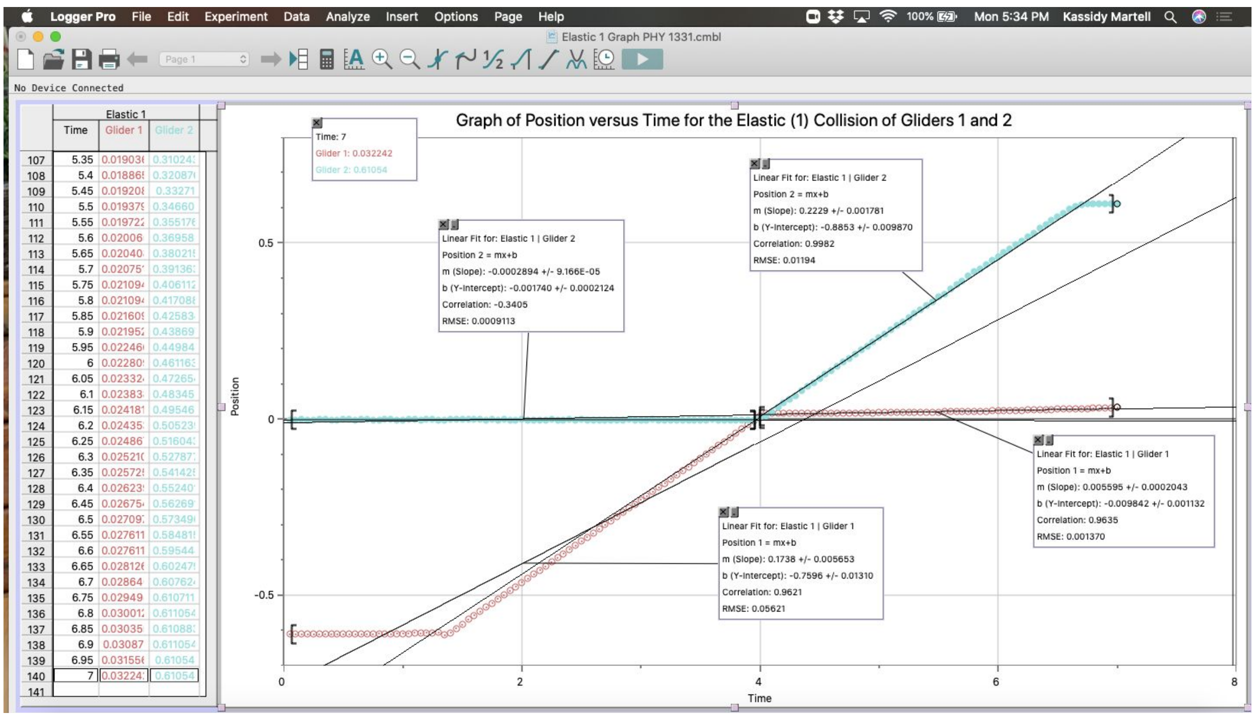
$$U = mgh$$
$$U = (5.40 \pm 0.10)(9.8 m/s^2)(7.5 \pm 0.10\ m)$$
$$U = 396.9 \pm 0.10\ J$$

Question 1b: Compare the values of kinetic and potential energy you obtained in the two previous calculations. Is energy conserved? If not, explain why there might be a discrepancy.

The potential energy of the lead ball dropped from a height of 7.5m is greater than the kinetic energy. This means that the energy is not conserved, as there are many external factors that are influencing these energies, for example friction.

Part 2:

Graph 2a: Using the data from the collision 1 file (elastic 1.csv), plot a graph of position vs. time for both glider 1 and glider 2 (you should show both plots on the same graph). Use the linear regression tool to fit the plots of both gliders before and after the elastic collision. You should have four linear regressions on your graph (glider 1 and 2 before and glider 1 and 2 after).



Calculation 2a: Recall that the slope of a linear "position vs. time" graph should give you the constant velocity of the glider. Using the slope of your linear regressions from Graph 2a, calculate the total momentum of the two gliders before ($p_i = p_{1i} + p_{2i}$) and after ($p_f = p_{1f} + p_{2f}$) the elastic collision. Compare the two momentum values using a "percentage change" calculation:

$$\% \text{ change} = \frac{|p_i - p_f|}{p_i} \times 100\%$$

Does your result agree with your expectation based on conservation of momentum? If momentum is not conserved, give a reason as to why this is the case.

Momentum: $p = mv$

$p_{1i} = m_1 v_{1i} = (0.1914 \pm 0.005\ kg)(0.1738 \pm 0.0057) = 0.0333 \pm 0.0054$
$p_{2i} = m_2 v_{2i} = (0.1919 \pm 0.005\ kg)(-0.0002894 \pm 0.0000092) =- 0.0000555 \pm 0.0025$
$p_i = 0.03324 \pm 0.00395$

$p_{1f} = m_1 v_{1f} = (0.1914 \pm 0.005\ kg)(0.005595 \pm 0.000204) = 0.00107 \pm 0.0026$
$p_{2f} = m_2 v_{2f} = (0.1919 \pm 0.005\ kg)(0.2229 \pm 0.0001781) = 0.04277 \pm 0.0026$
$p_f = 0.04384 \pm 0.0026$

$$\%\ difference = \frac{|(0.03324 \pm 0.00395) - (0.04384 \pm 0.0026)|}{(0.03324 \pm 0.00395)}\ x\ 100\% \ = 31.889\%$$

The momentum values slightly agree with each other, although there is about a 32% difference between the two values. Therefore, the values are not in agreement with the law of conservation of momentum, as the calculated value for the final momentum was greater than the initial momentum by 32%, when they should have been the same.

Calculation 2b: Again using the data from Graph 2a, calculate the kinetic energy of the two gliders before and after the elastic collision. Compare the two kinetic energy values using the same “% change” calculation you used above. Does your result agree with your expectation based on conservation of energy?

$$E_{kin} = \frac{mv^2}{2}$$

Before:
Combined mass: 0.3833 ± 0.005 kg
Average velocity: $0.0867\ \pm 0.00285$

$$\frac{(0.3833 \pm 0.005\ kg)(0.0867 \pm 0.00285)^2}{2} = 0.00144\ \pm 0.0039\ J$$

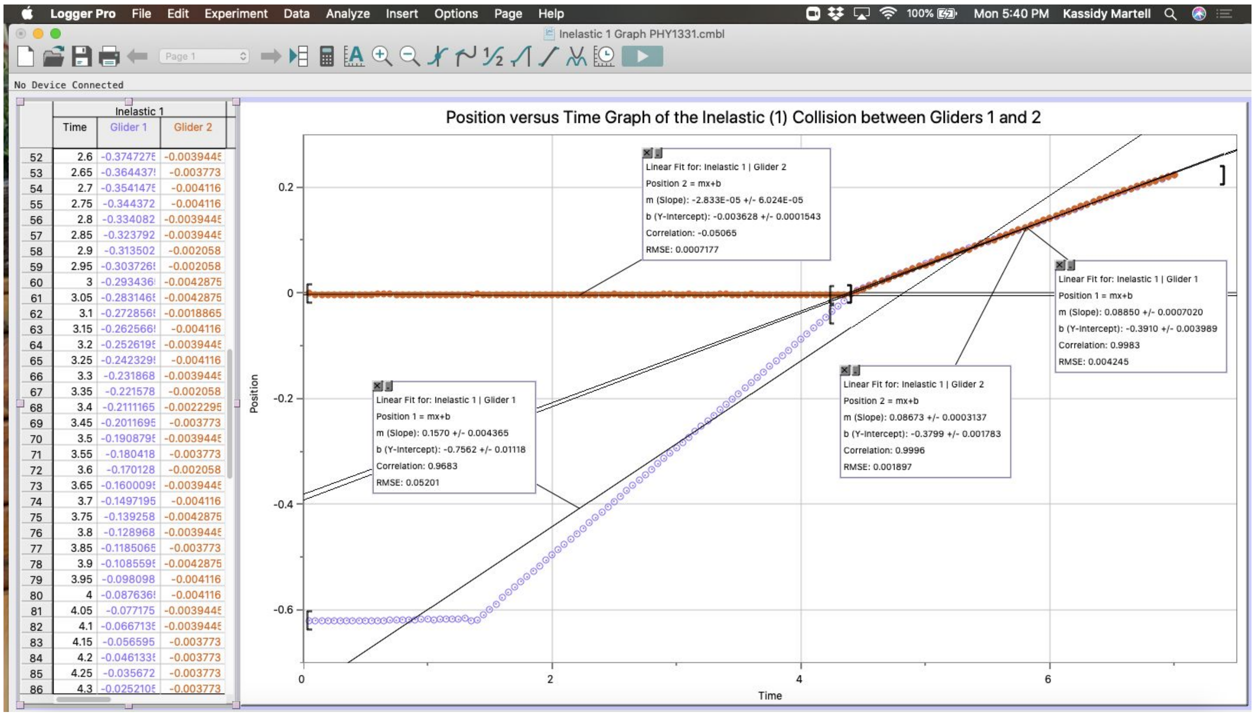
After:
Combined mass: 0.3833 ± 0.005 kg
Average velocity: 0.1142 ± 0.00099

$$\frac{(0.3833 \pm 0.005\ kg)(0.1142 \pm 0.00099)^2}{2} = 0.00250\ \pm 0.0030\ J$$

$$\%\ difference = \frac{|(0.00144 \pm 0.0039) - (0.00250 \pm 0.0030)|}{(0.00144 \pm 0.0039)}\ x\ 100\% \ = 73.6\%$$

The calculated result does not agree with the law of conservation of energy as the kinetic energy after the collision is about 74% greater than the kinetic energy before the collision. The expected value for kinetic energy should be the same before and after the collision.

Graph 2b: Using the data from the collision 3 file (inelastic 1.csv), plot a graph of position vs. time for both glider 1 and glider 2 (you should show both plots on the same graph). Use the linear regression tool to fit the plots of both gliders before and after the inelastic collision.



Calculation 2c: Using the slope of your linear regressions from Graph 2b, perform a similar analysis of the momentum and kinetic energy values of the gliders before and after the completely inelastic collision. Do your results agree with your expectation based on both conservation of momentum and conservation of energy theory for a completely inelastic collision? NB. For the velocity of the gliders after the collision, because their values will be very similar, you can either keep the values separate or you can use an average value of the two measured velocities.

Momentum: $p = mv$

$$p_{1i} = m_1 v_{1i} = (0.1914 \pm 0.005\ kg)(0.1570 \pm 0.0044) = 0.0301 \pm 0.0047$$

$$p_{2i} = m_2 v_{2i} = (0.1920 \pm 0.005\ kg)(-0.0000028 \pm 0.000006) =- 0.00000054 \pm 0.0025$$

$$p_i = 0.030099 \pm 0.0036$$

$$p_{1f} = m_1 v_{1f} = (0.1914 \pm 0.005\ kg)(0.08850 \pm 0.000702) = 0.0169 \pm 0.0029$$

$$p_{2f} = m_2 v_{2f} = (0.1920 \pm 0.005\ kg)(0.08673 \pm 0.000314) = 0.0166 \pm 0.0027$$

$$p_f = 0.0335 \pm 0.0028$$

$$\%\ difference = \frac{|(0.030099 \pm 0.0036) - (0.0335 \pm 0.0028)|}{(0.030099 \pm 0.0036)}\ x\ 100\% \ = 11.3\%$$

The law of conservation of momentum is very much applied in the inelastic collision as there is only an 11% difference between the momentums before and after the collision.

$$E_{kin} = \frac{mv^2}{2}$$

Before:

Combined mass: 0.3834 $\pm$ 0.005 kg

Average velocity: 0.0785 $\pm$ 0.00218

$$\frac{(0.3834 \pm 0.005\ kg)(0.0785 \pm 0.00218)^2}{2} = 0.00118\ \pm 0.0036\ J$$

After:

Combined mass: 0.3834 $\pm$ 0.005 kg

Average velocity: 0.0876 $\pm$ 0.000508

$$\frac{(0.3834 \pm 0.005\ kg)(0.0876 \pm 0.000508)^2}{2} = 0.00336\ \pm 0.0028\ J$$

$$\%\ difference = \frac{|(0.00118 \pm 0.0036) - (0.00336 \pm 0.0028)|}{(0.00118 \pm 0.0036)}\ x\ 100\% \ = 185\%$$

According to the calculations, the energy has almost tripled after the collision, which means it is not in accordance with the law of conservation of energy. In looking at the graph, the velocities of the gliders after the collision are almost the same, therefore their momentums and energies at this point should be constant.