Your Lab Notebook

Why keep a lab notebook (besides a grade, we mean?). The lab notebook should be a complete record of what you have done. As such it serves as both a memory aid and an archival record.

Following is a summary of the results from interviews with 13 graduate students who were actively involved in experimental research. They were chosen because they were involved in almost daily hands-on engagement with the experiments.

> "Researchers generally had a consensus view of the purpose for lab notebooks in their research. The notebook is intended to serve as a record of precisely what one did (both successfully and unsuccessfully) throughout the course of one's experiment–it was described as being the memory of the experiment. It was emphasized that the complexity of their experiments made it too difficult to remember all of the daily details, and so the notebook was essential for keeping track of them. Additionally, in order to make progress in their work, researchers had to synthesize results from different days–by comparing and contrasting different measurement, they were able to make sense of the subtleties of their experiments. This required that the details of various days' efforts were adequately recorded. These different measurements may have been taken over the course of days, weeks, or months. Also, from a summative perspective, information in the notebook was essential to corroborate anything that would ultimately be published. For many of the researchers, the notebook also serves as a place to develop new ideas for the future trajectory of the project, so that they could revisit and further refine these ideas as new results arose. Furthermore, the notebook served to communicate the researcher's efforts to others involved in the project either at present or to those in the future. In essence, the purpose of the notebook was to help make sense of the experiment, think through future directions of the project, create a foundation for publications, and communicate progress with others."
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> Jacob T. Stanley and H. J. Lewandowski, "Recommendations for the use of notebooks in upper-division physics lab courses," Am. J. Phys. **86**(1), pp. 45-53, January 2018; https://doi.org/10.1119/1.5001933.

As a memory aid, it will help you remember exactly what you were doing and what the previous results were. It is amazing how quickly those details disappear from memory. Even a week later, it can take you several minutes to remember what you have already done. If you are away for a month or a year, it is almost the only way to get back up to speed. Maintaining a good lab notebook will always improve your

productivity, even if you are a theorist or a computationalist.

As an archival record of your work, the lab notebook will help you establish what and when you did things if it ever becomes important to your employer (which might be you!). Many employers ***require*** their workers to keep appropriately detailed lab notebooks.

> "Remember kids, the only difference between [fiddling] around and science is writing it down."
>
> Alex Jason, Mythbusters ballistics expert
> used by Adam Savage on Mythbusters

1.0 What to include in your lab notebook

It is expected that you will have your lab notebook available anytime you are working in the lab. The lab notebook is your record of what was done and when it was done. The details should be recorded ***as the work is done***. Going back to reconstruct a lab notebook after the fact is counterproductive and results in a sketchy, and often inaccurate, description of the work.

You should record any information that would be necessary for someone to duplicate your experiment with only your lab notebook (and possibly the various lab handouts) as a guide.

Some of the items that should be recorded in your notebook:

- The actual date the work being described was done (every page should be dated).
- Your purpose in doing the experiment. This should be a few sentences describing what you hope to measure, calculate, or derive and how you are going to do it.
- Details on any equipment that you assemble for the experiment.
  - Relevant dimensions, materials, and characteristics for hardware used. A reference to a published fabrication drawing would be adequate if such is available and necessary. Draw a sketch of the experimental layout.
  - Commercial equipment should be identified by manufacturer and mode number. Lab equipment that is standard for the class can be identified by function rather than in detail. For example, you could put down "Digital Multimeter" in place of full identifying information if you use the standard class multimeter.

  - Circuit diagrams for any electronics you fabricate. A reference to a published diagram would be adequate if it is complicated. Simple circuit diagrams should always be included.
  - Details for any parameters in the above items that are not specified or given as "optional" in the diagram or drawing.

- Details on any transducers used to record information for the experiment.

  - If a transducer requires any calibration, the method of calibration and the results of the calibration must be included in the notebook.

- Details on any software written or used in the course of the experiment.

  - A listing for the software (for example, for Python or C++ code) or a printout of the block diagram (for LabVIEW code) may be appropriate if it illustrates important aspects of the acquisition or analysis.
  - Details on choices made in the software. For example, if it is a data acquisition program, you should include, as appropriate,

    * the specific hardware used for the acquisition
    * signal acquisition rates
    * data averaging details (if applicable)
    * input ranges specified
    * the format of any output files
    * any special methods used in the course of the acquisition.

- Details of any models used in analyzing the data. Completely describe the model(s) and any approximations made in arriving at the model(s).

  It is often appropriate to include a derivation of the model. If the model is derived somewhere else, include a reference to that derivation.

- ***Your actual data***.

  An experiment with no data is not complete, even if the data show that the experiment was a failure. Lists or tables of numbers are reasonable if they are short. For large collections of data, there should be properly labeled graphs.

  It is perfectly acceptable to print items for inclusion in your notebook and tape them in. They should be firmly attached to the notebook pages. Loose papers are not acceptable since they can't be considered part of the permanent record of the experiment.

- Your thoughts and interpretations of the data.

  It is completely appropriate to mention what you understand and what you don't about the data, and consider possible interpretations of what you are seeing. ("This data looks strange. Is there another source of noise that I haven't considered?")

A few reminders on content:

- ***Use units with all data*** unless the data are actually without units such as ratios of voltages. Any data without units are assumed to be in furlongs/fortnight.

  There are two online documents that are very valuable regarding the use of SI units. The NIST Guide for the use of the International System of Units (`https://www.nist.gov/physical-measurement-laboratory/special-publication-811`) and Writing with Metric Units (`https://www.nist.gov/pml/weights-and-measures/writing-metric-units`)
- ***Use labels for graph axes***.

  These labels should include both what is represented by the axis and the associated units if applicable. Use arrows and describe what is significant on the graphs as appropriate.
- ***Indicate uncertainty in your data and subsequent results*** as accurately as possible. See the document "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results" (`https://www.nist.gov/pml/nist-technical-note-1297`) for the proper way to handle and report uncertainty.

If you decide something in your notebook is in error, don't scribble it out or remove it. Just put a large 'X' through the erroneous material and leave it readable. Write in an explanation of why you think it is wrong. ("We didn't have the secondary power supply turned on, so the widget wobbled instead of precessing.")

Remember that your notebooks will be graded at the completion of each experiment group (comprising multiple lab sessions). You should have your notebook complete and ready to be graded when you finish the group of experiments.

You are supposed to be writing your notebook as you perform the experiments.

2.0 Notebook grading

Your notebook will be graded with the following scale. This scale assumes each lab is worth 40 points. Deductions can be in 1 point increments. If the lab is not worth 40 points, the points given below will be scaled appropriately.

- Remember that every page is to be dated indicating when the work was done.
- Description of the experimental setup. This includes clarity and completeness. 8 points.
- Description of any models used and the analysis methods. 8 points.

- Completeness of data recording. If any data is not to be used, is it clearly marked that way, with a reason why? 8 points.
- Error analysis. This includes error sources, sizes, and propagation. 8 points.
- Conclusions and understanding. This includes answers to any questions that are asked in the lab description. 8 points.

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