# PHY 1331 Lab Report 2

## Forces and Newton's Laws of Motion

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**1) Motion on a linear air track (15 pts)**

**Calculation 1a:** (2 pts) Calculate the average value of the acceleration of the glider ( $a_{avg}$ ) and its uncertainty ($\Delta\, a_{avg}$ ) for each of the hanging mass values. You should show one sample calculation and the rest of the calculated values should in Table 1 below. NB. Remember that when finding the average value of a set of repeated measurements, the uncertainty is equal to the standard error on those measurements.

*Sample Calculation:*

$$a_{avg}\ (mass\ 4.8\ \pm 0.1) = \frac{a_{trial1} + a_{trial2} + a_{trial3}}{3} = \frac{0.2296 + 0.2199 + 0.2308}{3} = 0.2268$$

$$a_{avg}\ (\textit{all masses}) = \frac{0.2268+0.4729+0.6890+0.9180+1.1300+1.3226}{6} = 0.7932$$

$$difference\ (a_{avg}(mass1) - a_{avg}(all\ masses)) = 0.2268 - 0.7932 = -0.5664$$

$$\Delta\, a_{avg} = a_{avg} + SE$$

$$SE = \frac{s}{\sqrt{n}}$$

$$s = \sqrt{variance}$$

$$variance = \frac{(difference\ a_{avg}(mass\ x) - a_{avg}(all\ masses))^2}{n-1}$$

$$= \frac{(-0.5664)^2 + ... + (1.3226-0.7932)^2}{6-1} = 0.1687$$

$$s = \sqrt{0.1687} = 0.4107$$

$$SE = \frac{0.4107}{\sqrt{6}} = 0.1677$$

$$\Delta\, a_{avg} = 0.7932 \pm 0.1677$$

**Calculation 1b**: (1 pts) Convert each hanging mass ($m$) into a mass factor by taking into consideration the mass of the glider

($M$): *mass factor* = $\frac{m}{m+M}$

You should show one sample calculation and the rest of the values will go into Table 1 below.

*Sample Calculation:*

($M$): *mass factor* = $\frac{m}{m+M} = \frac{(15.3\pm0.1)}{(15.3\pm0.1)+(191.5\pm0.1)} = 0.07398$

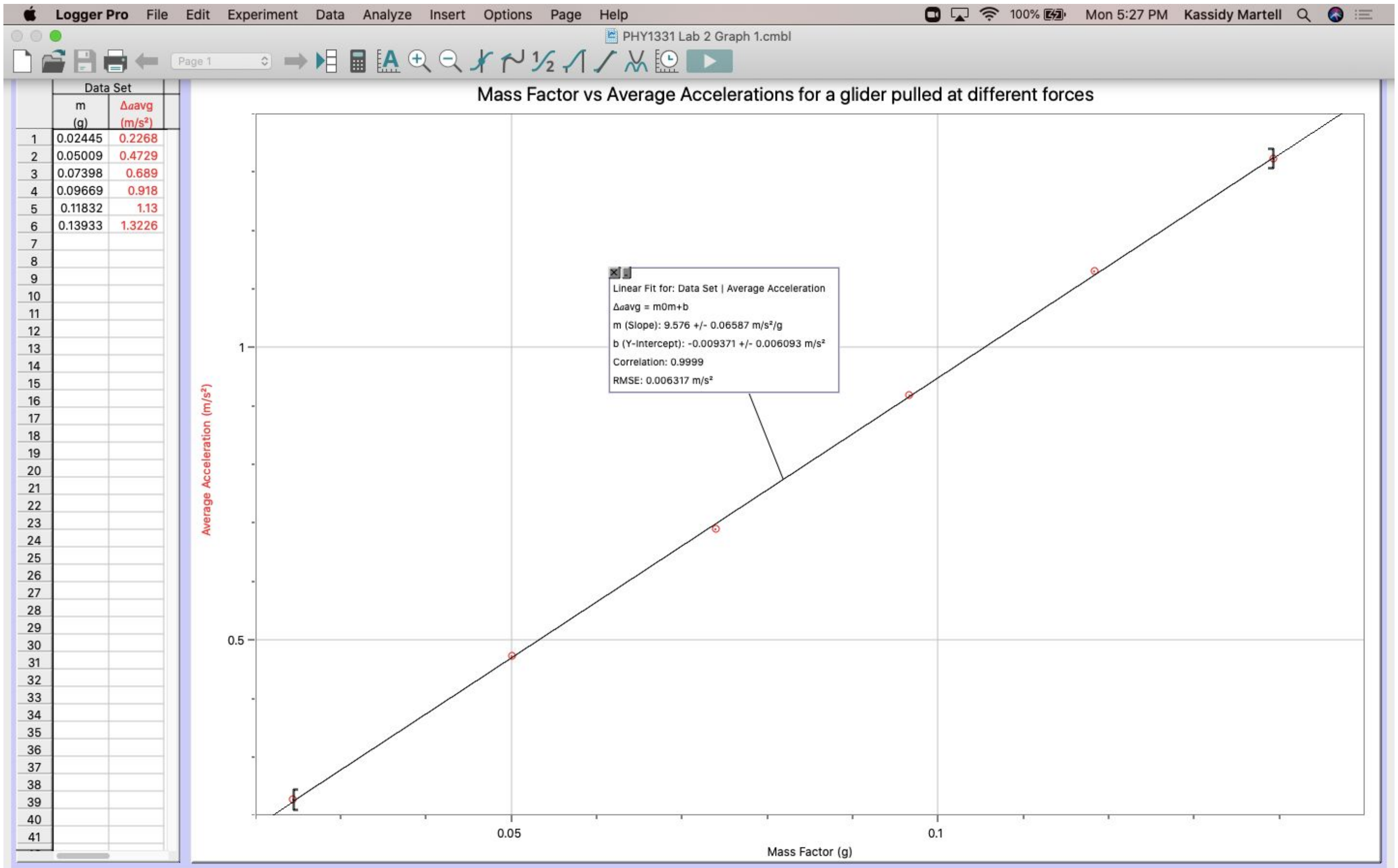
**Table 1:** (2 pts) Create a new table that contains the mass factor and the average value of the acceleration of the glider along with its uncertainty for each hanging mass. Make sure to label your table with an appropriate title. The values in your table should be rounded correctly

according to the rules in the tutorial "Basic data analysis" (bottom of page 3). Since the mass factor has no uncertainty associated with it, you may leave several decimal places in your table.

*Table 1*: Acceleration of a glider pulled by different forces, including mass factor and average acceleration with uncertainty for each mass.

| Hanging Mass (g) $\pm$0.1g | Acceleration ($m/s^2$) Trial 1 | Acceleration ($m/s^2$) Trial 2 | Acceleration ($m/s^2$) Trial 3 | Mass Factor | $\Delta\, a_{avg}$ |
|---|---|---|---|---|---|
| *4.8* | *0.2296* | *0.2199* | *0.2308* | *0.02445* | *0.2268* $\pm$ *0.1677* |
| *10.1* | *0.4697* | *0.4735* | *0.4755* | *0.05009* | *0.4729* $\pm$ *0.1677* |
| *15.3* | *0.6956* | *0.6800* | *0.6921* | *0.07398* | *0.6890* $\pm$ *0.1677* |
| *20.5* | *0.9120* | *0.9277* | *0.9145* | *0.09669* | *0.9180* $\pm$ *0.1677* |
| *25.7* | *1.1509* | *1.1203* | *1.1195* | *0.11832* | *1.1300* $\pm$ *0.1677* |
| *31.0* | *1.3215* | *1.3182* | *1.3280* | *0.13933* | *1.3226* $\pm$ *0.1677* |

**Graph 1**: (3 pts) Using the data from your table, plot a graph of the average acceleration vs. the mass factor for your glider on the air track. Use the linear regression tool to fit your data set and don't forget to show the uncertainty of your linear fit data as well as the data table. Be sure to give your graph an appropriate title that describes the data shown.




**Question 1a**: (2 pts) What does the slope of your Graph 1 represent? State this value along with its uncertainty (rounded properly). You should compare this experimental value with the well-known theoretical value using a percent error calculation. You should also see if the theoretical value falls within the uncertainty range of the experimental value. Do you feel that the experimental value agrees with the theoretical value?

The slope of graph 1 represents the value for gravity. The slope is 9.576 $\pm 0.06587$. The experimental value is similar to the actual value for gravity, there is a 2% error. The actual value for gravity ( $9.8\ m/s^2$ ) does not fall within the uncertainty range which is [9.51013, 9.64187], but there is only a difference of 0.158 between them. I believe that the experimental value does agree with the actual value for gravity as they are not the same but they are very close.

Percent error = $1 - \frac{actual}{theoretical}$

$\frac{9.576}{9.8}$ x 100% = 97.7%

$1 - 0.977 = 0.023\ or\ 2.3\%\ error$

**Question 1b**: (1 pts) What should be the theoretical value of the $y$-intercept of the linear regression from Graph 1? Does the value from your graph confirm this?

The theoretical value for the y-intercept should be 0. The y-intercept is at -0.00931 ± 0.006093, therefore the value from the graph confirms this as it is a value very close to zero.

**Question 1c**: (1 pts) Make a quick plot of the acceleration vs. the mass factor for each of the three trials. You do not need to include these plots in your lab report. From a brief analysis of the three plots, which student had the best experimental results?

According to the plots of each student's data, Student 1 had the best experimental results as at each mass factor, student 1 had the most data points that had the largest average acceleration compared to students 2 and 3.

**Calculation 1c**: (2 pts) Using the average value of acceleration for a hanging mass of 31.0 g, calculate the mass of the glider ($M$) in grams. Be sure to include the uncertainty (propagation of error) calculation for $M$. State your rounded value of $M \pm \Delta M$. NB. You must consider $\Delta m$ and $\Delta a$avg for your uncertainty calculation. $\Delta m$ is given in Table 1 from the experimental data and $\Delta a$avg is the value you found in Calc 1a.

$\Delta m$(31.0g) = 0.13933

$\Delta a_{avg}$ (31.0g) = 1.3226 ± 0.1677

$$a = g(\frac{m}{m+M})$$

$$1.3226 \pm 0.1677 = 9.8\ (\frac{31 \pm 0.13933}{31 \pm 0.13933 + M})$$

$$\frac{1.3226 \pm 0.1677}{9.8} = \frac{31 \pm 0.13933}{31 \pm 0.13933 + M}$$

$$1.3226 \pm 0.1677\ (31 \pm 0.13933 + M) = (31 \pm 0.13933)\ (9.8)$$

$$41 + (1.3226 \pm 0.1677)M = 303.8 \pm 0.13933$$

$$(1.3226 \pm 0.1677)M = 262.8 \pm 0.13933$$

$$M = 198.699g \pm 0.1535$$

Question 1d: (1 pts) Does the calculated value of $M$ from Calc. 1c agree with the measured value from the experimental data? You can use a percent difference calculation to compare as well as check if either value falls within the uncertainty range of the other value.

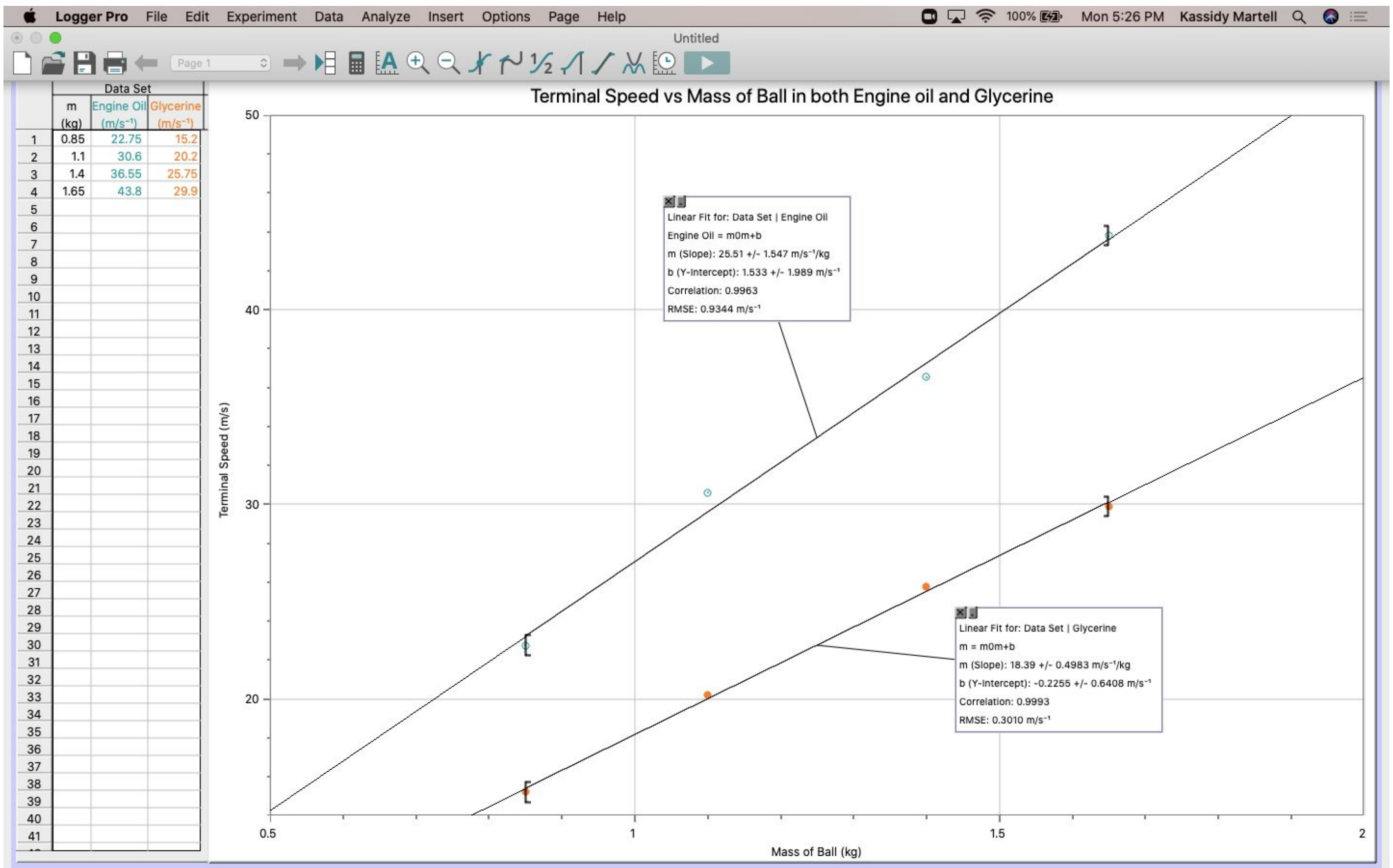
$$Percent\ difference = 1 - \frac{actual}{theoretical}$$

$$1 - \frac{191.5 \pm 0.1}{198.7 \pm 0.15} = 0.036\ or\ 3.62\%\ difference$$

The calculated value for M somewhat agrees with the actual value of 191.5, as there is a difference of 7.2 grams between them. This is not a major difference, but is still significant.

## 2) Resistive forces (10 pts)

**Graph 2**: (3 pts) Using the experimental data, plot a graph of the terminal speeds in both engine oil and glycerine as a function of the mass of the falling balls. You should show both data sets on the same graph. Use the linear regression tool to fit your data points and don't forget to show the uncertainty of your linear fit data as well as the data table. Be sure to give your graph an appropriate title that describes the data shown.




**Calculation 2a**: (3 pts) Using the slopes of the linear regressions from Graph 2, calculate the dynamic viscosities ($\eta$) for both engine oil and glycerine. Be sure to include the uncertainty calculations for $\eta$ taking into consideration the uncertainty of both the slope and $r$. You don't need to consider any uncertainty for $6\pi$ or $g$.

Engine Oil:

$$= \frac{mg}{V_T 6\pi r}$$

$$= \frac{9.8}{(25.51\pm1.547)(6\pi)(0.03\pm0.2)} = \frac{9.8}{(25.51\pm1.547)(0.18\pm0.2\pi)}$$

$$= 0.679 \pm 0.874$$

Glycerine:

$$= \frac{mg}{V_T 6\pi r}$$

$$= \frac{9.8}{(18.39\pm0.4983)(6\pi)(0.03\pm0.2)} = \frac{9.8}{(18.39\pm0.4983)(0.18\pm0.2\pi)}$$

$$= 0.942 \pm 0.349$$

**Question 2a**: (2 pts) Compare the dynamic viscosities obtained in Calc. 2a to the textbook values, 0.65 N·s/m2 for engine oil and 0.95 N·s/m2 for glycerine, using similar methods to those you used in Part 1. Do the experimental values agree with the theoretical ones? Which liquid would you say is "thicker"?

Engine Oil:

$$1 - \frac{actual}{theoretical} = 1 - \frac{0.65}{0.679} = 0.0427 \ or \ 4.27\% \ difference$$

Glycerine:

$$1 - \frac{actual}{theoretical} = 1 - \frac{0.95}{0.942} = 0.0084 \ or \ 0.84\% \ difference$$

I believe the calculated values agree with the actual values from the textbook, especially with glycerine having not even 1% difference between the actual and theoretical values. The "thicker" liquid would be the glycerine, as it has a higher viscosity than the engine oil.

**Question/Calculation 2b**: (2 pts) Consider the four different balls falling in both engine oil and glycerine. When the balls have reached their terminal speeds in each experiment, which ball will have the largest resistive force applied on it? Will this resistive force be the same in both liquids? Calculate the magnitude of this resistive force along with its uncertainty using the propagation of error formula.

$Resistive\ force = mg$

$Rf = 9.8(m)$

$Rf(0.85) = 8.33N$

$Rf(1.10) = 10.78N$

$Rf(1.40) = 13.72N$

$Rf(1.65) = 16.17N$

$Resistive\ force = 6\pi\, rV_T$

Engine Oil:

$Rf = 6\pi\ (0.65)(3 \pm 0.2)(25.51 \pm 1.547)$

$Rf = 937.66N \pm 0.8735$

Glycerine:

$Rf = 6\pi\ (0.95)\ (3 \pm 0.2)(18.39 \pm 0.4983)$

$Rf = 987.93N \pm 0.3492$

The ball of mass 1.65 will have the most resistive force on the ball. This force will be approximately the same in both liquids, with it being slightly higher in glycerine.