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Keeping a Laboratory Notebook

Unit: Laboratory & Measurement

NGSS Standards/MA Curriculum Frameworks (2016): SP3, SP8

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): SP3.C

Mastery Objective(s): (Students will be able to…)

- Determine which information to record in a laboratory notebook.
- Record information in a laboratory notebook according to practices used in industry.

Success Criteria:

- Record data accurately and correctly, with units and including estimated digits.
- Use the correct protocol for correcting mistakes.

Language Objectives:

- Understand and be able to describe the process for recording lab procedures and data.

Tier 2 Vocabulary: N/A

Notes:

A laboratory notebook serves two important purposes:

1. It is a diary of exactly what you did, so you can look up the details later.
2. It is a legal record of what you did and when you did it.

Your Notebook as an Official Record

Laboratory notebooks are kept by scientists in research laboratories and high tech companies. If a company or research institution needs to prove (perhaps in a court case) that you did a particular experiment on a particular date and got a particular set of results, your lab notebook is the primary evidence. While there is no right or wrong way for something to exist as a piece of evidence, the goal is for you to maintain a lab notebook that gives the best chance that it can be used to prove beyond a reasonable doubt exactly what you did, exactly when you did it, and exactly what happened.

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For companies that use laboratory notebooks in this way, there are a set of guidelines that exist to prevent mistakes that could compromise the integrity of the notebook. Details may vary somewhat from one company to another, but are probably similar to these, and the spirit of the rules is the same.

- All entries in a lab notebook must be hand-written in ink. (*This proves that you did not erase information.*)
- Your actual procedure and all data must be recorded directly into the notebook, not recorded elsewhere and copied in. (*This proves that you could not have made copy errors.*)
- All pages must be numbered consecutively, to show that no pages have been removed. If your notebook did not come with pre-numbered pages, you need to write the page number on each page before using it. (*This proves that no pages were removed.*) ***Never remove pages from a laboratory notebook for any reason.*** If you need to cross out an entire page, you may do so with a single large "X". If you do this, write a brief explanation of why you crossed out the page, and sign and date the cross-out.
- Start each experiment on a new page. (*This way, if you have to submit an experiment as evidence, you don't end up submitting parts of other experiments that your company may wish to keep confidential.*)
- Sign and date the bottom of each page when you finish recording information on it. Make sure your supervisor witnesses each page within a few days of when you sign it. (*The legal date of an entry is the date it was witnessed. This date is important in patent claims.*)
- When crossing out an incorrect entry in a lab notebook, never obliterate it. Always cross it out with a single line through it, so that it is still possible to read the original mistake. (*This is to prove that it was a mistake, and you didn't change your data or observations. Erased or covered-up data is considered the same as faked or changed data in the scientific community.*) ***Never use "white-out" in a laboratory notebook.*** Any time you cross something out, write your initials and the date next to the change.
- ***Never, ever change data after the experiment is completed.*** Your data, right or wrong, shows what you actually observed. Changing your data constitutes fraud, which is a form of academic dishonesty. Note that fraud is worse than plagiarism.
- ***Never change <u>anything</u> on a page that you have already signed and dated.*** If you realize that an experiment was flawed, leave the bad data where it is and add a note that says, "See page ____." with your initials and date next to the addendum. On the new page, refer back to the page number with the bad data and describe briefly what was wrong with it. Then, give the correct information and sign and date it as you would an experiment.

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Recording Your Procedure

Recording a procedure in a laboratory notebook is a challenging problem, because on the one hand, you need to have a legal record of what you did that is specific enough to be able to stand as evidence in court. On the other hand, you also need to be able to perform the experiment quickly and efficiently without stopping to write down every detail.

If you are developing your own procedure, record the Experimental Design Table and Flow Chart (see the Designing & Performing Experiments topic starting on page 36). Write "See detailed procedure starting on page _____." immediately after the flow chart, and proceed to taking and recording your data. Then, write the detailed description of the procedure afterwards.

If you are following a scripted protocol, record your intended procedure in your notebook before performing the experiment. Then, as you perform the experiment, note all differences between the intended protocol and what you actually did.

If the experiment is quick and simple, or if you suddenly think of something that you want to do immediately, without taking time to plan a procedure beforehand, you can jot down brief notes during the experiment for anything you may not remember, such as instrument settings and other information that is specific to the experiment and the values of your manipulated variables. Then, as soon as possible after finishing the experiment, write down *all* of the details of the experiment. Include absolutely *everything*, including the make and model number of any major equipment that you used. Don't worry about presentation or whether the procedure is written in a way that would be easy for someone else to duplicate; concentrate on making sure the specifics are accurate and complete. The other niceties matter in reports, but not in a notebook.*

* If your teacher requires you to keep a lab notebook and takes points off based on neatness, do your best to comply, but understand that this is absolutely not how laboratory notebooks are used.

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Recording Data

Here are some general rules for working with data.*

- Write something about what you did on the same page as the data, even if it is a very rough outline. Your procedure notes should not get in the way of actually performing the experiment, but there should be enough information to corroborate the detailed summary of the procedure that you will write afterwards. (Also, for evidence's sake, the sooner after the experiment that you write the detailed summary, the more weight it will carry in court.)
- Keep *all* of the raw data, whether you will use it or not.
- If there was a known problem that you figured out while taking a data point, resolve the problem and re-take the data point before recording it.
- If you are not aware of any problems when taking a data point, you cannot discard it, even if you think it is wrong; it is data and you ***must*** record it. You may put a "?" next to it. You can choose not to include the data point in your calculations, but you must justify this decision with an explanation.
- Never erase or delete a measurement after the fact. The only time you should ever cross out recorded data is if you made a mistake writing down the number. (If this happens, you must note it next to the correction.)
- Record all digits. Never round off original data measurements. If the last digit is a zero, you must record it anyway!
- For analog readings (*e.g.,* ruler, graduated cylinder, thermometer), always estimate and record one extra digit.
- Always write down the units with each measurement!
- Record *every* quantity that will be used in a calculation, whether it is changing or not.
- Don't convert in your head before writing down a measurement. Record the original data in the units you actually measured and convert in a separate step.

* From Dr. John Denker, at http://www.av8n.com/physics/uncertainty.htm

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Calculations

In general, calculations only need to be included in a laboratory notebook when they lead directly to another data point or another experiment. When this is the case, the calculation should be accompanied by a short statement of the conclusion drawn from it and the action taken. Calculations in support of the after-the-fact analysis of an experiment or set of experiments may be recorded in a laboratory notebook if you wish, or they may appear elsewhere.

Regardless of where calculations appear, you must:

- Use enough digits to avoid unintended loss of significance. (Don't introduce round-off errors in the middle of a calculation.) This usually means use at least two more "guard" digits beyond the number of "significant figures" you expect your answer to have.
- You may round for convenience only to the extent that you do not lose significance.
- Always calculate and express uncertainty separately from the measurement. Never rely on "sig figs" to express uncertainty. (In fact, you should never *rely* on "sig figs" at all!)
- Leave all digits in the calculator between steps. (Don't round until the end.) This may affect the order in which you enter calculation steps into the calculator.
- When in doubt, keep plenty of "guard digits" (digits after the place where you think you will end up rounding).

Integrity of Data

Your data are your data. In classroom settings, people often get the idea that the goal is to report an uncertainty that reflects the difference between the measured value and the "correct" value. That doesn't work in real life—if you knew the "correct" value you wouldn't need to perform the experiment!

In all cases—in the classroom and in real life—you need to determine the uncertainty of your own measurement by scrutinizing your own measurement procedures and your own analysis. Then you judge how well they agree. For example, we would say that the quantities 10 ± 2 and 11 ± 2 agree reasonably well, because there is considerable overlap between their probability distributions. However, 10 ± 0.2 does not agree with 11 ± 0.2, because there is no overlap.

If you get an impossible result or if your results disagree with well-established results, you should look for and comment on possible problems with your procedure and/or measurements that could have caused the differences you observed. You must *never* fudge your data to improve the agreement.

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Your Laboratory Notebook is *Not* a Report

Many high school students are taught that a laboratory notebook should be a journal-style book in which they must write perfect after-the-fact reports, but they are not allowed to change anything if they make a mistake. ***If you have been taught this, you need to unlearn it right now, because it is false and damaging!***

A laboratory notebook was never meant to communicate your experiments to anyone else. A laboratory notebook is your personal diary of experiments—it is your official signed and dated record of your procedure (what you did) and your data (what happened) at the exact instant that you did it and wrote it down. If anyone asks to see your laboratory notebook, they should not necessarily expect to understand anything in it without an explanation.

Of course, because your laboratory notebook is your journal, it *may* contain anything that you think is relevant. You may choose to include an explanation of the motivations for one or more experiments, the reasons you chose the procedure that you used, alternative procedures or experiments you may have considered, ideas for future experiments, *etc.* Or you may choose to record these things separately and cross-reference them to specific pages in your lab notebook.

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