Lab 3: Inertial Balance

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As was the case last week, the first thing I did for this feedback document was to go through and put in the rubric I was given. I got a distressing number of tables that were not typed on this lab; we want *all tables and graphs to be typed*, unless otherwise specified.

I tried to be very generous with partial credit on the last question, and I hope that my discussion of the types of error will help y'all not need that generosity to earn full credit in the future. As always, I hope that y'all'll feel free to email me if there is anything I can clear up or explain.

1 Table

Each column on this table is worth $\frac{1}{11} \simeq 0.91$ points, distributed as follows:

- 0.16 points for having a title
- 0.25 points for units in the title
- 0.5 points for data

As before, there is a 50% reduction in grade for tables that were not typed.

I remember last year, a lot of people neglected to put units in the trial columns; they made their titles match what they were given on the handout. I saw no reason to deduct points for not including units where we didn't, so I didn't mark points off *this time*, so long as you included units in the first column, where we did have them. I advise y'all to always include units in your titles in the future. I also didn't take points off for including units in the data cells, though I wish y'all wouldn't do that. Just put the units in the titles, and put numbers in the data cells so Excel can work with them more easily.

Speaking of Excel, please please please use Excel or a comparable program. We mark off points for tables that aren't typed, and it makes me sad every time I have to do that. You have to put the data into Excel anyways to get it graphed, so just take a screenshot or use the snipping tool and show me your data in a typed table.

I had a number of students invert the rows and columns on their tables. Please don't do that in the future. I also had some students go back and fill in their unknown mass here; you didn't need to do that, but it's cool that you were thinking about it.

2 Table

Each column on this table is worth 1.67 points, distributed as follows:

- 0.27 points for having a title
- 0.25 points for units in the title
- 1.15 points for data

As before, there is a 50% reduction in grade for tables that were not typed.

I had some students add an extra column for "Standard deviation of the Mean of P^2"; I didn't count points off, but that column is unnecessary, as the error used to calculate the Standard Deviation of P^2 is already a standard deviation of the mean.

As in part 1, please please please use Excel or a comparable program for **all future tables**. We mark off points for tables that aren't typed, and it makes me sad every time I have to do that. You have to put the data into Excel anyways to get it graphed, so just take a screenshot or use the snipping tool and show me your data in a typed table. There are online resources available to help you use the Microsoft snipping tool if you have a PC, or the Apple keyboard shortcuts if you have a Mac (the blue text here is hyperlinked to some instructions that should be helpful). I really hate taking points off for not typing the tables.

Also as in part 1, we just want units in the titles of the columns, you shouldn't invert the rows and columns, and it's unnecessary to go back and fill in the value for your unknown mass here.

3 Sample Calculations

As always, each equation is worth one point total, broken up as follows:

- 0.25 points for the generic formula
- 0.25 points for plugging numbers in
- 0.25 points for giving a final answer
- 0.25 points for the correct units

The mean period, standard deviation of period, and standard deviation of the mean of period should all have units of seconds (s), and the period squared and standard deviation of period squared should have units of seconds squared (s^2).

4 Graph

This graph is worth 10 points, broken up as follows:

- 1 point for having a title
- 1 point for labelling your axes
- 1 point for units on your axes
- 3 points for having data points (-0.5 if individual points plotted instead of averages)
- 2 points for error bars (must be to scale; do not leave the default error bars Excel generates)
- 1 point for fit equation in slope-intercept form ($y = mx + b$)
- 1 point for plotting line of best fit

As before, there is a 50% reduction in grade for a graph that was not computer-generated.

Most points deducted were for missing units, axis labels, or the line of best fit (the equation or the plot, or both). We will want those on **every** graph in this lab unless otherwise specified.

5 Label

This should be a free 2 points for everyone if you marked down the label from your mass.

We didn't want to know what you calculated the mass to be here. We just wanted the label on it. Acceptable answers were 1, 2, 3, 4, 5, 7, 8, A, C, D, E, F, G, M, O, or Igloo.

6 Unknown Mass

This section is worth another 10 points, distributed as follows:

- 1.5 points for the generic formula
- 1.5 points for plugging numbers in
- 1.5 points for giving a final answer
- 1.5 points for the correct units
- accuracy in your measurement:
  - 4 points if true mass within Mass ± error or 10% agreement
  - 3 points if true mass within Mass ± 2 error or 20% agreement
  - 2 points if true mass within Mass ± 3 error or 30% agreement
  - 1 point for trying

On the accuracy part, I went with whichever value meant the most partial credit. If you did not include the label on your unknown mass for question 5, I could not give you any points for accuracy here beyond the 1 point for trying. The correct method to find the mass was to plug the period^2 into your slope-intercept equation $y = mx + b$, and the correct way to find the error in mass was to divide the error in P^2 by the slope of that same line.

7 Discussion of Error

This one is grader's choice on partial credit, so I'll try to be generous.

I'm going to talk about some of the common examples of error that were given in some detail, in the hopes that y'all will get really good at talking about error. Each given example of error was worth one point (to a maximum of 3), and I gave at least half credit if an attempt was made. If a good example of error was classified incorrectly, I gave 0.75 points. While I don't want an essay here (the question is worth 3 points), the more you give me, the more generous I can be with partial credit. If I was not given sufficient explanation, I gave 0.5 points for making an attempt.

In addition to my discussion here, you can find some good explanations of the two types of error here and here. If you have questions about error that you can't answer with your own research, feel free to reach out to me for help. I may stop being as generous with partial credit on these discussions in the future, so it's in y'all's best interest to pay attention.

7.1 Systematic Errors

Systematic Errors are problems with the setup of the experiment, which drag all of your data points in the same direction. They are things that could possibly be corrected by setting up the experiment differently.

Air resistance and friction are generally safe options when talking about systematic error in a moving system; these non-conservative forces sap energy from the experiment, which will drag your data points in one direction (higher or lower, depending on what is being measured).

An error in the calibration of the equipment is also a possible option for systematic error; if a scale is zeroed at a mass that is not zero, this will throw all of its measurements off by some amount. For this lab specifically, if the masses given were not what they should have been, this would also drag the data in one direction.

7.2 Random Errors

Random errors are things that are harder to control, which push your data about the true mean randomly in any number of directions. Random error is minimized by taking more data points.

A piece of equipment being jostled unexpectedly and without being noticed is a possible example of random error. For this lab, if the photogate were to move mid-measurement closer to the center of oscillation, it would record a slightly shorter period, and it would record a slightly longer period if it were to move the other direction. This is unpredictable, and would certainly lead to inconsistencies in the data collected.

7.3 Bad Errors

As discussed here, it is assumed that the ones performing these experiments are being careful to do everything correctly. Bad errors are fixed by finishing your coffee before lab and paying attention to what you're doing.

Incorrect Pasco settings are a bad example of error for this and all future labs. It's not a problem with the experimental setup, and it doesn't just happen randomly. While it would be a problem, it's something that, if noticed, you would be expected to go back and fix, not talk about in error analysis.

Amplitude doesn't affect oscillatory period for the small angles we should have been working with in this lab. Therefore, for this lab, inconsistent releases should not cause any errors, so long as you followed instructions and allowed the inertial balance to stabilize before beginning measurements. An exception was made if violations of the small-angle approximation were mentioned, which would cause a systematic error (period longer than it should be).