Research Lab Notebooks General Information

Physics 623 - 2024

You will need a bound laboratory notebook, preferably with quadrille rulings, (Harvard Coop notebook style – spiral bound with brown covers – is nicest, but it has gotten a lot more expensive ($\tilde{\$}$30). But you'll be spending a lot of time with it, so it's a good investment. If you're on a really tight budget, let me know – I have a few recycled notebooks that are almost full length. The Bookstore usually carries Mead Five Star series with quadrille ruling. This is slightly smaller, so you'll need to trim dow full 8.5x11 sheet, and you have to number the pages yourself. But it is considerably cheaper. In any case, get one that's spiral bound so you don't have to hold it down with your elbow while you write in it.

Don't bring loose-leaf paper into the lab at all: data should be taken directly into your notebook (or a computer file), and the back sides of the pages can be reserved for scratch calculations or data plots. If you include scratch work there, box off the scratch work and $\times$ it out. Do the same for any other entries you have decided are erroneous. Addenda such as graphs and chart records should be securely taped in (tape, glue, staples available in lab). No pencil please; erasing can lose information (and pencil is hard to read). Just cross it out if it's wrong. Keeping everything in chronological order as much as possible makes the organization much easier. The notebook must be self-contained. You can't reference the lab instructions in it, but you are free to paste in a copy of anything you need (diagrams or procedure steps).

If you wish, you may take notes on lectures in your lab notebooks. These should be marked as "lecture notes," and will not be checked or regarded as part of the experiment write-up when your notebooks are graded. They can be referenced (by page number) from within an experiment write-up, just as any other outside source.

The lab notebook should be kept in the style of a research notebook as explained below. It should be sufficiently organized that someone else (or you two years later!) could follow it.

What should not be included:

1. No lengthy theoretical discussions or derivations which can be found in the handouts or in any textbook. If it is the result of an original derivation, give the most reasonable starting point and include the derivation (paste in a copy if you did the derivation before lab.) Circuit diagrams for your experimental setup are so useful and important that they should always be copied into the notebook (or cut out and taped in). Note that the sketches included in the handouts are often incomplete. You should embellish your cutout or drawing when necessary.

2. Equipment lists are not necessary. The type of instrument being used (i.e., digital voltmeter, oscilloscope) should be given whenever you think it is relevant to the particular measurement.

What should be included:

1. The title of the experiment.

2. A brief (1 or 2 sentence) description of the purpose of the experiment.

3. Each section where data are recorded should begin with a brief but precise statement of exactly what is being measured and under what conditions. Record any interesting or unusual observations and make a note of any particular problem you had.

4. If only one copy of a record is made (e.g., strip chart or computer printout), a copy should be printed or xeroxed for the other partner.

5. Whenever possible, compare results obtained by different methods or results with "accepted" values and comment briefly on any apparent discrepancies. Note that these differences are not "errors" in the sense we use the word and should just be referred to as a "difference". (See "Error Analysis" below.) Collect and tabulate all of your major results in a "Results" section so that these comparisons are easier to follow.

6. End the experiment with a few sentences describing the work and summarizing the results. (In an extended research program, you would stop every several pages and make a "summary page'.') This makes it much easier to come back later and follow the general line of work or locate a specific result. You are welcome to include a few sentences of how this experiment could be improved upon.

Tips on "Organization":

1. Go back every half-hour or so (and immediately upon completing the experiment) and add brief notes in the margin about what was going on at various points and how it fits in with what follows or precedes.

2. Put boxes around results and group related results together.

3. If data are plotted at a different location in the notebook from where they are tabulated put a note with the tabulated data giving a page reference for the plot, and vice versa.

   Do NOT try to conserve space in your notebook! Leave space for headers and notes, and you can use the left-hand pages for scratch calculations and temporary notes. Try to keep things in chronological order – it makes it much easier organize the structure. If you manage to fill your notebook, I'll buy you another one to finish the semester.

Error Analysis

(a) To find out what is meant by "errors", read the first two Chapters of *Data Reduction and Analysis for the Physical Sciences* by Bevington. The "Appendix A - Error estimation" is a 4-page Cliff's notes version of these.

(b) Whenever appropriate (which is most of the time) give an estimate of the uncertainty of any quantity written down as data. A common exception is if the accuracy is clearly high enough that it will not contribute significantly to the uncertainty in an interesting result, in which case you can just record the number to an appropriate number of significant figures. Consult your instructor if you are unsure of how to estimate the uncertainty in the results of a particular measurement; it usually takes some experience to do this, but you'll catch on. Uncertainties are generally given to only one significant figure (sometimes two, if the first digit is a 1). They can be recorded as either absolute or relative errors, whichever is more convenient. If the uncertainty is about the same for all numbers in a column, it can be shown with the first number only and will be assumed to apply to the rest.

(c) Propagate these estimated errors through any calculations which are done using the data, to find the implied uncertainty in the result. If you are unsure of the mathematics of error propagation, read Chapters 3 and 4 in Bevington. If you remember that there is only one significant figure in error estimates, you can usually do these propagations in your head. (Useful approximations for error propagation: $\sqrt{a^2+b^2} \approx a$ when $a \geq 2b$ and $\sqrt{a^2+b^2} \approx \frac{3}{2}a$ when $a \approx b$.)

(d) When comparing results with "accepted" values or with results obtained by another method, if the difference is smaller than your estimated uncertainties, there is no disagreement and you need only point this out. If they disagree by several times any estimated uncertainty, you should:

   a) recheck your calculations for a mistake
   b) recheck your measurements for some blunder such as a number recorded wrong or a misread scale.
   c) check for an unreasonably small error estimate (common, but don't arbitrarily increase a reasonable one).
   d) try to think of possible sources of systematic error or other reasons for the disagreement. Comment on possibilities in your notebook.

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4. Hints for effective use of time:

   a) Whenever practical, <u>plot data as you take it.</u> It takes only a little longer per *data* point, and you'll probably find that you take a lot <u>fewer</u> data points this way. Jump around when you take the data: go to the extremes first, whenever possible, to find the limits needed for the plot. Then go through and take data about 5 times more coarsely-spaced than you think you'll need. With that plotted, you can go back and fill in wherever it appears necessary. This way you'll avoid the common problem (for people who take all their data first and plot it later) of having 200 points in a row where nothing is happening and only two points in the range where things are changing (or of having your data stop just as things start to happen). Also, misread data points generally show up immediately.

   b) Do calculations and intermediate analysis steps at the earliest possible point: if a discrepancy shows up or you find that you don't have all the data you need, it's easiest to go back and recheck a point or measure more while you're still set-up to do the measurement.