PHYS 114: Physics I Laboratory
Lab Manual
Spring 2026

Department of Physics and Astronomy
SUNY Geneseo

Contents

Schedule of Labs for Spring 2026

Please read the corresponding section before coming to lab

Dates	Experiment
Jan 22	*No Lab*
Jan 29	Lab 1: Uncertainty in measurement
Feb 5	Lab 2: One-dimensional kinematics (part I)
Feb 12	Lab 2: One-dimensional kinematics (part II)
Feb 19	Lab 3: Newton's first law (part I)
Feb 26	Lab 3: Newton's first law (part II)
Mar 5	Lab 4: Two-dimensional kinematics
Mar 12	*No Lab… reserved for make-up labs 1-4*
Mar 19	*No Lab*
Mar 26	Lab 5: Newton's second law (part I)
Apr 2	Lab 5: Newton's second law (part II)
Apr 9	Lab 6: Conservation laws
Apr 16	Lab 7: Rotational inertia
Apr 23	Lab 8: Simple harmonic motion
Apr 30	Lab final exam

Lab Policies, Requirements, and General Information

Attendance

Attendance at all labs is required in order to pass the course. If you are sick, do not come to lab — please arrange a makeup with your lab instructor.

Required items to bring to lab

1. Lab Manual: Please be sure to read the appropriate section(s) of this lab manual before coming to lab.
2. Logbook: Bound logbooks are required for this lab, and can be purchased at the campus store. They should be quad ruled and only used for this physics lab. Each page should be numbered… even pages you haven't yet used! You are expected to use your logbook to record notes, comments, measurements, calculations, etc. during the lab and keep it up-to-date throughout the semester. See pages v – vi for more information.
3. Pencils and/or Pens: You may use either pen or pencil to write in your logbook. Note that if, after graduation, your career requires the use of a logbook, use of pencils will never be permitted. A significant part of professional logbook usage is *documenting* rather than *concealing* your errors.
4. Calculator: You should not need a calculator while you are in lab, although you are permitted to use on while doing the pre-lab assignments/quizzes *at home*. During lab, all calculations will be performed in Excel.
5. Laptop Computer: You will be using Excel on your laptop for data storage and analysis. Learning how to use Excel to plot and analyze data is an important course goal. You must use the desktop, not the online version. See pages xi-xii for more information.

General information about physics lab

1. It is important to show up to lab on time, since time will be limited in lab.
2. Students must come to lab prepared. This means having read the section in the lab manual for the current week's experiment, looking up any relevant material in the course textbook and completing any pre-lab assignment.
3. You may not leave lab early without approval of the instructor. Leaving lab early is not usually permitted so there is no reason to rush.
4. The lab area must be kept neat and orderly. As a lab physicist, you must keep your area clear of waste materials and leave the lab set up as you found it. This includes unplugging all electrical equipment, returning equipment to its original setup and throwing out trash.
5. A lab report will typically be due each week. Lab reports may include a worksheet, a written lab abstract, answers to lab manual questions, reading assignments, copies of your graphs, etc. Late submission of work will be graded down.
6. All lab reports will be submitted via Brightspace.
7. Lab reports will be graded on clarity, correctness, neatness, and proper use of the English language. While you might not lose credit for an "incorrect" value for a result where the value is known, you will still be expected to calculate it correctly from your data and come up with an explanation why it is wrong.

Plagiarism and Academic Honesty

[From the SUNY Geneseo College Bulletin. . .]

Plagiarism

Plagiarism is the representation of someone else's words or ideas as one's own, or the arrangement of someone else's material(s) as one's own. Such misrepresentation may be sufficient grounds for a student's receiving a grade of E for the paper or presentation involved or may result in an E being assigned as the final grade for the course. Any one of the following constitutes evidence of plagiarism: 1. direct quotation without identifying punctuation and citation of source; 2. paraphrase of expression or thought without proper attribution; 3. unacknowledged dependence upon a source in plan, organization, or argument.

Academic Honesty

Academic and intellectual honesty is expected of all students. In its simplest form, academic honesty requires that each student prepare and submit his or her own work. Students who have questions about permissible degrees of cooperation with others should consult the instructors of the courses in question for guidance. Incidents in which academic honesty is not practiced are dealt with under the student academic dishonesty policy.

Student Academic Dishonesty Policy and Procedures

Academic dishonesty includes cheating, knowingly providing false information, plagiarizing, and any other form of academic misrepresentation.

IMPORTANT NOTE: You must write up all lab reports, including abstracts, worksheets, etc. independently from others, including your lab partner. The work you submit must be your own. It is OK to discuss your interpretations of your results with your instructor or your lab partner while in lab, but you must always write up your own lab report independently from your lab partner or anyone else. You should not show a copy of your lab abstract or lab report to your partner or anyone else. If one student plagiarizes another student's lab report, both students are guilty of academic dishonesty.

Laboratory Log Book

Your logbook is an especially important tool in lab. It is to be used exclusively for this lab. Write your name, lab section, and lab instructor's name clearly on the front of the notebook. This lab manual gives the necessary instructions to complete each of the lab experiments/exercises. Your logbook should be a complete, self-contained, and detailed record of your laboratory activities. It is not necessary for you to copy over verbatim the particular instructions, but you should paraphrase them in your own words. Some third party should be able to look at your logbook, repeat the experiment you performed, and obtain similar results. A well-kept logbook will enable you to answer all questions concerning your calculations and other aspects of the experiment. Your logbook must be comprehensible and well organized, with your handwriting clear and lucid so that another person (your instructor) can read your logbook and understand what you did. Your logbook should begin with a TABLE OF CONTENTS and all sheets should be numbered sequentially in the upper right hand corner. Start each lab on a new page in the logbook. You must include the following (as required) items for each lab entry:

1. Lab Title, Date, Lab Partner. Write the name of the lab in large letters and underline it so that it is easy to find. Put the date of the lab right next to it on the top of the page, include the year in the date. Put your lab partner's name (first and last, spelled correctly) and email address underneath the title.

2. Pre-lab Notes. You can write down some notes in your notebook before you come to class. You will be able to use these notes on the quiz. Also use this space to write down additional notes during the pre-lab lecture your instructor gives at the beginning of the lab.

3. Sketch of the apparatus. You must include a large sketch showing the basic experimental set up with each component labeled.

4. Procedure. You must write down some notes as you complete the lab in order to explain what you did. Make it clear and concise. Do not plagiarize the lab manual. You can include raw data in data tables in-line with your procedure section as you collect it. It is important you write down raw data as it is collected with the proper units and uncertainties.

5. Graphs and Data Tables. You must print out copies (in addition to the ones you hand in) of all graphs made during lab or to complete the worksheet. You must cut them down to size and tape (not staple) them into your logbook so that they can be looked out without rotating the log book or unfolding any pages. Use transparent scotch tape only to tape in all four sides, not masking tape or duct tape.

6. Analysis and Calculations. You must write down all of the steps required to perform the data

analysis and calculations in your log book. Use symbolic equations, properly labeled, to show what math you are doing. Use Excel, not a calculator, to do the number crunching.

7. Final Results. Make a final summary chart similar to the worksheet that you will hand in for each lab. Make sure to properly format results and don't forget units! Make sure it is clear what the final result is.

8. Concluding Comments. Write 3-4 sentences to summarize the results of the lab. Answer the questions – Did your results make sense? Did they agree with the accepted value? What were some of the sources of error in the lab? Can you think of any sources of systematic error? What can be done in the future to improve the result of the lab?

Uncertainties and Presentation Format

Whenever collecting data, it is important to understand the limitations of the equipment used as well as the limitations of the experimentalist (you). It is not only important to obtain a measurement (the value) but also provide a record of how well you know this value (the uncertainty). Uncertainties are intrinsic to the experiment. Limitations in how precise a value can be known are often determined by the particular piece of equipment used. All measured values have an associated uncertainty; it is impossible to measure anything to exact precision.

There are two categories of errors — systematic errors and random errors. A systematic error is one which shifts every measured value in one direction. For example, if a meter stick was "shrunk", all values read off of this meter stick would be inaccurate no matter how carefully it was used. Systematic errors have the advantage that they can be corrected for if discovered but often are too difficult to detect. Random errors are those errors which arise when repeated measurements of the same quantity fail to give exactly the same value. These errors can come from, for example, interpolating between the scale divisions on a meter stick, how tightly a micrometer is placed on a block, at which point there is a color change, voltage fluctuations, etc. If enough measurements are made, you would expect (statistically speaking) that half of the measurements would be "too big" and half would be "too small" and that they would cancel each other out if you took the average of a large number of measurements.

For the purposes of our lab, there are only four total ways to obtain a value and each one has an associated way to obtain the uncertainty for that value. These four ways are shown in table 1.

If you obtain a quantity...	**...then the uncertainty is given by...**
...by obtaining one or two measurements,	...estimation
...from a theoretically based formula or calculation involving several variables,	...propagation of uncertainty rules (for our lab, an equation may be provided)
...by averaging many independent measurements together,	...calculating the standard deviation of the measurements.
...from a least-squares fit of a graph,	...the output of `LINEST()`

Table 1: This table shows the ways that you will find the uncertainty in a particular value in physics lab.

When an uncertainty has been obtained for a value, it is important to report those two quantities together in what is known as Presentation format. Uncertainties are estimates of our ignorance, so it is silly to claim that an uncertainty is precisely known (even when it is a calculated result from

`LINEST()` or the standard deviation). Therefore, you do not want to include too many significant digits on your uncertainty. A common convention used in physics journal articles is to report calculated uncertainties to two (2) significant figures. (Note that uncertainties that are estimated can be reported with one (1) significant figure.) Since the measurement can't be known to more precision than the uncertainty, the measurement value is rounded to the same decimal place as the last significant digit in the uncertainty. It is okay for the uncertainty and the value to have a different number of significant figures. Both the value and the uncertainty must have the same units and, if written in scientific notation, must be raised to the same power of ten. In addition, when using scientific notation, the decimal point must be placed after the first digit of the value. Also, when using scientific notation you must be careful with placement of parentheses (see examples in table 2). Here is a step-by-step approach to obtaining presentation format for calculated uncertainties (remember that calculated uncertainties must have two sig figs on the uncertainty)...

1. Round off uncertainty to two (2) significant figures
2. Round off value to same decimal place as last significant digit in uncertainty
3. If your value is greater than 10,000 or less than 0.01 then you should use scientific notation.
4. When using scientific notation, make sure value and uncertainty are expressed to same power of ten, with decimal point placed after first digit in the value. Example: $(5.423 \pm 0.034) \times 10^{-5}$
5. When the quantity has units, they are included only once at the end of the expression. Example: $(5.423 \pm 0.034) \times 10^{-5}$ kg

#	**Value**	**Uncertainty**	**Presentation Format**
1	2692878.804	166541.7383	$(2.69 \pm 0.17) \times 10^{6}$
2	49498.82142	2446.252488	$(4.95 \pm 0.24) \times 10^{4}$
3	0.104985579	0.002105881	0.1050 ± 0.0021
4	32.52397651	1.047228993	32.5 ± 1.0
5	0.000495871	7.06008E-06	$(4.959 \pm 0.071) \times 10^{-4}$

Table 2: Some examples of presentation format

Agreement

One last thing that we can use uncertainties for is to compare to different results and say whether or not they are in "agreement." Two values are in agreement if their uncertainties overlap, (from $x - \Delta x$ to $x + \Delta x$). For example, 10.50 ± 0.32 and 11.50 ± 0.25 are not in agreement because there is no overlap in their ranges. On the other hand, 10.50 ± 0.32 and 11.50 ± 0.90 are in agreement since there is an overlap. If you want to compare an accepted value (that has no uncertainty) to an experimental result, the accepted value needs to fall inside of the range from x–Δx to $x + \Delta x$.

How to write a lab abstract

Your lab instructor will sometimes assign an abstract to be turned in as part of a lab report. Here are some guidelines for writing a good abstract:

Format

- Type your abstract.
- Use 12 pt font, and double space.
- Make your abstract all one paragraph.
- Make your abstract fit on one page.
- Do not use figures or tables in your abstract.

Grammar

- Use past tense.
- Avoid using the first person. (No I, we, our, etc.)
- Passive voice is ok. "The voltage was measured."
- Simple language is better. Get to the point, don't try to impress anyone by using fancy words.

Other tips

- Don't mention Excel, `LINEST`, or Trendline.
- Don't ever say "the experiment was successful" or use the phrase "human error".
- When quoting uncertainties, find the $\pm$ sign (insert $\rightarrow$ symbol).
- Find the superscript key so that values can be written as 2.3×10^{-12}, for example, instead of 2.3E-12.
- If you use variables in your abstract, (*e.g.* m, θ, or T), make sure you define them appropriately. Also variable names should be italicized.

The SEVEN Elements in an Abstract

With very few exceptions, the following seven elements should be included in every abstract.

1. Purpose: <Explain what the purpose or goal of the experiment was. It is good to describe what quantity you actually measured (your final result). Please do not copy material or phrasing from the lab manual. Often times the educational purpose for a lab as specified in the lab manual will be different than the purpose as stated in your abstract.>

2. Experimental Setup: <Now put in one or two sentences about the experimental setup. This is probably the hardest part of writing an abstract! Don't just list the equipment, say how it was arranged. Beware of using superfluous phrases like "To do this...", "The apparatus used in this lab consisted of...", or "In this lab," etc..>

3. Experimental Procedure: <Now put in one or two sentences about the experimental procedure. An example would be "The voltage across the capacitor was recorded in 10 second intervals for a time period of 10 minutes." This section also can be a little tricky, and sometimes it may somewhat overlap with Element 2.>

4. Important Graphs Made and Fits Performed: <The data analysis will usually (but not always) involve plotting data in some fashion. Explain how the data was plotted and also describe

the type of fit performed to the data.>

5. How was the quantity of interest related to the slope (or intercept, or other parameter) of the fit? <Usually (but not always) the final result will be related to one or more of the fitting parameters (*e.g.* slope and intercept of a straight line). If so, describe how the quantity of interest was calculated from the fit parameters.>

6. Results: <This is the "punchline" of your abstract. What were the final numerical results (with uncertainties and units)? Make absolutely sure you format your result properly, using "presentation format".>

7. Comment: <After presenting your final results, you must provide some commentary on your results. Many times (but not always) you will compare your measured value with an accepted or manufacturer's value. You should state whether or not the measured value agrees with the theoretical or accepted value. Sometimes you will compare two measurements of the same quantity that you made using different techniques. You should also comment on whether or not these measurements agree. If your results do not agree, you should provide some reason that might explain the discrepancy.>

Sample Abstract

This abstract is only a “cartoon” of an actual abstract. It describes a trivial experiment, your abstracts will be much more involved and will provide many more details. The main point here is to show you that an abstract must be a single page, must be double spaced, and must briefly describe the apparatus, procedure, and results of your experiment.

Your Name

12 September 2025

Measuring the Thickness of Paper

An experiment was performed to determine the thickness of a sheet of paper in a copy of Young’s University Physics. The thickness of several groups of pages, each group consisting of a different number of pages, was measured with a ruler. The thickness was plotted versus the number of pages in the group. These data were fit with a straight line. The slope of this line is the thickness of a single page, which was found to be $(5.524 \pm 0.072) \times 10^{-2}$ mm. The primary source of error was the non-uniformity of compression of the paper when a measurement was made.

Lab Partner’s Name

Instructions for formatting your Excel chart

Studies have shown that students in physics labs lose a lot of points because they are careless about how they present their data graphically. The default settings used on Excel are pretty horrible and should be changed before printing out graphs for lab reports, logbooks, etc. Please observe the following rules when making a graph on Excel to be turned in as part of your lab report:

1. Label your axes. Axis labels should be in bold and should be in a larger font than the numerical markings on the axes. Make sure each axis has a descriptive title. Use the actual name of the physical quantity, not commonly used variable names. For example, you should label your axis as "Angle (deg)" instead of "Theta (deg)". Do not forget to include appropriate units on your axis labels.

2. Data points should appear as markers. Do not connect your data points with a line.

3. The line of best fit should be generated using the "trendline" feature on Excel. Make sure the equation of this line appears on the graph. At least three significant figures should be displayed for the slope and intercept of the trendline equation.

4. Make sure that tick marks appear on both the horizontal and vertical axes.

5. Be careful with borders—place a border around the graphing area (the axes) but no border around the entire graph object. See example in figure 1 below.

6. Note that by default, Excel makes plots appear in a "widescreen" aspect ratio (5 inches wide by 3 inches high) that is not appropriate for most scientific plots. The graph size should be changed to approximately 4 inches wide by 3.5 inches high. When making multiple plots, please note that you may need to adjust the graph sizes slightly to make them fit nicely on your page layout.

Your instructor will show you how to download and install the PHYS 114 graph formatting template on your computer. This will make it easy to format your graphs properly for our lab.

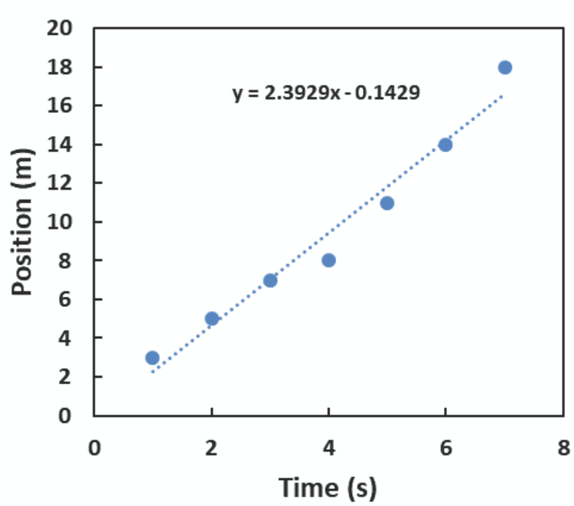

Figure 1: This shows how you can produce a nicely formatted figure using Excel.

Tips for Using Microsoft Excel

How to use the LINEST() function

`LINEST()` is the bread and butter Excel function for generating fitting parameters and associated uncertainties for polynomial functions. You will use `LINEST()` to fit straight lines and quadratic equation data. The first step for using `LINEST()` is to set up a section of the spreadsheet to enter in the formula. For a straight line fit, it takes a 2×2 array and for a quadratic fit, it takes a 3×2 array. Label each of these sections appropriately (see example in figure 2) so that you know which parameter goes with which cell.

	A	B	C	D
1	#	t (s)	x (cm)	v (cm/s)
2	0	0.0000	4.0	18
3	1	0.0167	4.3	96
4	2	0.0333	5.9	144
5	3	0.0500	8.3	198
6	4	0.0667	11.6	258
7	5	0.0833	15.9	
8				
9	x vs. t	A	B	C
10	value	1723	0.09	3.943
11	uncertainty	51	4.4	0.078
12				
13	v vs. t	slope	intercept	
14	value	3492	26.4	
15	uncertainty	160	6.5	

Figure 2: This shows a portion of an Excel spreadsheet and demonstrates the use of `LINEST`.

For linear equations, highlight the four boxes (B14:C15, in this example) and start typing

```
=linest(y_axis_data,x_axis_data,1,1)
```

For this example,

```
=linest(D2:D6,B2:B6,1,1)
```

For quadratic equations, highlight the six boxes (B10:D11, in this example) and start typing

```
=linest(y_axis_data,x_axis_data^{1,2},1,1)
```

For this example,

```
=linest(C2:C7,B2:B7^{1,2},1,1)
```

To get Excel to enter this equation into all of the cells of the array, you must press CTRL-SHIFT-ENTER. Only pressing ENTER will not give you the result you desire.

Additional tips for using Microsoft Excel

1. Excel assumes angles are in radians when using such functions as `sin()`, `cos()` or `tan()`. You can use the `radians()` function to convert a number from degrees to radians. To go the other way, from radians to degrees, use the `degrees()` function.
2. To get Excel to give you the number π as an output, use the function `pi()`. Nothing goes inside of the parenthesis. This will give you π to 15 digits.
3. To get the natural log of a number, use the function `ln()`. Likewise, to raise e (the base of the natural logs) to a power use `exp()`.
4. Use Excel to do your math for you. After you take your quiz, you can put your calculator away and do all calculations on Excel.
5. Make sure to clearly label and effectively organize your spreadsheet as you make it.
6. Don't forget to give an appropriate name to your file and to save it often.