ADVANCED LAB NOTES

Contents

Intro

These are some notes for Advanced Lab Experiments - this is still very much a work in progress.

Lab Notebooks

Before you turn in your notebook, ask yourself the following:

- Did I put a date on all my notebook entries?
- Did I document my procedure reasonably well?
- Did I perform a thorough error analysis?

Formal reports

General Error Analysis

Presentations

Think of yourself as an audience member. What kinds of presentations have you enjoyed the most? Try to make a presentation that you would enjoy listening to. To this end, a few explicit pointers:

1. If you had time to do only one thing, I would tell you to practice. Practicing your presentation makes a world of difference, it helps you avoid running over the time limit (or too much under it, for that matter.) For a 10 minute presentation, I would advise practicing at least twice before presenting. Also, *look at your audience more than you look at your slides.* A technique that you can use to make the audience feel more engaged is to divide the room into roughly three parts, a left, center, and middle third. When you speak, alternate between looking at these sections. But make sure not to switch too fast, about three seconds per section is long enough to make people feel like you are having a conversation with them, but short enough so it doesn't seem weird.

2. Remember to not speak too fast - about 150-200 words per minute is a good rule of thumb.

3. Don't have too many slides - for a 10 minute presentation, I would make between 5 and 10 slides.

4. Make sure to minimize the amount of text on the slide. The audience is here to hear you talk - if they wanted to read a book, they would have done that instead. As a rule of thumb, no more than ten words per slide. Instead, use visual aids to illustrate your point - pictures of your apparatus, graphs with large axis labels, etc. If you spend 80% of your time practicing, spend 20% on not making the presentation an eyesore.

   Use high-resolution vector graphics and sans-serif fonts. Try to not cram too much stuff on a slide.

   On a Mac, use Keynote to make your presentation, and use LaTeXit to typeset the equations. The animations are nice, but you will probably not have a chance to use them because most conference computers run Windows. So export your presentation to a PDF format and use that.

5. If you use images from elsewhere, make sure to cite the sources.

6. Make sure to know your error estimation method thoroughly - you should be able to explain what you did clearly and concisely.

7. A logistical thing you can do to make everyone's lives easier - email your professor/TA with your presentation so that they can put it on the computer before class. Or arrive 10 minutes early with your presentation on a flash drive so you can pre-load it on the computer. This will be very much appreciated.

John A. Leavitt Experimental Physics Prize

- Source: Funded by an endowment established as a memorial to the late John A. Leavitt, Professor of Physics, 1960 to 1995.
- Eligibility: Undergraduate students who in the Physics Department's Advanced Lab Sequence completed the following four experiments: the Charge-to-Mass Ratio of a Electron, the Millikan Oil Drop Experiment, the Universal Gravitational Constant, and the Photoelectric Effect. The student selected will have the highest cumulative average score on the four experiments as determined by the laboratory supervisor.
- Value: Award recipients will receive $1000, in the form of an unrestricted check.

Gravitational Constant

In question 24 of the lab description, you will not be able to get a value of 6.9% as a correction with the values that are given in the handout. You will have to use r = 4.5 cm instead of 5 cm as specified on the first page of the handout. This is from the writeup of this experiment that can be found in the red folder.

C_p / C_v *experiment*

Hints for deriving the gas flushing equation

Here are some hints for deriving the gas flushing equation. We first define the fraction F:

$$F = \frac{\text{Volume of gas}}{\text{Volume of Jar}} = \frac{V_{gas}}{V_{jar}}$$

where the gas can be CO_2, Argon, etc. We can then write a small change in F as follows.

$$F + dF = \frac{1}{V_{jar}} \left[V_{gas} + dV_{flush} - F dV_{flush} \right] \tag{1}$$

where V_{gas} is the original amount of gas in the jar, and dV_{flush} is a small amount of gas pumped in to flush the jar. The third term on the right hand side, $-FdV_{flush}$ is motivated as follows. After dV_{flush} has instantaneously mixed with the whole volume of the mixture, a small amount of the mixture, dV_{mix} will escape.

$$dV_{mix} = dV_{flush},$$

and the amount of gas in the expelled dV_{mix} will be given by

$$(F + dF) dV_{mix} \approx F dV_{mix} = F dV_{flush}.$$

We can write the equation (1) as an ODE and solve it[1] to get the final equation,

$$F = 1 - e^{-\frac{V_{flush}}{V_{jar}}}.$$

Good luck!

[1] Show your work explicitly!

Op-Amps

After looking a bit online, it turns out that the integrator circuits drawn on the handout are not *ideal* op amp integrators, but *practical* ones. You should see something a little bit more complicated than a triangle wave for your output when you input a square wave. You can go over the analysis of the *ideal* integrator and include it in your lab notebook, and say that the extra feedback resistor makes the circuit quite a bit more complicated to analyze, and just leave the differential equation for the practical integrator not solved analytically. You can do the same for the differentiator.

Range of α particles

The formula for converting pressure into effective distance is:

$$d_{\text{effective}} = \left(\frac{(288^\circ d)}{76\text{cm Hg}(T + 273)} \right)$$

where d is the distance between the source and the detector, and T is the room's temperature in degrees celsius. (There is a thermometer in PAS 246 near the secondary entrance at the back of the lab.)

Counting Statistics

Steps for Geiger-Mueller counter

1. Display the raw output from the GM tube on the oscilloscope. Make a semi-log plot of pulse height vs applied voltage for a range of voltages. Comment on the shape of the graph.

2. Route the output of the GM tube into the amplifier, and display the amplified signal as well as the GM output on the scope on different channels. Then route the output of the amplifier into the SCA, and the output of the SCA into the oscilloscope. The output of the SCA should be a square pulse 5V high. It converts the analog signal into a digital one. Once you see this pulse, route the output of the SCA into the (positive) input of the Counter. See if you can get it to display the number of particles detected. Play around with the settings of the electronics and figure out what the different settings do. Write a one- page "Users manual". Make sure to note down what settings work best to display the signals on the oscilloscope!

3. Now, turn on the computer, press enter a few times until you see the

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   C:\>
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   prompt. This is advanced lab, so you will use an advanced operating system called DOS. Type "dir" and hit enter to list the folders in the C drive. Navigate to the Counts folder by typing "cd counts" (and pressing enter). Then type "counts.exe" and hit enter to start up the counting program. Press A to begin the first program, which counts the number of events in a fixed time interval. Enter plateau.txt as the file name, set number of repetitions to 10 Take a range of voltages (about 20 should be fine) from 900 - 1200 and plot log(counts/min) vs voltage applied. Take at least 10 repetitions per voltage setting. This should be easy with the program. Insert a floppy disk into the computer, then enter"copy plateau.txt A:ät the prompt. Once the green light on the floppy drive turns off (meaning it has finished copying), then eject the disk and put it into the USB floppy drive attached to one of the computers on the central table. On that computer, navigate to the A dive and copy the text file(s) onto that computer for further analysis.

4. Calculate the detector efficiency based on the sample's creation date, initial activity, and half-life, and the solid angle subtended by the detector face at the center of the point source.

5. Record the number of counts in a fixed time interval (at least 50 repetitions) and create a histogram from it. Does the distribution look Gaussian? Now take the number of counts for a few different time intervals. What is the standard deviation of each set? Plot the Log of the standard deviation on the y-axis and the log of mean of the data set on the x-axis. what is the slope? Hint: It should be about 0.5 based the statistics of nuclear counting!

Photoelectric effect

Error analysis

The value for Planck's constant is basically the slope of your eV_0 versus frequency (f) graph. Assume that the error in the frequency is negligible, that is, assume that you know the wavelength of the light that you are shining on the photocathode to a high degree of precision. Now you can find the error in Planck's constant, which will just be the error in the slope of your eV_0 vs. f graph. You can find this error using the methods in Bevington & Robinson in the the chapter on linear regression (Chapter 5 I think).

However, to find the error in the slope, you need the errors in the y-values. These correspond to the errors in measuring the stopping voltage. The stopping voltage was determined by drawing a tangent line to the linear portion of your S-shaped $I - V$ curve and extrapolating it to the x-axis. There will be some error in this x-intercept. You can find this error by finding the error in the slope and converting that into an error in the x-intercept (i.e. take the maximum slope and the minimum slope and take 1/2 the distance between the resulting x-intercepts). Or you could just interchange the x- and y- axes and use the usual methods from Bevington & Robinson to find the error in the y-intercept, which would now be your stopping potential. But in both these cases, the error in the slope is not as straightforward as before. You see, most of the chapter on linear regression in Bevington & Robinson has been written assuming that the error in the x values is negligible. However, in your case, you would have some error in both the voltage and the current measurements. The procedure to incorporate non-negligible errors in the x values is known as *bootstrapping* and has been described in page 102 of Bevington & Robinson. This procedure basically absorbs σ_x into σ_y, enlarging the σ_y error bars. And then you can carry on with the usual method of finding the error in the slope based on the enlarged σ_y values and taking $\sigma_x = 0$.

Index of Refraction

There is a temperature correction that you can apply...usually values for the index of refraction of gases are given assuming 0 degrees celsius. Find this temperature correction and account for it. Use the temperature from the thermometer next to the solar spectrum chart near the rear entrance of the lab.