

Lab Work, Notes and Reports

“It is very necessary that those who are trying to learn from books the facts of physical science should be enabled by the help of a few illustrative experiments to recognize these facts when they meet with them out of doors.” James Clerk Maxwell “Introductory lecture on experimental physics” in “The Scientific Papers of James Clerk Maxwell”, W.D. Niven editor, Volume II, pp 242 to 243, Cambridge University Press (1890).

Just like when learning to drive a car, to perform open heart surgery or to acquire pretty much any skills, book knowledge is insufficient. Hands on practice makes the driver, surgeon, skier, scientist or engineer. To deepen the understanding of what you learn in the lecture, you will carry out some experiments. “An experiment is a question which science poses to Nature, and a measurement is the recording of Nature’s answer.” Max Planck in “The Meaning and Limits of Exact Science”, Science (30 Sep 1949), 110, No. 2857, 325. You will develop some skills and concepts of this interaction with Nature. They are best learned in the laboratory. These skills include posing questions, build models and devise experiments, collect and analyze data, and critically comparing results to predictions or theory. Keeping good laboratory and composing formal reports of results helps communicating with peers. You will need some background on statistics to perform quantitative testing of hypothesis. These skills apply to quantitative work in many fields, including health- and life-sciences, mathematics, and engineering and chemistry. Many students in introductory physics courses have had lab experience in chemistry and other disciplines. We build on that experience. Your teaching assistants will not be as specific about their requirements as your chemistry teaching assistants were. You will often be expected to figure things out on your own in consultation with your lab partner, and will be graded on the quality of those decisions. Since you will be working more independently, you will be required to document your work more carefully, with less input from your teaching assistant.

To accomplish these goals, you will be expected to:

- Pose a question to Nature.
- Build simple physical models that incorporate lecture material.
- Design and perform simple experiments to test or improve these models.
- Employ representative software packages to collect and analyze data.

- Document your experimental methods, results, and data analysis in a lab notebook.
- Evaluate and compare results using uncertainties.
- Communicate your work in writing (short and long formal assignments).

Student responsibilities

You should be prepared for the laboratory activities. At times, the laboratory material may not have been covered in class. You should

- Read the syllabus. The regulations/guidelines in this syllabus take precedence over any oral commitments that may be made. The lab director is responsible for the final interpretation of these policies.
- Before each lab, read the relevant chapter of the lab manual, particularly if the material has not already been covered in lecture. Review related course material
- Arrive at your lab on time. Note that the lab rooms change from week to week. The room schedules are posted on the bulletin boards across from the elevators on the second, third and fourth floors of Webster Hall.
- Bring your lab manual, calculator, pen and pencil, a lab notebook with carbonless copies, and scratch paper to lab each week.
- Come prepared to perform mathematical calculations based on the level of math appropriate for the course. This includes algebra, geometry, and trigonometry. For Physics 201 and 202, calculus is also required.
- Do not bring food, tobacco, or beverages into a lab room.
- If you miss or expect to miss a lab due to sickness or another valid reason, arrange for a make-up laboratory as described in the Requests for Make-Up Laboratories section of this syllabus.

During the laboratory session, your TA will provide introductory material. She/he is there to guide and nudge towards sound experimental practice. The TA will not provide plain answers to you but will respond with counter questions. If specific equipment must be set up or malfunctions, your TA will help or call for further assistance. You should

- Note down the date, class and section, the laboratory experiment name, your lab partner.
- Don't panic, be creative, trust your reasoning skills. Interact with your lab partner; bonus credit may lurk around.
- Use only carbonless copy laboratory notebooks with page numbers.
- Complete all labs and the lab exam.
- Computers have crashed. If at all possible, record all measurement data and results in your lab notes! You and your lab partner should each have all data.

- Make sure that all submitted work is your own. Academic dishonesty is not tolerated and is grounds for failing the course.
- Submit the original of your lab notes to your TA. This will be part of your grade. Retain the copy to complete any take home assignments.

After the laboratory session

- Complete all writing assignment and any formal reports as requested.
- Submit your work in the mail slot of your section on the 3rd floor of Webster.
- Do so on time! Do so in the correct mail slot. Failure may result in loss of credit.

Written communication of laboratory work

Records of laboratory work take at least two forms. The lab notebook is a protocol of all activities in the lab. Formal reports communicate key findings and results to a larger audience.

Lab notes: For reference and legal purposes, the primary record of lab work is the lab notebook. In virtually every work environment, be the research lab at universities or in industry or in a medical practice or repair shop, detailed records of activities are maintained. These are the lab notes. They function as memory aides, means to collect thoughts and to lay out upcoming steps in work and research. The notes are used as a workspace for new ideas and the efforts towards their validation, or to prove them wrong. They are a chronological and legal record. We require that you use a commercial notebook with index pages at the front, and numbered carbonless copy pages for notes. Many introductory chemistry laboratories use suitable notebooks. If your chemistry notebook is otherwise suitable and has blank pages left, you are free to use it for this course. At the end of each laboratory, you will submit the copy pages from your notebook to your teaching assistant. You will submit the copies for any work you do outside of class with the rest of the lab assignment. You will retain the original copies for your record and study. When you fill up one notebook, you are expected to obtain another.

Formal report: For communication within a broader technical community, lab work is summarized in technical reports. These reports communicate results and omit many details recorded in your lab notebook. Because the preparation of proper lab reports require considerable time and effort, we will not require a complete report for each laboratory. However, to satisfy UCORE requirements, some formal writing is necessary. For some labs, we will ask that you submit a well written, formal report, where you focus on communication tasks.

These two forms of communication employ different standards that can be only partially implemented in an instructional lab. What we require is described below.

Lab notes—official record of attendance and work performed¹

In general: The contents of your lab notes are the basis for grading the labs and for you to succeed in the exam. Neatness is not essential, but lab notes must be legible. **If a TA cannot read it, you will not get credit.** Your notes must include a full record of activities in the lab section. The details will be discussed during the first “introductory session” of your lab. Essential components are:

- *Identify yourself* Your name, WSU ID, your partner’s name, the date, the class and lab section, the Teaching Assistant’s name (TA). Is this a makeup lab?
- *What do you want to know?* The objective of the lab. What concept of physics is up for testing.
- *What do you know?* A collection of knowledge to help with the answer. Key components of the teaching assistant’s (TA) introduction belong here.
- *What equations are useful?* Write down equations that are to be tested. These may come from your TA or the classroom lecture or are derived here in the lab.
- *Sketches and free body diagrams* of the experimental setup with definitions. Make **large** drawings. Do not clutter with irrelevant details. Define components (i.e. cart, motion sensor, track, “The track is level). Add physics parameters and define them (i.e. momentum p, initial position xo).
- *Make predictions:* What results do you expect to observe? For example: “The cart will roll along the track with constant speed”, or “The cart will accelerate until it hits the end of the track”. Illustrate with drawings. Specify, if something is constant, increases linear or “comes to a full stop”.
- *Timestamps:* What was done or observed when? Note the time on the right margin! At least once on each page.
- *Write down any activities chronologically.* Note the values of setup parameters. “Tracking the fall of a basketball with a motion sensor”. “The track is set horizontally as checked with a level.”
- *Data and results* Raw data, analysis results and units must be recorded. Tables are very useful. Values that you enter into Excel spreadsheets **must** appear in your handwritten notes.
- *Error analysis* is essential to lab work as the measured values and their units. Uncertainties and standard deviations quantify the reliability of a measurement.
- *Graphs* Large format graphs of recorded data (landscape format full page printouts; use zoom and pan). Label them and note where they belong in the lab notes. Clearly mark, which part of the graph is used for any analysis such as curve fitting.

¹A detailed introduction to the lab notebook is found in: Howard M. Kanare, *Writing the Lab Notebook*, (American Chemical Society, Washington, DC, 1985).

- *Math derivations* Details of mathematical derivations or algebraic steps. The grader should be able to follow your algebraic steps.
- *Comparisons* Experimental findings should be compared to predictions. A quantitative method to do this will be introduced in the labs. If there is disagreement, point that out and explain. Disagreements will not result in loss of grade credit. Failure to point out disagreements or not to discuss them will lead to points subtractions.

Lab notes and exams At the end of the semester, you will take a lab exam in which parts of a few selected experiments are to be reproduced — usually with small changes. Parts of the exam will be impossible to resolve if you did not keep good records in your lab notebook. The exam is much easier if your notes are complete.

With the exception of computer-generated graphs and tables printed during lab, lab notes must be handwritten in pen. Although lab notes are not formal documents, they are legal records. Any attempt to remove information from the record after the fact destroys this value and is considered scientific misconduct. *If you decide that any original data or notes are in error, put a single “X” through it, make short note in the margin explaining why it is in error, then record the new information in a new entry.* Both sets of data must be legible in your lab notes. Your grade will not be lowered due to properly marked errors. This practice conforms to standard scientific and engineering practice. You are free to work through any derivations that should appear in your lab notes on scratch paper before entering them in your lab notebook.

In case of a dispute over lab attendance or what you did in lab, pages torn from your lab notebook will not be accepted as evidence. Likewise, notes on regular notebook paper will not be accepted as evidence. A computer printout is evidence only if it is permanently attached (taped, not stapled) to an original page in your notebook or shows the signature of the supervising teaching assistant. Missing original pages are evidence for suspicious activity and carry a “presumption of guilt”: we will assume you are guilty of something—the only question is what.

If you rewrite or type your notes, understand that your original notes are the official record, not the rewritten notes. Notes made after the fact are not valid records and will not be treated as such. The copy pages with your notes must be submitted in order to receive a grade for laboratory work.

Each entry in your lab notebook should start with the current date and time in the right margin. If you work on your lab notes at home after lab, the entries made at home must also begin with the current date and time (the time of writing, not the time of the lab). Each entry must be recorded at the same time the work is performed. Entries must be sequential. Leaving one or more blank pages or part of a page in your notebook for later work is not acceptable. When you move on to a new page, draw a diagonal line through any large blank areas of the previous page. To work on an earlier lab after you have started work on a later lab, start your addition on first blank page in sequence. Mark the top of the new page, “Continued from page ...” and another note at the bottom of the old page, “Continued on page ...”. Many lab notebooks provide spaces for these notes. Your lab notebook should also have an index for this information.

Unlike formal lab reports, texts in lab notes should be brief. These are not novels. Think of headlines and bullet lists. It is appropriate to write out questions you have about the lab and one or

two sentences of introductory material in your notebook before coming to lab; these entries must be dated at the time or writing. Each step of your procedure must be recorded as you actually perform it. Do not copy procedures from the manual into your lab notes before coming to lab. (When pre-recorded procedures are absolutely necessary, draw a vertical line down the center of the notebook page, with your intended procedure on the left and your record of what you actually did on the right.) Likewise you should record your data as you take the data. There is no data section. To help you avoid missing important points, the lab manual includes some questions about each lab; these questions should be answered in your lab notes where the questions arise in the lab. If you print a graph or data table in lab, attach it to your other notes as close as possible to the handwritten notes that describe the data and how it was collected. Do not collect your computer printouts at the end. Submit your notes in chronological order.

Your lab notes must be sufficiently detailed that you or another student with your background can reproduce your work. The reader must be able to “trace” your work from the original data, through your analysis, to your conclusions. Your notes should leave no doubt about how the data were collected, what sensors and sensor settings were used (if any), and which equations were used to calculate the quantities you report. Define any symbols used in your equations and include appropriate units for numerical data. Sample calculations are often necessary.

Each graph printed during lab should fill a full sheet of paper to allow room for notes. To provide this room, computer-generated graphs should normally be printed in the “landscape” (rather than the “portrait”) mode. Landscape mode will print the x -axis along the longer dimension of the paper and thus makes most graphs about 50% larger. In some cases it is useful to display computer-generated graphs, for example, showing position, velocity, and acceleration as functions of time, on the same page to facilitate comparison. These graphs should be printed in the mode that most completely fills the page. All graphs must have a *descriptive* title that indicates what is being graphed. (“Graph 1” or “Exercise 1” is not sufficient.) Labels and units are required for both the x - and y -axes. If you are asked to draw a “curve” through your data points, this should always be a best-fit curve (for example, a straight line if appropriate) that best represents your data. Best-fit lines can be drawn by eyeball and a ruler, or with the help of the computer. If you are asked to calculate the slope (or perform other analysis) of the graph by hand, show the results of this analysis directly on the graph, clearly identifying which points are being used to calculate the desired quantities. When a computer-generated best fit curve is displayed on a graph, the resulting equation (with parameters and uncertainties) should also be displayed on the graph. This allows the reader to evaluate the curve fit results without referring back to the text. Refer to the “Uncertainty/Graphical Analysis Supplement” near the back of your lab manual for more information about using graphs to find mathematical relationships between graphed quantities.

Keeping good records during lab takes time, and it is virtually impossible using formal English, with complete sentences and paragraphs. Record your actions and data in the most clear, efficient way possible. Use phrases instead of sentences. Annotated diagrams—simple sketches with the parts labeled and notes—save time and are easier to understand (i.e. grade). Descriptive titles for graphs and table columns also help. If an equation is used to describe the data in a graph, write the equation on the graph. Putting it elsewhere usually requires additional text.

Lab reports—formal communication with peers

Although lab notebooks are the primary records of lab work, they are poor communication devices. Experimental results are communicated in technical reports. Unlike lab notes, these reports omit most “historical” aspects of the work: false starts are omitted. While one often reports the manufacturer and model number for important pieces of equipment, operational details are usually omitted. (The operational details must be recorded in your lab notes.) While lab notes often include derivations, technical reports normally include only the result. As communication devices, we expect lab reports to conform to the standards of formal written English, with appropriate word choice, grammar, and structure.

Because writing formal lab reports is time consuming, an entire report will not be required for each lab. Some labs will require short writing assignments that focus on one element of an entire report—perhaps an introduction or an experiment section. If the teaching assistant believes a submission is inadequate, the teaching assistant may require that it be rewritten and resubmitted for partial credit. As time permits, we will require complete, formal reports for one or two labs. The deadline for the submission of complete reports will be specified at the time of assignment. Typically a week or two are granted after the lab is performed. Your teaching assistant will inform you of the report requirements.

Lab reports (partial or complete) must be typewritten or printed from a text editor, using the format specified in the “Formal Lab Report Instructions” supplement near the back of the lab manual. You will have the original copies of your lab notes to use in preparing your report. Carbon copies of all relevant lab notes must be submitted to your teaching assistant for credit. The statements and conclusions in your formal report must be supported by the data and analysis in your lab notes. Omissions and gaps in logic, when observed, will lower your grade.

Special requirements for lab assignments

Cover Page

A cover page is required for every submission. It must include:

- The title of the experiment
- Your name and student ID number
- The name of your lab partner
- The date that the lab was performed
- The name of your teaching assistant
- The course and lab section numbers (for example, Physics 101, Lab Section 5)

Nothing else should appear on this page. Lab reports that are submitted in the wrong slot or are otherwise misplaced take much longer to reach your teaching assistant if the information on the cover page is incorrect or incomplete. Work submitted during lab might not require a cover page.

Uncertainty analysis

Many experiments involve a quantitative comparison between values of the same quantity determined by two or more distinct methods. When you compare two values, you must address the question of whether or not they agree within the limits of the expected or measured uncertainties. The Uncertainty/ Graphical Analysis Supplement near the back of your lab manual defines important quantities, such as the standard deviation, and supplies details about determining uncertainties. As the semester progresses, you will need to make decisions by yourself on appropriate methods for calculating the uncertainties in your various measured and calculated quantities. Physics 102 and 202 students are expected to be aware of the uncertainty methods learned in Physics 101 and 201, respectively, and to use them appropriately.