PHYSICS 274L — GENERAL PHYSICS III LAB

UH MANOA — Spring 2021 Semester

Course Information & Policies

Updated: 11 Feb 2021

Class Meetings
Monday & Wednesday 3:30–5:30pm
Weeks #1-7: Lectures in Watanabe 420 & via Zoom ("Here or There")
Weeks #8-16: Experiments in Watanabe 419 (days/times for sign-ups TBD)

Instructor
Mr. Michael Nassir
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Office: Watanabe Hall, Rm. 426, (808) 956-2922
Zoom "Office" Hours: *Week of Jan. 18 onward:* (Combined with PHYS 151 hours)
Mon. 9:30-11:30am & Fri. 3:00pm–5:00pm, or other times by appointment
Zoom Address: Meeting ID: **413-810-7726**
OR Use this link to launch Zoom & join meeting: https://hawaii.zoom.us/j/4138107726
Passcode: **EmcSquared**

T.A.
John Russell
E-mail: jwruss@hawaii.edu
Office Hours: Tue. 1:00-2:00pm & Thu. 1:00-2:00pm
Zoom Address: Meeting ID: **934-4398-5433**
Passcode: **kDD9yM**
OR Use this link with passcode embedded:
https://zoom.us/j/93443985433?pwd=Y3hRcmpBZlRTUk5XWTE5TVpUVEpUQT09

Required Materials

Bring the following items to every lab experiment:

- **Lab Notebook** — Any bound, or 3-ring, or electronic journal for recording measurements & observations.
- **Laptop Computer** — for data analysis following each experiment & for writing formal lab reports.
- **Scientific Calculator** with scientific (power-of-10) notation, trig functions, exponents and logarithms. (Graphing features NOT necessary.)

Textbooks

- Your PHYS 274 textbook or equivalent reference(s)
- Taylor, John R., *An Introduction to Error Analysis*, 2nd ed. (1997)
  paperback: ISBN 0-935702-75-X (UH Bookstore: ~$63 new, ~$48 used)

Online Resources

- Lab manuals & related materials — to be distributed via Google Drive folder
- Homework & report submission — via Laulima course site
- Experiment signups — via Google spreadsheet

Course Description

This course is intended to:

- Supplement the material of PHYS 274 (wave optics and modern physics) by illustrating some of its concepts with hands-on experiments.
- Supply you with more advanced understanding of the mathematical and statistical tools and experimental techniques used by experimental physicists, beyond the simple techniques used in introductory labs. You will increase your skill using these tools and techniques via repeated practice with a variety of different experiments.
- Develop your formal scientific-writing skills. This course also satisfies a Writing-Intensive focus requirement: minimum 4000 words (~16 double-spaced pages), although you should exceed that amount over the course of your lab reports.

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. Much of our theory and calculations require only algebra and trigonometry, but calculus will make frequent appearances, and you will need to use partial derivatives (Calculus III) when performing error analysis.

• A grade of "C" or better is required in all of the above completed courses.

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 (current topics: wave diffraction & interference, deBroglie wavelength, photoelectric effect, Hall effect, atomic spectroscopy, semiconductors, superconductivity).
- Apply common theoretical equations and principles of wave optics & modern physics appropriately to physical experiments.
- Gather experimental data, including initial estimation of, or calculation of, measurement errors on all values.
- Within the constraints of prescribed experiments, exercise intermediate-level scientific judgment during data-gathering process and data analysis: 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 final calculated values with correctly propagated uncertainties (using partial derivatives).
- When appropriate, draw statistically valid scientific conclusions from final results & uncertainties.
- Identify and employ important content and stylistic elements of scientific writing.
- Compose a formal report similar in length and style to a scientific "letter" (short journal article).

Tentative Course Schedule (Dates Subject to Change)

DATE	EVENT	TOPICS & READING: Taylor, *An Introduction to Error Analysis*, 2nd ed.
M Jan 11	Lecture	Intro to PHYS 274L Lab, Syllabus, Google Drive, Zoom
W Jan 13	Lecture	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
(M Jan 18)	HOLIDAY	
W Jan 20	Lecture	3.11, (3.3–3.10): Error Propagation (Calculating Uncertainty for a Derived Value)
M Jan 25	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 27	Lecture	Chap. 6 (all): Rejection of Outlying Data (Chavenet's Criterion) Chap. 7 (all): Weighted Averages
M Feb 1	Lecture	§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 3	Lecture	Chap. 8 (all): Least-Squares Fits, Linear Regression: Unweighted & Weighted Chap. 12 (all): Goodness-of-Fit (Chi-Squared Statistics)
Feb 8 & 10	Hands-on Lecture (bring laptop)	Python Matplotlib (via Colab): Intro to plotting graphs & least-squares fitting
(M Feb 15)	HOLIDAY	
Feb 17	Lecture	Scientific Writing: Content & Style, Journals & Paper Formats, ArXiv, Search Tools
Feb 22&24	Hands-on Lecture (bring laptop)	LaTeX (via Overleaf): Intro to typesetting reports/papers Keeping Lab Notebooks Sign-up for Lab Experiments
M Mar 1		Start of Lab Experiments
W May 12	Mid-Finals Week	Last Day to Submit Final Lab Reports

Final Grade Determination

Total points possible in the course:

320 points = 4 Lab Reports × 80 points each
80 points = 4 Prelab Questions × 20 points each
40 points = 4 Lab Notebooks × 10 points each
40 points = 4 Preliminary Results × 10 points each
approx. 220 points = Homework Assignments *(exact point total TBD)*
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 cutoffs may be lowered at the discretion of the instructor.

Experiments

You must complete the following FOUR experiments and reports during 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*

Order of Experiments

• You can sign up to complete your experiments in any order.
• EXCEPTION: Everyone should complete #2 (Bragg Diffraction) **before** attempting #5 (Electron Diffraction).
• If you are currently enrolled in PHYS 274 lecture, we suggest that you sign up to complete the experiments **roughly in the order above**, since it approximates the order that the topics are covered in lecture.

Pacing & Attendance

• You will have roughly 9 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:* If you are not scheduled to perform an experiment or discuss your work on a particular day, you do NOT need to attend lab on that day.

Partners

You may sign up **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 information 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 during one of our final lectures — you will be given a link to a Google spreadsheet for this purpose. If you wish to change your appointment, **please send an e-mail to the instructor/TA for that experiment.**

Prelab Questions

You are required to complete an 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. The goals of the Prelab Questions are to:

(1) ensure that you understand the fundamental physics and theory of the phenomenon to be studied; and
(2) ensure that you understand the main quantities to be measured and the ultimate goals/outcomes of the experiment.

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

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

PRELAB QUESTIONS will be scored on a scale of 20 points for each experiment.

Lab Notebooks

You are expected to keep a lab notebook, to be 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 permanent, narrative journal of your experiment, just as a traditional bound lab notebook does. You should expect to draw from the contents of your lab notebook while preparing your formal written lab reports.

Although we will not collect and 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 scored** — see below.

We encourage you to calculate some or all of your preliminary results promptly after taking 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 do so 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 will be scored on a scale of 10 points for each experiment:

~5 points: Pre-lab notes on theory, experimental goals, etc.

~5 points: Data & notes taken during experiment, plus any preliminary calculations/graphs

Preliminary Results

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 with handwritten calculations and informal printouts or graphs are 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 time and effort of writing your formal lab report.

PRELIM RESULTS will be scored on a scale of 10 points for each experiment.

Formal Lab Reports

We recommend that you commence work on your formal lab report *as soon as possible* after presenting your preliminary results — the sooner that you begin your writing, the better you will remember the details of your experiment.

• 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.

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

• Final reports must be typeset using LaTeX.
• Final plots & graphs may be prepared using matplotlib or other tools, but they must conform to standard expectations of clarity and completeness.

• Each final report will be scored on a scale of **80 points, 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. May 12, whichever is sooner, in PDF format. We will create a method for submission other than e-mail (possibly Google Drive folders, possibly other — TBD). Reports will be graded by the person in charge of that particular experiment: either Mike Nassir or our TA.

Late reports will be penalized (TBD). 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 TWO lab reports** for better scores, if you wish: 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

In this lab, you are welcome to conduct experiments and to take data with a partner. (Indeed, for certain 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.

However, if you are "working with" a classmate while making a measurement, there are a few guidelines to follow:
(1) You should take turns occasionally and each ***make some of the measurements yourself***, so that each of you gets the educational value and experience of using the equipment and "seeing for yourself."
(2) All final lab reports should be written by you ***in your own words***, even if the raw measurements or data you are using are identical to your partner's. If you do perform the experiment with a lab partner, ***make a note in your lab report*** of the name of your partner for that particular experiment.

In the end, your submitted work should reflect ***your own understanding***. Any 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 use 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.

If any **equipment breaks or fails** during your experiment, please inform your instructor or TA; 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.

Our classroom (Watanabe 420) and our lab room (Watanabe 419) are both usually quite chilly, 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 has never contained glass, liquid mercury, or chemicals.