David Curie
Partners: Marie Curie, Pierre Curie
Lab 4: Force and Acceleration

Force and Acceleration: Time and Magnitude Qualitative Comparison

This is answered in my description in Part I. See my comment about the simultaneous occurrence of the peaks.

Finding the "Known" Value of the Mass

I calibrated the force sensor and hung the iOLab device by a string. I recorded the acceleration of gravity while the device was at rest and measured the force (i.e. "weight") of the device as it was suspended. Using *F=mg*, I solved for *m*.

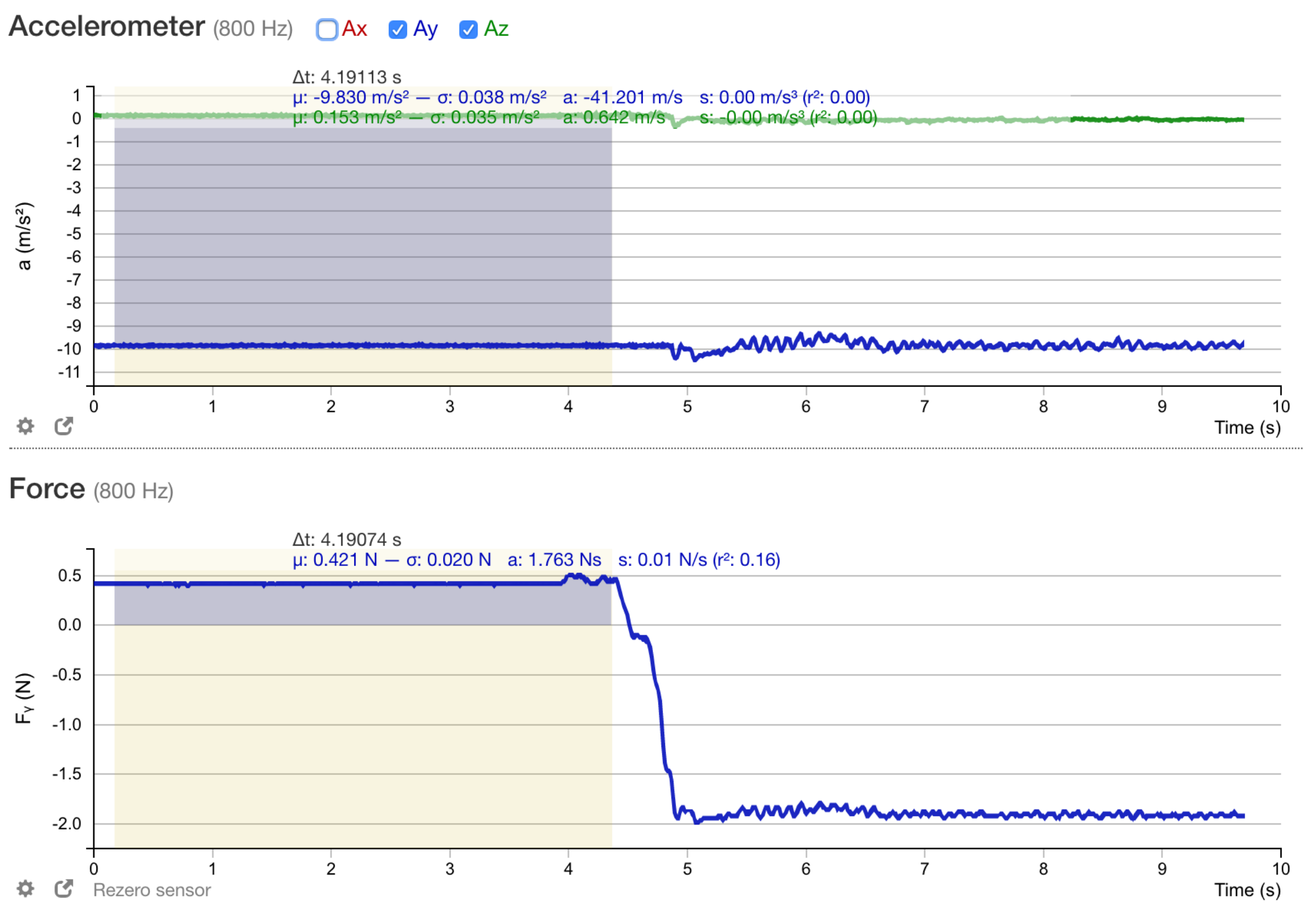

Figure 1a: Acceleration of gravity at rest

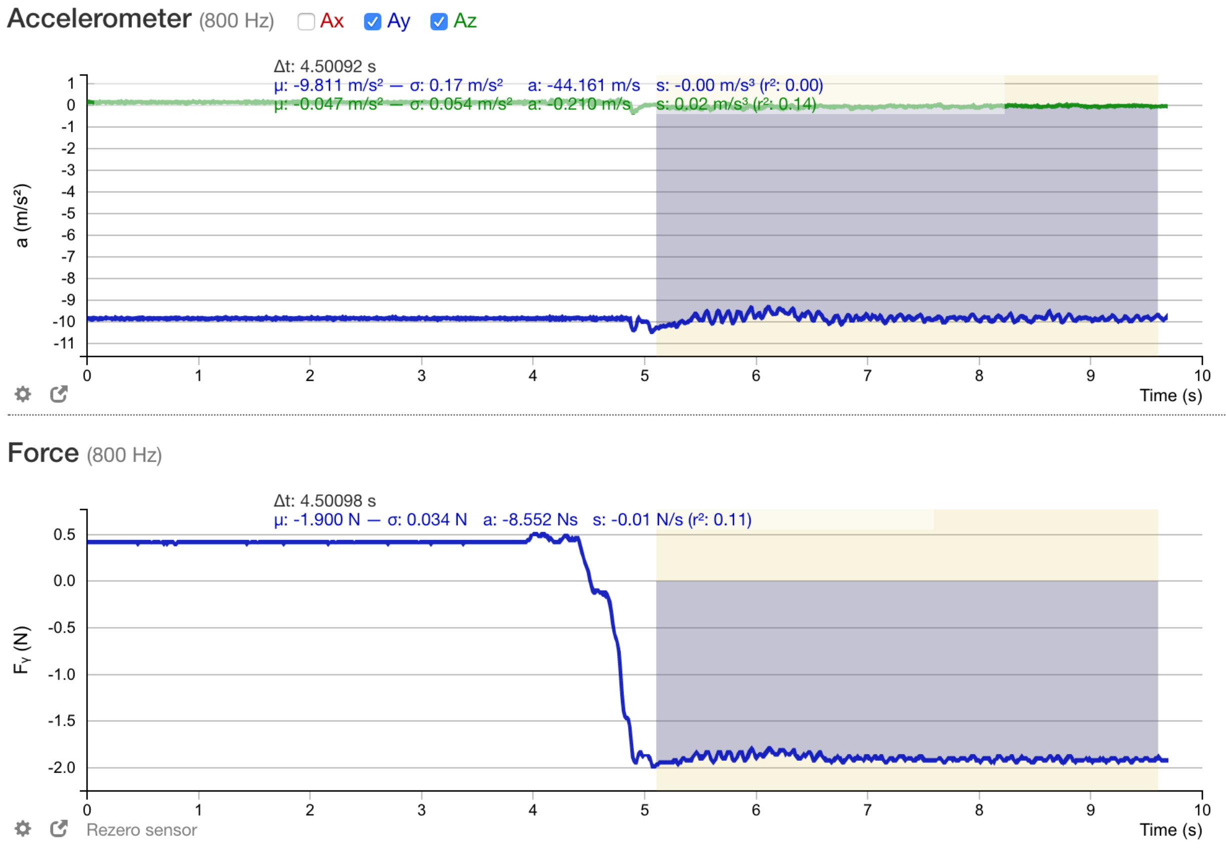

Figure 1b: Force of gravity while suspended

	Value	Abs. Unc.	Rel. Unc.
g	9.830 m/s^2	0.035 m/s^2	0.36%
Fg	-1.900 N	0.034 N	1.79%
m = |Fg|/g	0.193 kg	0.004 kg	2.15%

The values from the screenshots above allow me to determine the mass. I have to remember that the device measures a positive acceleration at rest, but conventionally this means that the acceleration from gravity is acting downwards (negative) on the device. Using -g and my measured Fg gives me a positive mass.

Quantitative Measurement of Force and Acceleration

Part I

My goal is to determine the mass through a series of F=ma relationships. If I can gather enough (F,a) data points, I should be able to plot them and see if they fall in a straight line. If they do, then we know that Force and acceleration are linearly correlated. We suspect the slope of this line to represent mass.

I pushed my iOLab device 5 times. I gathered the peak force and peak acceleration using the cursor tool. I only cared about the y-component of the acceleration, but I left the x-component visible to confirm that my device did not accelerate sideways when I pushed it.

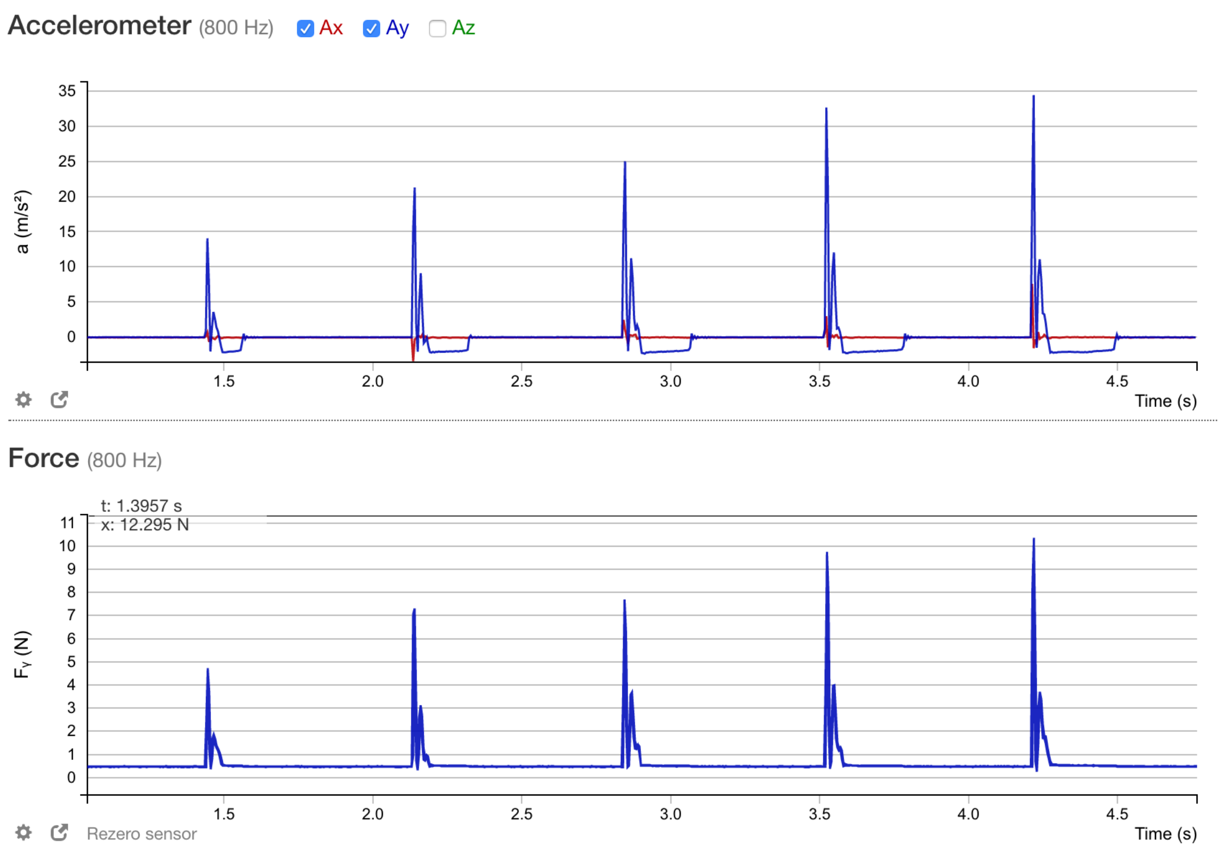

Figure 2a: Peak Force and Acceleration Measurements

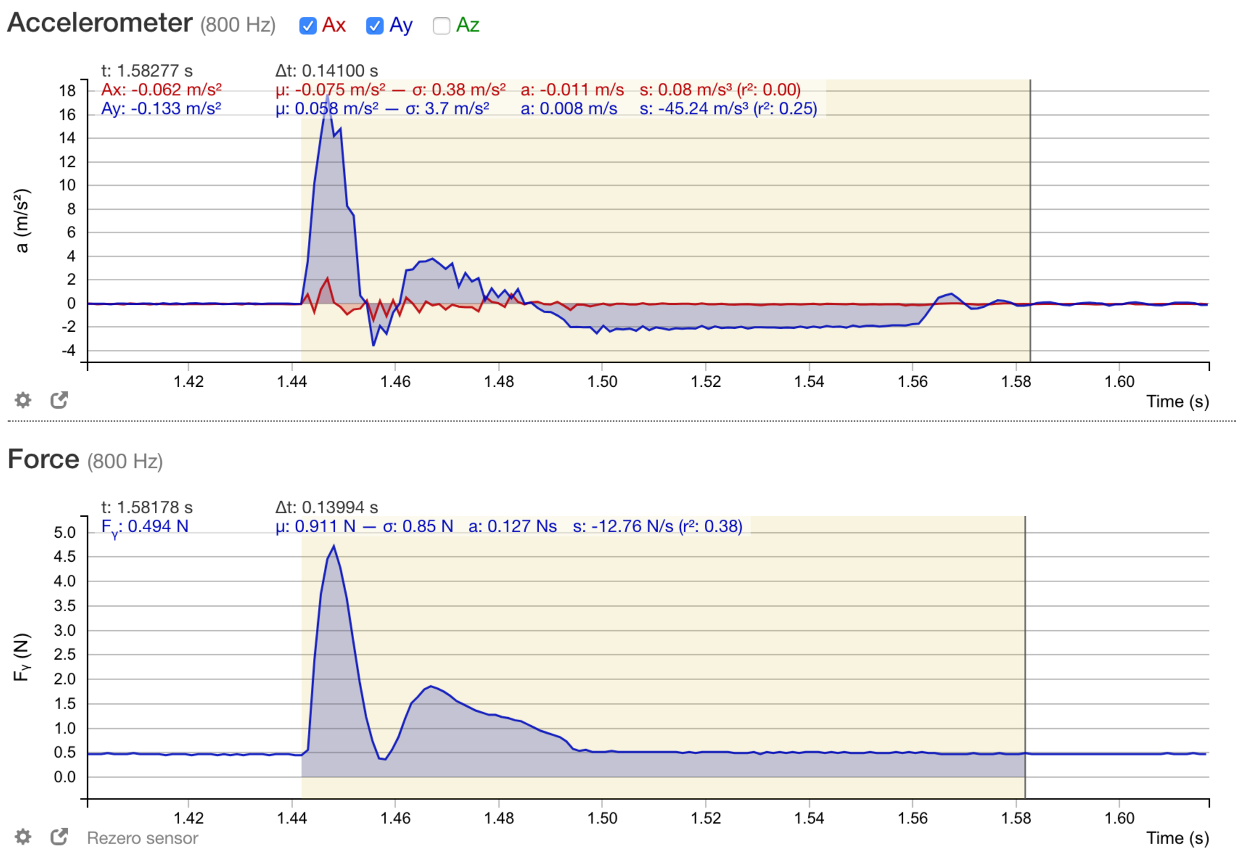

Figure 2b: Detail for one force and acceleration peak

The screenshot above shows the detail of one acceleration peak. Notice that the peak acceleration occurs at the same time as the peak force. The region of negative acceleration after the initial spike in positive acceleration corresponds to when the device is slowing down due to friction. This acceleration is the same constant negative value for all peaks, regardless of the strength of the initial push. For stronger pushes, this region extends for a longer duration. The area under the positive acceleration (speed picked up during the initial push) should equal the area above the negative acceleration (speed lost when slowing down). This is confirmed by the sum of these two regions, highlighted above, which nearly equals 0 m/s (a=0.008 m/s in top graph).

[Insert Data + Plot]

I forced my line of best fit through the origin because I felt it was more proper to compare F=ma to y=mx instead of y=mx+b. The mass is 0.218 kg as determined by the slope of the above line. The linear relationship in force and acceleration confirms Newton's 2nd Law to the degree that we can test it.

Discussion

My mass as determined in this section appears slightly higher than I was expecting as determined from the earlier part of this lab. I see at least two problems:

- I ignored the effects of friction.
    - Our measured force represents the applied force, not the net force. The net force will be smaller than we measure because friction opposes our push, which means that in our (F,a) pairs, our F values are too high. This shifts our slope up, which makes us believe we have a higher mass. The actual mass should be lower than 0.218 kg.
- My initial force readings were not reading 0 N when I was at rest.
    - Careful inspection revealed that my force readings were at 0.5 N when I knew there to be no applied force. This makes all of my peak forces 0.5 N too high. In my (F,a) pairs used to determine the slope, my F values are slightly larger than they should be. This makes my slope steeper if I keep the line forced through the origin, which causes me to believe my mass is higher.

The percent difference between these two numbers is around 12%.

Given these errors, I believe my true mass to be closer to 0.193 kg than 0.218 kg.

Part II

I connected my iOLab device to a spring and hung it from a fixed object. I pulled down on the assembly and monitored the force and acceleration over many cycles. I then selected the y-acceleration and unselected the x- and z-accelerations so that I could make a parametric plot of just the y-acceleration and force. The results appear below.

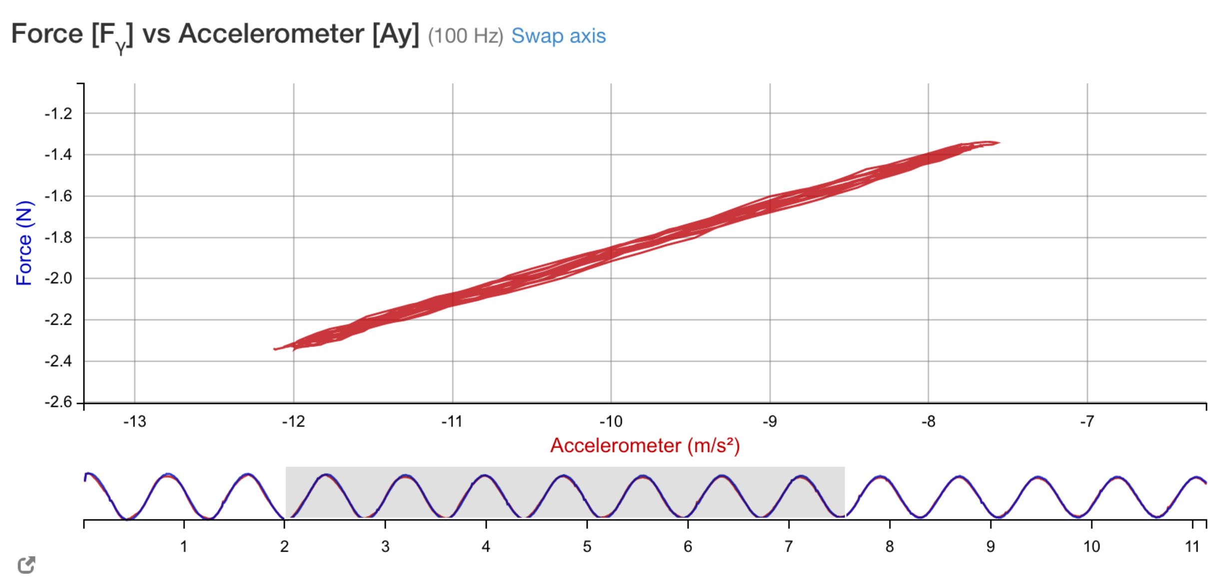

Figure 3: Oscillating force and acceleration, parametric plot

I can gather an approximate mass from this data by estimating the slope of this line. It was not easy to inspect the slope with the built-in tools of the iOLab software, so I used the cursor tool to pick out two data points that are on opposite ends of this line so that I could estimate the slope by hand.

	X	Y	
Pt 1	-12.0 m/s^2	-2.3 N	
Pt 2	-8.0 m/s^2	-1.4 N	
Slope = Δy/Δx = mass			0.225 kg

This data is again too high compared to what I am expecting. I don't really trust my mass to this precision. This line is thick and points are not well-defined. I will make an educated assessment that I trust this number to 2 significant figures based loosely on the significant figures in my (x,y) values.

Assumed mass = 0.22 kg ± 0.01 kg

Discussion

My calibration error should not have much effect on this slope because I expect each force reading to increase or decrease by the same amount if there was any offset. This means my Δy would be unchanged in my calculation above. If I had instead derived an equation from this set of data and explicitly forced it through the origin, I may have arrived at a different slope.

The value from Part II is consistent with my mass from Part I. Perhaps my measurements from Part I and II are accurate, but I somehow measured my mass as too small in the initial determination. I see that my initial acceleration due to gravity is reading as 9.83 m/s^2, when I believe it ought to be closer to 9.81 m/s^2. If I used a larger denominator in Fg/g, I would end up with a smaller overall mass.

Summary

	Initial Mass	Part I	Part II
Initial Mass	0.193 kg ± 0.004 kg	12% Diff	13% Diff
Part I	12% Diff	0.218 kg	1% Diff
Part II	13% Diff	1% Diff	0.22 kg ± 0.01 kg

What to include in your lab reports

- Explain all calculations.
- Do your results match expectations? Explain.
- Error Analysis
- Explain all plots and what information you gathered from them!

These were already included above. If they weren't, I would go back and put them in.

Questions to answer in the Discussion section

- How do you find the mass of the device from the slope of the plots?
- Do the values for mass you found in Parts I and II match the known value from slide 4 (within uncertainty)?

These questions are already answered as I presented my findings. If they weren't answered then I could explicitly answer them here, but it would be cleaner if I went back to the relevant section where I presented the data and made sure I included these things.