How to Keep a Laboratory Notebook

1 Introduction

The ultimate standard for keeping a laboratory notebook is that another person in your field could reproduce your results using only your laboratory notebook. Keeping a legal record of your work may be required by some industry and government employers, and is standard practice in research laboratories. This record is a laboratory notebook: a bound, hard-cover book with printed page numbers. Your notebook should contain a complete record of each project you work on in a form that will permit the preparation of a full report. Since such a report could be required months or years after the completion of your portion of a major project, the notebook must contain records of all plans, procedures, set-ups, equipment and parts used, data, formulas, calculations, MATLAB scripts, plots, thoughts, conclusions, and anything else that is relevant. In both industry and the research world, if your work isn't fully and correctly documented, the time you spent on the project was wasted.

Reasons for keeping a laboratory notebook include the following, all of which have happened to me:

- the project leads to a journal publication
- the project results in the filing of a patent
- the work is part of a large hardware development effort (in my case, space systems) requiring detailed reports after you have been reassigned to a different program or left the organization
- part of the work on the project is done at a remote facility to which you have limited access
- a product you have helped to develop fails in operation, requiring a complete investigation of all design and testing related to its development and production
- one of your colleagues is investigated for illegal conduct

Your laboratory notebook is an important legal document and may become evidence in court if, for example, your work leads to a patent that is contested. Inadequate documentation of your work could, in the most extreme cases, cost you your job, cost your employer millions of dollars in lost earnings from potential patents, or cost you or your employer significant legal fees.
As automated data acquisition systems have become more common, the practical and legal challenges of managing the resulting data have become more complex. Some organizations are moving to electronic lab notebook systems, but the legal status of these programs has not yet been fully established. Current practice is to keep both electronically-readable backup copies of your data and to keep print copies. Since the data files you might record in this course are not large, I will use the existing, legally accepted standards for lab notebooks as outlined below. If you are interested in the topic of electronic lab notebooks, you may submit a report on the available products and their legal status for extra credit points that will be counted in the oral exam score.

2 Standards for Maintaining a Laboratory Notebook

A legal laboratory notebook must be permanently bound and, ideally, has pre-printed page numbers. If your lab notebook does not have page numbers, you should number every page at the top outer corner in permanent ink before use. (A “page” in this sense is a surface upon which you can write, so for each physical “leaf” there are two pages, the front and the back. Both must be numbered.) The purpose of these practices is to demonstrate that information has been entered in chronological order and that no pages have been added or deleted.

Your goal in keeping your notebook is to ensure that it could successfully be used by someone who did not work with you to prepare a report, publication, or patent application based on your work without any other input from you. In the industrial world, your notebook is often issued to you by, and belongs to, your employer. Thus, it is extremely important to ensure that your records are clear and complete and adhere to professional standards. Many organizations have internal policies on laboratory notebooks. Examples that are available on the web include Los Alamos National Laboratory [1] and the University of California, San Francisco [2].

2.1 Organization of the Notebook

- Clearly indicate on the inside or outside of the front cover your name and the starting date of the entries.
- Use the first three pages for a table of contents. Add to the table of contents as you add new projects.
- Start every new project on a new right-hand page. Title the page and list the names of those working with you.
- Date every page in a consistent place (top right corner, bottom center, etc.).
- Pages should never be removed from the notebook.
• Use a narrative style to tell the story of your project clearly. Describe the purpose of the project, your hypothesis for the outcome or outcomes, the methods, materials, and equipment you use, and the purpose of each set of measurements or calculations. The notebook is a record of your work as it evolves, so additional equipment, procedures, or observations are added as the project progresses.

• Include any observations or ideas that come up during the course of your work such as a suggestion for a better way of making a measurement in the future or a problem with a piece of test equipment. Also include your conclusions.

• If you use information from a text book, data sheet, application note, or other source, be sure to cite the source.

• Record in your own words any procedures that are in the handout or a reference. This is the only way that you will be able to report what you actually did. This is also how you can catch an error later. Another person should be able to repeat your work from your notebook without the handout.

• Record your observations and the formulas you use for calculations in your notebook as you work, even if you do the actual calculations with a spreadsheet or MATLAB.

2.2 Recording Projects in the Notebook

• All information must be recorded in ink. All entries should remain part of the record, so don’t mark over or “white out” anything, no matter how sloppy or dumb you think it looks. Mistakes should be crossed out with a single line so that they can still be read. The information you think is incorrect could be important later in understanding your thoughts and measurements. If changes are made, date them and put your initials next to the date.

• Clearly identify the original experimental data. When possible, use tables to make the records easier to understand later. Be sure to record the units of your measured quantities, not just the values. The original data readings are the most important pieces of information you have. If you record them electronically (for example, from an automated data acquisition system), put a printed copy in your notebook as soon as possible. Print the data and permanently attach it to the notebook pages by taping the entire length of each edge or using glue (a glue stick works well). There should be no loose edges. It is good practice to sign in ink across the tape or the glued edge and onto the notebook page.

• If you use constants or conversion factors, identify them clearly and provide a reference to the source.

• All data and observations should be entered on right-hand notebook pages.

• All calculations, figures, and sketches should be on left-hand notebook pages. Clearly identify the steps in a calculation (for example, with equation numbers), and the units of all quantities used. Figures should include brief descriptions
of the equipment used. For example, the function generator box in a block diagram of a test set-up should also include at least the manufacturer and model number (Agilent 3321A). If the calibration history of the instrument could be questioned (for example, because you are testing a deliverable piece of hardware to show that it meets specifications), the serial number of the particular instrument should also be included.

- Leave several blank pages at the end of each experiment for further analysis and conclusions. If you don’t use all of this space, you can line it out and initial it. It is better to leave more room than you need, rather than having to jump to a new page in the middle of the next project.

2.3 Data Analysis

- Show all calculated values in the notebook and clearly indicate how they were calculated. In the usual case, you will have a table with data values followed by calculated values in columns to the right of the data.

- Data values should have an associated uncertainty, and each calculated result should be represented with the appropriate number of significant figures. The propagation of experimental errors to the calculated final results should be included and clearly described.

- If you use software to analyze your data, the resulting tables and graphs should be permanently attached to notebook pages. The values used to produce a graph should be clearly designated (this is called an “explicit data link”). Typical language is, “$I$ and $V$ from columns 4 and 6 of the table on page 23.” The programs, scripts, or formulas used must also be documented in the lab book.

- Graphs should conform to the standards of professional practice, not the defaults in Excel or MATLAB. That is, the data should be clearly identified, the axes should be labeled with both the variables and their units, the graph should be titled, and fits to models should be shown as smooth curves. When you have completed your error analysis, error bars should be used to indicate the estimated error in the data. For random experimental error the fitted curve will be outside of the error bars for about a third of the points.

2.4 Concluding a Project in the Notebook

- At the end of a project, tabulate the final results including the results of your error analysis. Summarize briefly what you did and your conclusions. For example, if you developed a spice model of a diode, there might be regions where the model is not as accurate. If you tested a device, you might describe how well it met its specifications and any concerns you have about marginal performance.

- When you are done, void any blank space by drawing a corner-to-corner line through the space. You can also void a section that you decide to rewrite either because there
are mistakes or because the original version is hard to read. Voided space doesn’t count in the final documentation. This practice is important because it demonstrates that you haven’t gone back and changed anything later, but still allows you to correct any errors or communicate a new understanding.

3 Important Considerations

Good notebook habits are an important professional skill. The following are practices that help to build a record of consistent, professional practice in the lab.

- If the work may lead to a patent, it is common to have another person acquainted with the project but not working directly with you (your corroborator) read and check your work regularly (often once a week). This person should record their review by writing, “On this date I read the entries in this notebook from the entry dated on page to and including the most recent entry above.” They then print and sign their name and date their entry.

- Note the continuation of work to the next page.

- At the end of the day (or the lab period), summarize the status of the project briefly to indicate where you left off. This is also a good place to write any plans for the next time you work on the project.

- When you have a procedure that you may use again, summarize it clearly so that you can reference the page rather than rewriting it. If this is something you do often, you can use a special page (usually the last one) in the table of contents to keep track of these procedures.

- Don’t write anything in your lab notebook that would embarrass you later. Vent your frustrations elsewhere.

- If your work leads to an idea that might be patentable, clearly summarize the concept in a separate entry in your notebook. Have your corroborator sign and date this entry separately. Also ask a third person who is capable of understanding your idea but is not an inventor to sign and date this entry.

- Never rely only on electronically stored data, notes, or records. Print out back-up copies at regular intervals and bind them into notebooks. Sign and date each page of these books in the same way that you do your lab notebook.

References

[2] University of California, San Francisco, Office of Technology Management, “OTM RECOMMENDED LABORATORY PROCEDURES, http://otm.ucsf.edu/docs/otmLabProc.asp (last checked 6 October 2009). These procedures are widely used in academia. For example, they are also used at Stanford.