PHYSICS 274L — GENERAL PHYSICS III LAB

UH MANOA — Spring 2023 Semester

Course Information & Policies

Updated: 9 Jan 2023

Class Meetings Monday & Wednesday 3:30–5:20pm
Weeks #1–8: Lectures in Watanabe 114
Weeks #9–16: Experiments in Watanabe 419 (days/times to be arranged via sign-ups)

Instructor Mr. Michael Nassir
E-mail: nassir@hawaii.edu
Office: Watanabe Hall Rm. 426, (808) 956-2922

Office Hours: • Tuesdays 2:00–5:00pm in Wat 421 Physics Library & Study Center
(concurrent with PHYS 151 office hours)
• At other times by appointment, either in Wat 426 office or via Zoom

T.A. John Russell
E-mail: jwruss@hawaii.edu
Office Hours: Mon. & Fri., 1:00–2:00pm in Watanabe 403

Required Materials

Needed for at-home homework assignments & in-class "hands-on" lectures (weeks #5–8):

- **Laptop Computer** — Used for certain homework calculations, journal article searches, practicing Python, practicing LaTeX.
- **Scientific Calculator** with scientific (power-of-10) notation, trig functions, exponents and logarithms. (Graphing features NOT necessary.)

Bring to your lab experiment sessions:

- **Lab Notebook** — Any bound, or 3-ring, or electronic journal of your choice for recording measurements & observations.
- **Laptop Computer** — Use for recording some data, for data analysis following each experiment, and for writing formal lab reports.
- **Scientific Calculator**

Textbooks

- Your PHYS 274 textbook or equivalent reference(s)
- Taylor, John R., *An Introduction to Error Analysis*, 3rd ed. (2022)
  Paperback: ISBN 978-1-940380-08-7
  Available at UH Bookstore (~$80 new, ~$61 used)

OR

- Taylor, John R., *An Introduction to Error Analysis*, 2nd ed. (1997)
  Paperback: ISBN 978-0935702750

Online Resources

- Handouts, worksheets, lab manuals, experiment signups & related materials — via shared Google folder:
  Access first requires Google login using your hawaii.edu account:

https://tinyurl.com/PHYS274L-Spr23

- Laulima's "Assignments" tool will be used for collecting certain (PDF-format) assignments, and "Gradebook" tool will be used for recording scores, but NO other course materials will be posted in Laulima.

Course Schedule (Subject to Change)

DATE	EVENT	TOPICS & READINGS:
M Jan 9	None	
W Jan 11	Lecture	Intro to PHYS 274L Lab: Syllabus, Google Drive Chapters/Sections from Taylor, *An Introduction to Error Analysis*, 2nd or 3rd edition: Chap. 1 (all): Nature of Measurement & Uncertainty §4.1: Random vs. Systematic Error, Precision vs. Accuracy §2.1–2.2: Writing Uncertainties & Rounding Conventions (Significant Figures) §2.7–2.8: Fractional/Percent Uncertainty §1.5, 3.1, (3.2): Estimating Uncertainty for a Single Measurement *Also see: PHYS 151L/170L Mechanics Lab Manual*, Chap. 4 (in Google Drive)
(M Jan 16)	HOLIDAY	
W Jan 18	Lecture	§3.11, (3.3–3.10): Error Propagation (Calculating Uncertainty for a Derived Value)
M Jan 23	Lecture	Chaps. 4 & 5: Gaussian Probability Distributions, Empirical Determination of Uncertainty for Repeated Measurements §2.3–2.4, 5.8: Agreement of Values (*Z*-score, *t*-score)
W Jan 25	Lecture **HW #1 Due**	Chap. 6 (all): Rejection of Outlying Data (Chauvenet's Criterion) Chap. 7 (all): Weighted Averages
M Jan 30	Lecture **HW #2 Due**	§9.1–9.2: Covariance §9.3–9.5: Linear Correlation Coefficient (Pearson's *r*) §3.2, Chap. 11 (all): Poisson (Counting) Statistics
W Feb 1	Lecture	Chap. 8 (all): Least-Squares Fits, Linear Regression: Unweighted & Weighted Chap. 12 (all): Goodness-of-Fit (Chi-Squared Statistics)
M Feb 6	Hands-on Lecture (bring laptop) **HW #3 Due**	Programming in Python (via Colab) — *Part 1:* Python Basics: Variable Types & Simple Data Structures; Arithmetic Operations; Arrays & Array Operations
W Feb 8	Hands-on Lecture (bring laptop)	Programming in Python (via Colab) — *Part 2:* More Python Basics: Flow Control; Conditional Statements; Defining Functions
M Feb 13	Hands-on Lecture (bring laptop) **PythonHW Due?**	Scientific Writing — *Part 1:* Format, Content & Style of Scientific Articles; Major P&A Journals *Also see:* Mack, *How to Write a Good Scientific Paper* (in Google Drive) *Also see:* Keshav, "How to Read a Paper" (in Google Drive)
W Feb 15	Hands-on Lecture (bring laptop)	Scientific Writing — *Part 2:* Astro & Physics Search Tools: ADS, Inspire, UH Libraries; ArXiv & Astro-ph
(M Feb 20)	HOLIDAY	
W Feb 22	Hands-on Lecture (bring laptop) **HW #4 Due**	Programming in Python (via Colab) — *Part 3:* Plotting Graphs with Matplotlib; Least-squares Fitting
M Feb 27	Hands-on Lecture (bring laptop) **HW #5 Due**	• Intro to word processing using LaTeX (via Overleaf) — *Part 1:* Main structure & syntax of LaTeX, Sections, Headers, Special Characters, Lists • Sign-up schedule for Lab Experiments (Google spreadsheet)
W Mar 1	Hands-on Lecture (bring laptop)	• Intro to word processing using LaTeX (via Overleaf) — *Part 2:* Math Mode & Equations, Figures, Tables, Hyperlinks • Keeping Lab Notebooks
M Mar 6 onward	**Lab Experiments Begin** **HW #6 Due**	**Dates TBD via sign-up schedule** — see following sections for due-date policies
W May 10	Mid-Finals Week	Last Day to Submit Final Lab Reports

PHYS 274L UH Manoa Catalog Course Description

(1 4-hr Lab) Experiments illustrating selected concepts of 274, including diffraction and interference of light, wave nature of matter, photoelectric effect, atomic spectra, and semiconductors. Pre: PHYS 152L or 272L; and PHYS 274 (or concurrent). DY (Diversification: Laboratory Science)

Prerequisites

• **PHYS 152L or 272L; and PHYS 274 (or concurrent).** This also implies satisfactory prior completion of PHYS 151, 151L, and 152; or of PHYS 170, 170L, and 272.
• **MATH 243 or 253A (Calculus III)** is a pre- or co-requisite for PHYS 274, and hence for this lab. Most of our theory and calculations require only algebra and trigonometry. However, calculus will make occasional appearances, and you will need to use partial derivatives (Calculus III) when performing error analysis.
• **Grades of C (not C–) or higher are required in all of the above completed courses.**

W-Focus

This course satisfies one Writing-Intensive Focus course for UH Manoa's General Education requirements. This requires a minimum of 4000 words of writing (~16 double-spaced typewritten pages), although you should exceed that amount over the course of your lab reports.

PHYS 274L Course Goals

This course is intended to:
• Supplement the material of PHYS 274 lecture (wave optics and modern physics) by illustrating some of its concepts and phenomena with hands-on experiments.
• Supply a more advanced understanding of the mathematical and statistical tools and experimental techniques used in physical & astronomical research, beyond the simple techniques used in introductory labs. These tools and techniques will be applied to a variety of experimental situations.
• Develop formal scientific-writing skills and familiarity with scientific literature. This includes an introduction to commonly used software by the physics & astronomy community for word processing, creating graphs/plots, and fitting data with mathematical models. These tools will be used to conduct analysis and compose a formal lab report after each experiment.

PHYS 274L Learning Outcomes

At the conclusion of this course, students should be able to:
- Define and use the terminology of selected important topics within wave optics & modern physics.
- Apply common theoretical equations and principles of wave optics & modern physics appropriately to explain/predict the behavior of physical experiments.
- Collect readings of experimental data, including reasonable estimation or calculation of measurement errors on all values.
- Within the constraints of prescribed experiments, exercise intermediate-level scientific judgment during the data-gathering process and analysis of data: identify important and unimportant quantities, choose frequency/number of measurements, devise unbiased measurement methods, choose when to reject outlying values, etc.
- Compile and analyze raw data to arrive at reduced/calculated values with correctly propagated uncertainties.
- Draw statistically valid scientific conclusions, including judgments of statistical agreement or disagreement, from final results & propagated uncertainties.
- Perform computerized least-squares regressions for numerical data.
- Create plots/graphs of numerical data that include error bars, best-fit mathematical functions, and overall formatting appropriate for scientific publication.
- Describe and identify common/expected elements of content and style for scientific articles.
- Name and briefly describe the major refereed scientific journals for physics & astronomy, and briefly describe the peer-review process for scientific papers.
- Use major physics & astronomy repositories and search engines to locate and access scientific articles.
- Compose formal lab reports similar in length and style to a scientific "letter" (short journal article), employing similar prose and formatting, at an intermediate level.

UH Manoa Institutional Learning Outcomes (ILOs)

PHYS 274L Lab supports the following UH Manoa ILOs:

#1. Know — Breadth and Depth of Knowledge
  #1b. Specialized study in an academic field (within the major) — *introductory & reinforcement level*
#2. Do — Intellectual and Practical Skills
  #2a. Think critically and creatively — *introductory & reinforcement level*
  #2b. Conduct research — *introductory level*
  #2c. Communicate and report — *introductory & reinforcement level*

Departmental Program Learning Outcomes

PHYS 274L Lab supports the following Physics degree program LOs:

#2. Be able to formulate scientific problems in mathematical terms and apply analytical and numerical methods towards its solution — *reinforcement level*
#3. Develop skills to design experiments and analyze data through electronic instrumentation and devices, and computer control — *introductory & reinforcement level*
#5. Generate fluency in the scientific enterprise and awareness of possible career paths available to the undergraduate physics major — *introductory & reinforcement level*

PHYS 274L Lab supports the following Astronomy & Astrophysics degree program LOs:

#2. Be able to formulate scientific problems in mathematical terms and apply analytical and numerical methods towards its solution — *reinforcement level*
#3. Develop skills to design observing projects with research telescopes and projects drawing upon data in the literature and in archives — *introductory & reinforcement level*
#5. Generate fluency in the scientific enterprise and awareness of possible career paths available to the undergraduate astronomy and astrophysics major — *introductory & reinforcement level*

Final Grade Determination

Total points possible in the course:

approx.	260 points	= **Homework Assignments** *(exact point total TBD)*
approx.	80 points	= 4 **Prelab Question Sets** *(exact point total TBD)*
	20 points	= 4 **Lab Notebook Checks** × 5 points each
	20 points	= 4 **Preliminary Results Checks** × 5 points each
	320 points	= 4 **Final Lab Reports** × 80 points each
approx.	700 points Total	*(exact point total TBD)*

Your **overall course percentage** will be computed as a simple fraction of your total points earned divided by the total points possible. An overall percentage of 90% will guarantee you at least a final grade of A–; 80% at least a B–; 70% at least a C–; and so forth. In the final determination of grades, these numerical (percentage) cutoffs may be lowered at the discretion of the instructor, but they will not be raised.

"Showing Your Work"

For most mathematical questions on Homework and Prelab assignments, you must SHOW YOUR WORK to receive full credit. Written-out work should include:

1. **Initial Formula(s)**, followed by major algebraic rearrangement steps (if necessary)
2. **Substitution**: "plugging in" known values, followed by major calculation steps (if necessary)
3. **Final Answer**: underlined or boxed, with proper **units**, **sci. notation** (if needed), & **proper rounding**
4. Additional **diagrams** or **comments**, as needed to define quantities.

• Overall **organization** and **neatness** matter! Disorganized or illegible work may be penalized.
• When using an automated tool (spreadsheet, Python code, etc.) to perform a repetitive calculation, as for mean or standard deviation, **briefly describe the method/tool used**.

Lab Experiments

You must complete the following FOUR experiments and lab reports during the second half of the semester:

#1: One- and Two-Slit Diffraction	***Nassir***	
#2: Bragg Diffraction	***Russell***	[*lab partner very useful*]
#3: Michelson Interferometer	***Russell***	[*lab partner somewhat useful*]
#5: Electron Diffraction	***Nassir***	*prerequisite: Exp. #2 Bragg Diffraction*

Pacing & Attendance

• You will have roughly 8 weeks to complete four experiments and reports, which **averages to approx. one experiment every two weeks**. Please pace yourself accordingly when signing up for experiments.
• Do NOT schedule more than one experiment per calendar week.
• *After lecture portion of semester has ended:* You only need to attend lab if you are scheduled to perform an experiment or meet for a preliminary results check.

Partners

You may sign up to conduct experiments **either alone or with ONE partner**. The partner does not need to be the same person for each experiment, but can be if you wish. (See section on "Collaboration" below for more advice on working with a lab partner.) Certain experiments are much easier to perform with a partner's assistance — see above list.

Signups

We will sign up on a schedule of experiments (Google spreadsheet) during one of our final lectures. After that, the spreadsheet will be "locked," so if you wish to change your appointment, **please send an e-mail to the instructor/TA for that experiment.**

Prelab Question Sets

You are required to complete a set of Prelab Questions on the theory and objectives of each experiment before you begin performing that experiment. Please bring your completed Prelab Questions with you to the experiment. Your instructor/TA will briefly review your work before you begin the experiment, and you will be allowed to correct your Prelab Questions before submitting them. The goals of the Prelab Questions are to ensure you understand:

(1) the fundamental physics and theory of the phenomenon to be studied;
(2) the main quantities to be measured and potential sources of systematic & random error; and
(3) the ultimate goals/outcomes of the experiment.

When you arrive, if your Prelab Questions are judged to be significantly incomplete or incorrect, you may be asked to leave and reschedule your experiment for a later date.

Before you begin your experiment, your instructor/TA will also introduce and orient you to the apparatus to be used, including any significant safety issues.

PRELAB QUESTIONS will be worth 10–25 points for each experiment. Plan to submit each set of Prelab Questions as you would a homework assignment, either on paper or as a PDF (via Laulima).

Lab Notebook Checks

You are expected to keep a lab notebook that is used before, during, and after your experiments. You are welcome to use a format of your choosing — a bound composition or engineering notebook, a looseleaf binder, or an electronic journaling or note-taking program. If you choose anything other than a bound lab notebook, you should still treat it as though it were one — namely, your format should allow you to keep a permanent, narrative journal of your experiment, just as a traditional bound lab notebook would. You should be able to draw from the contents of your lab notebook while preparing your formal written lab reports.

Although we will not collect or retain your lab notebook, we will ask to view your notebook before, during, and/or after your experiment. **Before you leave lab on your experiment day, your lab notebook and record-keeping will be reviewed and roughly scored** — see below.

We encourage you to calculate some or all of your preliminary results promptly after gathering your data for that particular experiment — the sooner that you do so, the better you will remember the peculiarities of your data and the circumstances of your observations. It is wise to perform at least some calculations before you leave lab, immediately after conducting your experiment.

BEFORE YOU LEAVE LAB, you must visit your instructor/TA to show your LAB NOTEBOOK for scoring. It should include:

- Pre-lab notes on theory & procedure and any pre-lab calculations
- Raw data measured during experiment, collected into tables or presented as graphs
- Additional observations and experiences (instrument settings, sketches, unusual occurrences, etc.) while conducting the experiment
- Any preliminary graphs or calculation of final results

LAB NOTEBOOK CHECKS will be scored on a scale of 5 points for each experiment:

~2.5 points: Pre-lab notes on theory, experimental goals, etc.

~2.5 points: Data & notes taken during experiment, plus any preliminary calculations/graphs

Preliminary Results Checks

Within **ONE WEEK** of your experiment, you must visit your instructor/TA for that experiment to show your **preliminary results — calculations and/or graphs — with uncertainties** on all relevant final values.

For this presentation of preliminary results, **use of your lab notebook or computer screen with handwritten calculations, informal printouts, or preliminary graphs is fine** — equations, tables, or graphs do NOT need to be formally prepared in the manner that they will appear in your final lab report.

Although you and your lab partner will have identical/shared raw data, you should each ***independently*** perform any calculations, error analysis, or least-squares fitting, and create your own graphs — this is to provide you with the educational value of doing so.

Your instructor/TA will check that your data and results are reasonable, or if there are any obvious problems or deficiencies with your raw data or analysis. This is an important step before you invest the full time and effort of writing your final lab report.

Prelim Results may be presented in person (to the instructor/TA for that experiment, either during office hours or at times to be arranged), **or may be submitted as a PDF via Laulima's Assignments tab.** In-person is definitely recommended if you are stuck or have questions.

PRELIM RESULTS will be scored on a scale of 5 points for each experiment.

Final Lab Reports

We recommend that you commence work on your formal final lab report for each experiment *as soon as possible* after calculating your preliminary results — the sooner that you begin writing, the better you will remember the details of your experiment. You can begin work on your Introduction and other sections even earlier.

Report Guidelines

• Lab reports *typically* contain **between five and 10 pages of double-spaced type, although you are not required to meet any minimum or maximum length.** Depending on the particular experiment, a longer or shorter report may be appropriate to present all necessary information. *Use as much space as needed to contain the relevant information and calculations*, while still being as economical as possible with your language.

- One aim of this exercise is to develop your judgment about which information and details are relevant and important to include in a scientific report.
- Scientific writing requires conciseness: saying things precisely, but with as few words as possible.
- The tone of your writing should be formal, as in most textbooks and journal articles.
- We will review samples of professional scientific publications in class, which you can use as a guide for all of the above.

• Plots & graphs may be prepared using Python's matplotlib or other tools (gnuplot, SciDavis, etc.), but they must conform to standard expectations for scientific publication: labeled axes, titles, error bars, reasonable units, etc.

• Final reports must be typeset using LaTeX.

• Submit all final reports in PDF format, via Laulima's Assignments tab.

FINAL REPORTS will be scored on a scale of 80 points for each experiment, following a preset Lab Report scoring matrix.

Due Dates

The **due date** for any lab report is **TWO WEEKS (14 calendar days) after you perform your experiment,** or by Wed. Dec. 14, whichever is sooner. Reports will be graded by the instructor/TA in charge of that particular experiment.

Late reports may be penalized — to be decided. Short extensions can be granted on a case-by-case basis — please discuss with us, as needed.

Resubmission

You have the option to **revise and resubmit up to TWO lab reports** for better scores, if you wish — specifically, the first of your reports submitted to Mike Nassir, and the first of your reports submitted to our TA. We recommend that you exercise this option, since draft-writing has substantial educational value.

- Your revisions should directly address the corrections & comments provided by the grader, and your revised report must be resubmitted *with the old report (with score sheet/comments) attached*.
- Any resubmission is due *one week* after the initial graded report is returned to you.

Collaboration with Partners

In this lab class, you are welcome to conduct experiments and to take data with a partner. Indeed, for some of our experiments, working with a partner makes data-taking much easier! Working in pairs or groups is common in science labs, and indeed is encouraged: teamwork can help you to make measurements and catch errors faster, and explaining something to another person is a great way to learn it yourself.

Guidelines

(1) If you perform an experiment with a lab partner, **note your partner's name in your lab notebook and final lab report**.

(2) **Occasionally switch roles so that each of you makes some of the measurements yourself.** We want each of you to gain the experience of using the equipment, and see for yourself the experiment's challenges and potential sources of error. While taking turns might introduce some inconsistency in your methods or measurements, that risk is outweighed by the educational value of you both gaining hands-on experience.

(3) **You should individually prepare all calculations, graphs, and error propagations**, even if the raw measurements or data you are using are identical to your partner's. Again, this is so each of you gains proficiency with applying statistical methods, using plotting software, etc. You are welcome (indeed, encouraged) to compare your final results with your partner for rough agreement.

(4) **Final lab reports should be written by you in your own words**. In the end, your submitted work should ***reflect your own understanding***. Any written passages or calculations that are simply copied or plagiarized from another student, or from any other uncited source, will be given **no credit**. Serious cases of plagiarism may be referred to the Office of Judicial Affairs for disciplinary review.

Lab Conduct & Safety

Our experiments include a few lasers, a microwave transmitter, some high-voltage power supplies, and some exposed circuitry. While these items are safe to use with the basic protections provided, they are NOT completely harmless! **Your instructor or TA will review relevant safety tips during your orientation for each experiment.** We invite you to ask questions.

Breakage

If any **equipment breaks or fails** during your experiment, please inform your instructor or TA promptly; do NOT leave it to be discovered as a rude surprise by the next person who tries to use it. We have only one apparatus for each experiment, so non-working equipment must be fixed promptly.

Food & Beverage

- Aromatic food or complete meals are NOT allowed in lab. Please consume them outside on the Watanabe lanais.
- Beverages and small snacks are permissible, but should be kept away from experimental apparatus and computers.
- Clean your hands before touching equipment or computers.
- All food & beverage containers should be discarded OUTSIDE of our lab room.

Attire

- Our lab room (Watanabe 419) is usually very cold, so we encourage you to **bring warm clothing when attending in person.**
- We do NOT require lab-specific attire (closed-toe shoes, lab coats, goggles) — our lab room has never contained glass, liquid mercury, or chemicals.