2014

331-01/02 Modern Physics I Lab

Jonathan Morris

Modern Physics I - Lab

PHY 331 Fall 2014

T (section 01) W (section 02)

1:00pm-2:50pm LND 3 (basement)

Instructor: Dr. Jonathan Morris
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Office Hours: T 3pm-4.30pm, F 11am-12noon
If my office door is open then you're welcome to see if I'm free to chat.

Course Description: In this course you will learn lab techniques that will assist you in further understanding the material covered in Modern Physics I, PHYS 330. This is a one credit hour lab course and is separate from the PHYS 330 lecture with a separate grade. The topics covered in lab predominately complement the lecture, but a few topics are independent material.

Course Objectives: After completing this course, students should:

- Display intellectual curiosity about and intuition into the processes of the physical universe, with emphasis on discoveries post 1895 to present.
- Display critical thinking skills, especially those skills required for the analysis and synthesis of knowledge pertaining to the physical universe, with emphasis on discoveries post 1895 to present.
- Demonstrate technical proficiency in the principles and techniques of theoretical and experimental modern physics.
- Have a working knowledge of how to manipulate and interpret complex sets of data with the use of computer software such as Microsoft Excel.
- Display effective oral and written communication skills especially with regards to communicating scientific theories and models, data, results, outcomes, and proposals.
- Have a greater appreciation for the rigor, meticulousness, and applications of the discussed scientific material.
- Experience the satisfaction of realizing that physics is everywhere in our daily lives.

Syllabus layout
This syllabus contains information that will help you prepare for lab, help you in lab, and help you prepare the material that is going to be graded. It's in your interest to read it.

COURSE SCHEDULE

Week	2014 Date	Lab (Group completing the lab that week)
1	8/26-27	Introduction and muon data collection
2💻	9/2-3	Analysis of muon data
3✂	9/9-10	Lab report for the muon experiment due
		Handheld spectrometer – remember to bring your cut out pieces!
4☺	9/16-17	Spectrometer Film (A) ǀ e/m (B) ǀ Photoelectric (C)
5☺	9/23-24	Spectrometer Film (B) ǀ e/m (C) ǀ Photoelectric (A)
6☺	9/29-30	Spectrometer Film (C) ǀ e/m (A) ǀ Photoelectric (B)
7	10/7-8	Lab report for the e/m experiment due 10/8 in PHYS330 class
		Fall break - no labs
8💻	10/14-15	CITI online course certificate due
		Analysis of spectrometer films – bring your films!
9	10/21-22	Lab report for the Spectrometer Film experiment due
		Exam 1 (bring your lab books!)
10	10/28-29	Electron diffraction (A) ǀ X-ray diffraction (B) ǀ Hydrogen-Deuterium (C)
11	11/4-5	Electron diffraction (B) ǀ X-ray diffraction (C) ǀ Hydrogen-Deuterium (A)
12	11/11-12	Electron diffraction (C) ǀ X-ray diffraction (A) ǀ Hydrogen-Deuterium (B)
13💻	11/18-19	Lab report for hydrogen-deuterium experiment due
		Diffraction analysis
14	11/25-26	Formal lab report / Scientific paper on photoelectric effect due 11/26 in PHYS330
		Thanksgiving week – no labs
15	12/2-3	Lab report for electron and x-ray diffraction due
		Exam 2 (bring your lab books!)
16💻	12/9-10	Presentations

Symbol meaning

💻 If you have a laptop with Excel please bring it to carry out your own analysis.
✂ Remember to bring your cut out pieces! (This will make sense closer to the lab.)
☺ For those students doing the spectrometer film lab; please wear clothes that you do not care about getting damaged (i.e. discolored, potential holes). Some of the chemicals used to develop the film can damage cloth. Lab coats and protective gloves will be provided and must be worn. You should not leave on this day feeling ☹ because your clothes are damaged.

We will stick to this schedule as best as we can. If we have unavoidable changes to schedule (e.g. lab cancellation due to snow day) then a new schedule will be distributed as soon as possible.

ASSESSMENT INFORMATION (see below for information on each type of assessment)

Pre-Lab Assignment / Lab notebook / Lab summary	45%
Exams (10% each)	20%
Formal Lab Report / Scientific Paper	15%
Presentations	10%
Responsible Conduct of Research (CITI Completion)	10%

General rules

- Writing **must** be clear and legible. If the work cannot be read then it cannot be graded!
- Numbers between -1 and +1 **must** have a leading zero! E.g. -0.4 and not -.4, or 0.67 not .67.
- Numbers **must** be followed by units where applicable. A length of 12.2 tells us nothing. Include units!

Pre-Lab Assignments

Pre-lab assignments will be completed in your notebook. You must turn in the original copy (not the carbon copy) at the beginning of each lab; otherwise the grade for that pre-lab is a **zero** and you will not be prepared for class. Directions/guidance for the pre-labs will be available on Canvas for each lab. Students are responsible for coming to lab prepared with all necessary material.

Lab notebook/summaries

The notes that you make prior to the experiment (independent of pre-lab assignment), during the experiment, after the experiment (analysis) and the lab report make up the amount of work that you will tear off the original pages from your lab book and hand in for grading on the deadline specified on the schedule. For more information please see the relevant pages of this document and general rules at the top of this page.

Scientific paper

Please see the relevant pages of this document and general rules at the top of this page.

Exams

The exams will test your note taking ability, understanding of the science, ability to take measurements and data interpretation skills. You must bring your lab book with you to both exams. Your answers will be written in your lab book! You will be given a colored pen to write with and to circle answers in your lab book. Only information written or circled in colored pen will be graded.

Presentations

Each student will present one experiment of their choosing (pick one that you found most interesting!). The presentation will consist of a 4 minutes long talk in front of the class and will have 1 minute for a question. A projector will be available for projecting images from a computer screen (e.g. Powerpoint). You are welcome to come to see me prior to the presentations to talk about what you want to present.

Responsible conduct of research / CITI completion
Please see relevant pages of this document.

Late work
All lab reports turned in late will be penalized **1/3 of a letter grade** for each class day late (i.e. from B to B- for each day late). Following departmental policy, lab reports turned in 2 weeks after the due date will be awarded zero unless prior arrangements are made.

Grading scale:

	87-89 B+	77-79 C+	67-69 D+	Below 60 F
93-100 A	83-86 B	73-76 C	60-66 D	
90-92 A-	80-82 B-	70-72 C-		

PRE-LAB ASSIGNMENT / LAB NOTEBOOK / LAB SUMMARY 45%

Content

There will be four types of entries in your notebooks:

- The first is the pre-lab assignment which you are to complete before class begins and instructions for these will be given out before the lab. Feel free to make extra notes prior to the experiment.
- The second type consists of your notes on the short presentations which I will occasionally give on how a given piece of equipment works or other information pertinent to the lab.
- The third is the experimental notes you make as you work through the given experiments.
- The forth is the data analysis which you will perform after the lab is completed.
- The fifth is the experiment summary and conclusion. What did your experiment and analysis determine?

While it is important to keep a good, organized record of everything you do in your notebooks, your lab notebook grade will be determined primarily on the pre-lab assignment, pre-lab preparation (separate to pre-lab assignment), experimental notes, and summary/data analysis.

Your experimental notes should follow a logical sequence. Your description of an experiment should include the following: a title; a statement of purpose; a theory section in which the working equation is derived, a description of the apparatus, a section outlining the procedure, a data and analysis section, and a conclusion.

Ideally, the derivation of the working equation (what you ultimately use to determine a given quantity) presented in the theory section should be your own, starting from first principles to show that you understand the physics of the situation and written before you come to lab. Use caution if you pattern your theoretical analysis on the manufacturer's write-ups or other cookbook discussions on file. They are sometimes clumsy, omit steps and otherwise follow an approach different from what you learned in your other physics courses. It is better to think of tackling the problem as a homework assignment in the appropriate course. Copying a derivation from a book is better than no derivation at all, but it would be better to look at several sources and then do your own. If possible, start out with as realistic a model as possible, then make the necessary approximations; that way you can estimate the influence of the approximations on your results.

The description of the experimental set-up should include two parts: the overall set-up and the specific equipment. For the overall set-up, the description could be a plan view, circuit diagram, or schematic of the various components in the apparatus. It should be detailed enough to allow someone else to reproduce your work. Several sketches/pictures may be necessary, such as a general view plus several details. If algebraic symbols are to be used, they should be indicated on the diagram as well as listed in a table. For the specific equipment you use, it is not a bad idea to include the company name and model number the first time it is referred to.

The data and analysis section should include your raw data in tabular format (if the data table would be too large then you can give information about where someone could access the datafile), as well as graphs, derivations and error analysis. As soon as you get some results graph them on the spot and make a rough calculation to see if your results are reasonable. Many people have spent hours collecting beautiful lists of worthless numbers because they omitted this step. Make sure things are going right before you continue too far.

The conclusion should briefly summarize your work, as well as restate your final numerical values of the desired quantity. You should also determine the error if at all possible and how the experiment could be improved.

General Lab Book Rules

Entries - All entries must be dated on each page, written in ink and in serial order, i.e. no blanks are to be left for filling in later. Any additional loose information sheets, such as ideas jotted down on separate paper at odd times, computer graphs or graphs on millimeter paper, occasional Xerox copies of pertinent tables or figures, etc., must be permanently affixed, preferably with glue or transparent tape. No erasures, white-outs or scribble-outs are allowed. Corrections are done by putting a line through the erroneous entry and writing the correct entry above or to the side. Large mistakes, i.e. many lines or an incorrect drawing, can be marked by an "X" across the whole thing, with a dated comment on why it is X'd out.

Table of Contents - The first few pages of the notebook should be reserved for a table of contents. At the very least it should contain the starting page number of each experiment. Greater detail would be useful in looking up material about which you or the instructor have questions. Hint: you'll find that this will help you in exams!

Units - All dimensioned quantities should have the correct units wherever they are used. If prefixes are used please make sure that they are correct.

Uncertainties – Every measurement that anyone makes will have an uncertainty. You cannot measure a quantity exactly and so you must report the quantity and uncertainty. Having an uncertainty on a value does not mean that you made a mistake in the measurement it is simply a way of providing limits to your quantity and it is good experimental practice to report them.

Uncertainties are to be written in the form x= 1.24 ± 0.01 cm. The uncertainty should have only one significant figure and the quantity should be reported to as many decimal places as the uncertainty. Reporting a value as $(1.4235\pm0.021)\text{x}10^7$ m/s is incorrect, this quantity should be written as $(1.42\pm0.02)\text{x}10^7$ m/s. This is because the uncertainty tells you that you cannot determine the quantity to better precesion than $0.02\text{x}10^7$ m/s. If the uncertainty is $0.021\text{x}10^7$ m/s you could ask "what does the 1 mean in this number?"

Not only should a numerical value of the uncertainty be given but also a justification for that value; e.g. "smallest division is 0.1 mm and I can interpolate to 1/4 division so the error is 0.03 mm." This brings us to the type of uncertainties.

Systematic Error: constant error throughout a set of measurements, e.g. measuring tape was broken at 2.4 cm then a 31 cm long piece of wood will measure 33.4 cm, or your bathroom scales read 0.3 kg before you stand on them so your measurement will have an extra 0.3 kg (watch for this at airports as the airline may charge you for extra luggage when in reality their scales are not calibrated!). [Section 2.2, Squires] A more subtle systematic error could be an error that changes with time due to a drift in calibration.
Parallax Error*:* If there is a gap between the scales and the object then you'll get an error due to your line of sight not being perpendicular to the scale, this is parallax error. [Section 6.2, Squires]
Random Error: When you repeat a measurement you won't get exactly the same result. Random error occurs when repeated measurements vary around the mean value without a pattern. Random errors can be estimated by the spread in repeated measurements.
Discrete Readings: If you are reading a digital display then you can read the digital display up to an accuracy of ±0.5 of the smallest digit, e.g. a reading of 126 would be reported as 126±0.5 or 2.3 would be 2.3±0.05.

An *accurate* measurement is one that is free from systematic error or parallax error.
A *precise* measurement is one where the random error is small.

Manipulation of uncertainties

Typically the value that you're interested in is not the value that you measure. You need to do some data analysis before reaching your final answer. During this analysis you will add, subtract, multiply, divide, take the log, take the exponent, etc. and each time you do something the uncertainty on your value will change. When your value C is a function of A and B then the uncertainty on C is given by the table on the following page.

Relationship between C, A and B	Relation between the uncertainties
$C = mA$	$\Delta C = m\Delta A$
$C = A + B$ $C = A - B$	$\Delta C = \sqrt{\Delta A^2 + \Delta B^2}$
$C = AB$ $C = \frac{A}{B}$	$\frac{\Delta C}{C} = \sqrt{\left(\frac{\Delta A}{A}\right)^2 + \left(\frac{\Delta B}{B}\right)^2}$
$C = nA$	$\frac{\Delta C}{C} = \frac{\Delta A}{A}$ or $\Delta C = n\Delta A$
$C = \ln A$	$\Delta C = \frac{\Delta A}{A}$
$C = e^A$	$\frac{\Delta C}{C} = \Delta A$

See chapter 3 in Taylor and table 4.1 in Squires

For more information check out "*An Introduction to Error Analysis: The study of uncertainties in physical measurements*" by J.R. Taylor (University Science Books, 1997), "*Practical Physics*" by G.L. Squires (Cambridge University Press, 2001), "*Statistics: A guide to the use of statistical methods in the physical sciences*" by R.J. Barlow (Wiley, 1999).

Pre-Lab Preparation

When beginning a new experiment, pre-lab preparation may involve reading a handout or sections from the text-book. Subsequently, it means "digesting" what you have read and planning what to do next. In your notebook, record the references you read (page numbers, etc.) and outline the basic theory behind the experiment and make a rough outline of the procedures you will follow. Diagrams are usually helpful for describing procedure and/or theory. If the experiment involves an apparatus with which you are not familiar, attempt to describe its operating characteristics as best you understand them.

Pre-class preparation is one of the most important parts of the experiment. In the real-world of science, preparation and planning for an experiment take a large share of the time. Building and debugging the apparatus, data analysis, and writing the results take much of the rest of the time. Actual data taking usually occupies very little of the time. This is why students are expected to devote a considerable amount of time to work done outside the lab.

FORMAL LAB REPORT / SCIENTIFIC PAPER 15%

In your future career you are likely to be in the position of having to write reports for bosses, colleagues and/or collaborators which describes a procedure, analysis, and conclusions or you may be in research and have to write a scientific paper.

PHYS331 lab reports provide a way for you to learn, improve and develop your report writing skills. Reports have different parts which provide different information. The following pages will provide an idea of what to include in your reports.

The key thing to remember when writing a report is that you cannot assume and must not assume that the reader knows what you did or why you did it! It is your responsibility to describe and explain to the reader why, what and how you did your experiment. You know that Dr. Morris knows what you did, why you did it and how you did it, but that is not the point. Your work will be graded based on how someone would be able to read your work and come to an understanding about what you were trying to do, how you did it and what you found out. The English used should be clear and straight to the point – do not use fluffy language, i.e. do not write things like "*the beautiful irradiant glow from the pristine white curvaceous tube through which electrons flit through the nothingness of vacuum delicately belies the truth of the physics within*". If you email me with a similar fluffy description of one of these experiments you will earn extra credit of 5 points towards your next exam (it cannot be one submitted by someone else).

The formal lab report / scientific paper should contain the following sections:

Title: The title should identify the paper typically in no more than 10 words but that is not a strict limit. The title should inform the reader about what you did, what you concluded or what you hoped to find out.

Abstract: The abstract is a one paragraph (definitely no more than two paragraph) summary of what you were investigating, brief description of the method, summary of the results and conclusions. The abstract serves two purposes: it provides a brief summary for those who have a passing interested in the field to let them decide whether your paper contains anything useful/interesting to them, and secondly it serves the people who are interested in your field because it condenses your work into a short summary. Outside of science, bosses may read an abstract but no further whereas colleagues may read the whole report.

Introduction: The introduction should lay out (i) the physical problem under investigation and why it is interesting and (ii) how the experiment will play a part in this problem. This section should include some background information and theory (any equations that have been derived should be mentioned along with the necessary variables). After reading this section the reader should be ready to hear about the experiment and the methods. Diagrams and figures that condense the physics into an easy to understand visual aid are very useful in this section.

Methods: Describe the equipment that you used and what you did. Do not produce a list of instructions. This section, as with every section, should be written in prose. When equipment is initially mentioned then you should mention the make and model number. Your methods should include enough information that someone familiar with the equipment could repeat your experiment and check your results but be careful not to use phrases that only experts in the field will understand. You can add additional information so that a novice could perform the experiment but be careful not to bore everyone with minute detail. Diagrams and other figures are useful in this section.

Results (aka "Data and Analysis"): In a scientific paper you do not publish long tables of data because this will detract from the paper and may confuse people. Instead you try to produce one or more graph(s)/table(s) that condense all of that information into an easily understandable form. Not all data needs to be in this section but the data that you show should be representative! That means that it should be a faithful and honest representation of the measurements. To some of you this may sound like you are only publishing the best data and are hiding something – indeed some people may do this – you'll be glad to hear that some modern journals are moving towards a completely open policy of including all data on their websites so that people can check published results. Any analysis that you carried out to get to this stage should be described – did you use a particular model to understand your data, did you fit your data with a particular line, did your analysis produce any further results, etc.? Any equations that have been used should be included in the methods or results sections along with descriptions of these equations and where they came from.

Discussion / Conclusion: Different journals call this section either discussion or conclusions but they are the same thing. This section should include comparison with (i) relevant theories and (ii) other published measurements, along with a comparison of your expected results and the actual results as this will help describe the state of the problem in light of your results.

The information about what each section contains is based on excellent description given by Squires ["Practical Physics" by G.L. Squires, Cambridge University Press 2001].

Graphs: In most journals the graphs do not include a title above the graph but **must** include labels for the axes with units. The description of the graph is included in the caption of the graph and this replaces the title. If more than one data set is included on the same plot then you must include a legend to label each dataset otherwise this is really confusing. Make sure that your graph is of a good enough resolution that you can read the graph.

Tables: All columns should include a title and units if necessary. The table should have a descriptive caption that is easily cited. For example:

Object	Volume (m3)	Mass (kg)	Density (kg/m^3)
Blah	1	1000	1000
Thingy-me-bob	123	1	8.1×10^{-3}

Table 1. Density, volume and mass of blah and thingy-me-bob.

Figures / Diagrams: All figures and diagrams should include a descriptive caption.

References / Bibliography: All references that you used should be listed at the end of the report.

Format: You will be provided with instructions from the journal *Proceedings of the National Academy of Science of the United States of America*, PNAS for short, for you to follow. These instructions guide authors, such as you, through the expected formatting protocol. If the author does not follow these instructions then their paper will be rejected by the editors before it is read by anyone! Some editors may allow you a chance to edit your manuscript but others will not.

RESPONSIBLE CONDUCT IN RESEARCH / CITI 10%

Why do I need to do this? This online training course provides insight into the life of a scientist and provides training that is required before you can work on research projects funded by certain grants. You'll find that future training courses follow a similar pattern to this one.

These training courses take time!!! So start early. Come to see me if you have questions.

1. Log into www.citiprogram.org

2. Register with CITI . When asked if requesting CME/CEU credits answer NO.

3. Under Select Curriculum- Xavier University-Cincinnati, Ohio the following subheadings will appear.

    1. Human Subjects
       Select: Students conducting no more than minimal risk research.
    2. If you want to take Good Clinical Practice (GCP)
       Select: Not at this time.
    3. Responsible Conduct of Research Course Selections
       Select Physical Science Responsible Conduct of Research Course.

4. When taken to a page listing MY COURSES at least two will be listed
    Physical Science Responsible Conduct of Research, RCR
    Students – Class Projects, Basic Course.
   You may take both of these course or any other listed previously; however, what we are asking you minimally to do is to complete the **Physical Science Responsible Conduct of Research Course by October 14th or 15th, 2014. Please hand in the print out of the certificate / completion page.**

The Required Modules are
- Introduction to the Responsible Conduct of Research
- Research Misconduct
- Data Acquisition, Management, Sharing and Ownership
- Publication Practices and Responsible Authorship
- Peer Review
- Mentor and Trainee Responsibilities
- Using Animal Subjects in Research
- Conflicts of Interest and Commitment
- Collaborative Research
- Human Subjects
- The CITI RCR Course Completion Page

ETIQUETTE AND COURSE REQUIREMENTS

General Lab Rules

- Do not eat, drink, or smoke in any laboratory.
  There could be chemicals and/or radioactive materials in the room and you do not want to contaminate your food or drink. Smoking is prohibited inside any building at any time.
- Report any spill of liquids/chemicals immediately to the instructor and move away from the spill.
- Wear safety glasses where appropriate and/or instructed.
  There are special UV absorbing glasses in the spectroscopy laboratory.
- Be cautious of high voltages!
  These are required for the photomultiplier tubes, for some of the discharge tubes, and for the x-ray tubes.
- If you accidently expose a box of film notify the instructor immediately.
- Do not attempt to operate any equipment without prior instruction on its use.
- Do not attempt to repair equipment without prior consultation with an instructor.
- Observe radiation hazard warning signs in the x-ray laboratory.

Remember that your safety and the safety of other people is the number one priority of *any* laboratory. Do not put yourself or anyone else at risk. If you see someone doing something stupid, or something that could put themselves or others at risk, you have the right to tell them to stop. Tell them to stop, inform the instructor, and explain to the other person why you think it was a risk.

Any student who puts the safety of themselves or other students at risk will receive zero for that lab. Repeat offenses will lead to a fail of the class.

Lab books

You will be provided with a lab book. You **must** bring this to every lab and each PHYS331 exam. The lab book will have perforated carbon copy paper so that you can hand in one copy of your work and keep another copy. Everything (except your formal lab report and presentation) will be included in your lab book! Its contents make up a possible **65%** of the course! Don't lose it!

Writing must be easy to read so that Dr. Morris can read your work. If it is not legible then you risk getting zero for the work.

Attendance and Makeup labs

Attendance is mandatory! You **must** inform the instructor of any missed labs prior to missing a lab with a valid reason (e.g. interview, bereavement, university trip, etc.). If possible then you will be offered a time to make up the lab before the end of the semester. If you do complete a lab during a makeup period then you will be expected to complete all work necessary for that lab.

Courtesy: Please leave your cell phones, i-Pods, etc. turned off during class unless specifically asked to have them out during class.