

# PHYS 0520 Syllabus (Fall 2016)

August 22, 2016

## Introduction

### Instructors

Lectures are not the primary component of this course. The instructor:

Prof. Brian D'Urso  
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218 Allen Hall

will help conduct the experiments and provide advice on analysis. When appropriate, occasional lectures will be given. Guidance in the lab will also be provided by:

Prof. Istvan Danko  
izdanko@pitt.edu  
412-624-9030  
329 Old Engineering Hall (OEH)

who is in charge of equipment for this lab. He is responsible for all advanced teaching labs in the department of Physics and Astronomy.

### Scope

This is a lab course normally taken by sophomore honors students in either physics or engineering physics programs. It carries 3 credits. The subjects both look back to topics from the introductory physics sequence and look forward to courses taken later in the undergraduate experience. The only prerequisite is the introductory physics sequence, either 0174-0175 (calculus based) or 0475-0476 (honors). Previous 'experimental' experience of many types is useful. The main purpose of the course is to get you thinking like a physicist in the lab.

### Textbook

There is unfortunately no complete textbook for all the material in this course, but we require the following text for data analysis:

- Measurements and their Uncertainties, Ifan G. Hughes and Thomas P. A. Hase

The instructor can give advice on background material at the appropriate level for many topics. The handouts (all in CourseWeb) are mostly self-contained but definitely not complete. Some reading from other sources will be required.

## **Attendance**

Official class time is Tuesday and Thursday, 1:00-3:50 p.m. It is dangerous to miss lab sessions because of the work required to complete labs. The instructor will generally only be available during regular class times; other students can also help with problems. Sometimes, there are conflicts with religious holidays; in the past, these students have to make extra effort but it always worked out. The lab will be open Mon-Fri roughly 8:30 a.m.-5:00 p.m. and every student is welcome to use the facilities outside class times.

## **Grades**

Your grade for the course will be based on the work on the experiments (80%) and on the final project (20%). Each experiment will provide a grade based on the notebook. The course is small and the emphasis is on your work, so the instructor will know each student well. Approximately 6 labs (2 required, 4 optional) will be required for the course. There will be no exams. Failure to hand in a notebook for a lab on time without prior permission will drop your lab grade by one letter grade (10%), with an additional letter grade (10%) drop for each week it is late.

## **Writing Option**

This course can be used to satisfy your Writing Option requirement. Since you already have to do some writing for the course, this is a good option. That course requires 3 formal documents. They will be significantly expanded versions of your notebook. This course has a separate lecture; the first lecture will be TBD.

## **Lab Experiments**

You must submit an ordered list of 7 experiments you would like to complete, including the name of a partner when recommended, by the end of the second week of classes. We will return a tentative schedule of your labs to you by the end of the third week of classes. Keep in mind that you schedule may have to be modified as the semester progresses due to equipment problems, scheduling changes, etc.

The time required for each experiment is typically 4 lab sessions, but some may require somewhat more or less. The balance will be between finishing in reasonable time and a deep enough understanding of the material. Any experiment taking more than 2 weeks can be a problem. Your lab notebook with the experiment lab report will be due by the end of the second lab session following the scheduled completion day of each experiment.

## **Surveys**

With your help, I am hoping to improve this course and the available experiments. For that purpose, I will give you a survey at the beginning and end of the course, as well as a few questions to answer with each lab experiment. Please answer the surveys thoughtfully, as your feedback will help improve the course.

## **Disability Services**

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, [drsrecep@pitt.edu](mailto:drsrecep@pitt.edu), (412) 228-5347 for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.

## **Academic Integrity**

Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam, including dictionaries and programmable calculators.

## Lab Reports

You will buy two (2) standard experimental notebooks (“Computation Book” types are recommended) in which the complete dated record of procedures, events, original data, calculations and results of every experiment is to be kept. Typically, you will be writing in one notebook while a lab report in the other is being graded. Progress on each experiment is documented in the notebook. You bring the notebook every day to class and regularly write down your measurements and comments. The comments include thoughts on how the measurement is done and what it means. The goal is to write enough that a reader, e.g. the instructor, can follow the key steps and understand the problems encountered along with their solution. A typical lab session should produce a few pages of notes. Your lab notebook with the experiment lab report will be due by the end of the second lab session following the scheduled completion day of each experiment. Although you may work in pairs and are urged to collaborate in all aspects of carrying out the experiments and analysis, each student must keep a complete, dated record of each experiment and its analysis.

Keeping a useful and accurate lab notebook is a difficult but most useful skill to acquire. Evaluating a lab notebook is difficult and time-consuming. To improve the evaluation process so that it provides most useful feedback to students and to streamline the evaluation process, I have developed the following rubric.

1. Motivation (10%)
2. Figures (15%)
3. Diary (15%)
4. Data (15%)
5. Analysis (15%)
6. Summary (10%)
7. Going Above and Beyond (20%)

### Motivation

What is the purpose of the experiment? What physical principles are being explored or illustrated? What will be the difficult parts of the experiment? What are the main goals? A good Motivation section should answer these questions and lay the intellectual groundwork for the experiment to follow. This often includes a derivation of essential formulas or relations. You should define the symbols you use, often including a sketch illustrating the definitions.

### Figures

There are two kinds of figures in a lab notebook. **Sketches** clarify a definition or illustrate a piece of equipment or how a measurement was performed. These should be schematic, focusing on the essential working principles involved, not on the cosmetic appearance of apparatus. **Graphs** display data in a visual format that should permit trends to be seen and a comparison between theory and data to be made. Graphs (including computer-generated graphs) should have proper

labels and units, and data points typically should have error bars. Do not draw lines between data points. Lines or curves going through the data points should be labeled.

## Diary

The lab notebook should be detailed enough to be clear to you or someone else who wishes to duplicate your work at a later time. You must write a sufficient narrative as the experiment proceeds so that, years later, you could reproduce the results you obtained. Notes, tables, and graphs should be neat and compact, leaving as little empty space in the lab notebook as is compatible with clarity and the logic of organization. There should be no loose sheets or graphs in your notebook.

All procedures obtained from other sources (e.g., lab manuals or lab protocols) should be included as a permanent part of your notebook the first time they are used. It is OK to cross-reference previous experiments, but you should specify any changes or differences in the experiments. Do not count on your memory – write all observations in your notebook while you are doing the experiment. **Do not underestimate how rapidly you forget experimental details.** How was the equipment wired up? Does the distance recorded in my notebook include the radius of the ball? Is the “width” parameter in my book the distance between the edges of the slits or between their centers? Sketches and careful definition of quantities are essential to make the diary clear. When recording data, think carefully about the quantities you will need, and leave space to add more columns when you realize what you’re missing.

Make your diary entries in **chronological order** on the right-hand page. *Do not leave gaps to be filled in later.* Use the facing left-hand page to add computer plots, error analysis, or other comments on the diary entries on the right-hand page. Date these supplementary entries. If you make a mistake, *cross out the entry*, do not use “white-out” or erasers.

## Data

Record your data neatly in tables, having carefully defined the quantities you record. The grid-lined paper in the Computation Book is convenient for formatting tabulations, and for guiding line drawings and making rough plots. High resolution plots, photos, and Xerox copies of shared data should be glued or taped in place. Consider as you take and record data whether it is internally consistent, whether it agrees with the trends you expect; note any suspicious data points or events. Make a quick plot of the data if necessary to monitor the trend. **Repeat every measurement at least three times in as independent a manner as possible in order to establish a statistical basis for estimating random error and to reduce the chance of blunders.** Many experiments will require you to transfer your data to a computer and store them in files on disk. Obviously, it is not practical in these cases to print out all your data and paste them into your notebook. However, we expect to see in your lab notebook representative plots or tables. In addition, we expect a clear description and summary of the data files so that when you return to them days or weeks later, you are able to identify particular files with procedures you carried out in the lab.

## Analysis

Here is the real guts of the report, where you tie together the theory and the data. Use your raw data to compute quantities you can compare to theory, including the uncertainties of the experimentally

observed quantities and the values you calculate from them. Prepare a graph or graphs to illustrate the relationships you observed, and their agreement with theoretical predictions. Be sure to include error bars on plots.

Analyze data in the lab in a preliminary way as you go along to check for reasonableness. If you are making a series of measurements of one quantity as you vary another, plot the results as you go along so that you can see the trend, catch blunders, and judge where you may need more or less data. If you get through all the manipulations and preliminary analysis of an experiment in less than the allotted time, take the opportunity to perfect part or all of the experiment so as to obtain the best possible data set.

Discuss the meaning of your data, including points of agreement and disagreement between your data and theory. Consider the measurement or measurements that limit the accuracy of your results and possible extensions to the experiment. Avoid the use of percentage error as a method of quantifying disagreement with theory or expected result. Instead, quote results with uncertainties, and quantify the agreement in terms of probabilities or confidence intervals.

## Summary

Summarize your report on no more than 1 page, describing succinctly what you did, what you observed (by referring to sketches, tables, and graphs prepared earlier in your book), and what it means. Avoid excessive use of “I” and “We”.

## Going Above and Beyond

If you do everything in the lab handouts exactly as written, you will get a maximum of 80% credit for the lab. The remaining 20% is given for experiments or analysis that goes above and beyond what is written in the handouts. This could be an idea that you have for getting more data, it could be getting higher quality data than required, or it could be trying an alternative analysis method. Your “above and beyond” doesn’t always have to succeed to get credit, but you should explain what you tried to do, why you thought it might work, and what the result was.

## Survey Questions

Write an approximately one paragraph response to each of the following questions:

1. What about the lab experiment did you find most useful for your learning?
2. What aspects of the lab experiment were most challenging?
3. What about the lab experiment could be improved?

## Final Project

In addition to lab notebooks, one final lab project report should also be submitted on any experiment you choose, but **you must make an original contribution to improve or extend the experiment or analysis**. The expectation is that this original contribution will be more significant than the “Above and Beyond” component of a typical experiment. The simplest approach will be to improve one of the experiments that you completed earlier in the semester, but new experiments or even experiments from outside the instructional lab will be considered. Working in pairs for the final project is recommended, although each team member must turn in their own independently-written report. In any case, you will have to get the approval of the instructor before you begin work.

The final project report will be graded on the basis of clarity (explain what physics underlying the experiment, what apparatus you used, what did you measure, how did you analyze, what did you find), novelty, and correctness of analysis. Each report should have the following sections:

- I. Introduction (15% weight): about 2 pages, which explain the physics behind the experiment. Important formulas should be given, and the essential physics explained.
- II. Experimental Methods (35% weight): 2-4 pages, details of all the apparatuses and materials used in the experiment. Neat labeled sketches, either hand-drawn or computer-aided, are a must. How were the measurements carried out, and how was the data analyzed.
- III. Results and analysis (35% weight): 2-4 pages, Summary of all the data acquired in the experiment and their analysis (including tables, graphs, images, etc.).
- IV. Discussion and conclusions: about 1 page, Summary of the main results of the experiment, and the conclusions from these results.
- V. Bibliography/References.
- VI. Style and English plus last 2 sections: 15% weight.

Reports should be in PDF format (only!) and should be printed and handed in and emailed to the instructor (dursobr@pitt.edu). Note that converting from Word to PDF sometimes results in missing symbols and messy equations, so you must check your PDF before uploading. I recommend learning  $\text{\LaTeX}$  for preparing your lab reports, and can provide additional resources for this if requested.

## Guidelines for “Writing Option” (PHYS 1661)

This course can be used to satisfy your Writing Option requirement, which requires 3 formal documents. They will be significantly expanded versions of your notebook. This course has a separate lecture. If you take the Writing Option, you must submit two additional “formal reports” on two different labs that you have done (the final report from PHYS 0520 also counts as the third report for PHYS 1661). Deadlines for submission will be announced. Even if you take the writing option, you still have to submit your lab notebooks and a regular final lab report as per the requirements for all the other students.

The formal reports are expected to be significantly better than the ordinary lab reports in style of writing, completeness, and content. The format to be followed is roughly that required for manuscripts submitted to scientific journals. There are many conventions and formal rules that must be observed when submitting papers for publication and you may find some of them tedious and time consuming, but editors are merciless in returning poor manuscripts. Your instructor will play the role of the editor in this course and will suggest improvements. The first draft of your paper will be returned to you with comments, and after a discussion with your instructor, you will submit the second and final draft.

Please, write your paper on a computer, and turn in a printed copy and a pdf by email (dursobr@pitt.edu). Note that converting from Word to PDF sometimes results in missing symbols and messy equations, so you must check your PDF before sending. I recommend learning  $\text{\LaTeX}$  for preparing your lab reports, and can provide additional resources for this if requested. Use double line spacing. Insert all figures and tables (with captions) at the end of the text (one figure per page), after the list of references. Use the equation editor in Word for equations. In  $\text{\LaTeX}$ , this is much easier. Write the text in a single column. Your paper will be returned to you with comments.

The style of writing should be clear and concise. Do not say the same thing over and over in different ways. Avoid excessive use of the passive voice. It is acceptable to write “We varied distance  $x \dots$ ” rather than “The distance  $x$  was varied  $\dots$ ”. Do not copy or rewrite chapters of textbooks; you are not likely to improve on the original. There are no bonus points for “overweight” reports. More likely you will be asked to get rid of the excess bulk through strenuous exercise. Even though this is writing exercise, the physics should be correct and should be explained correctly.

If you have never read a paper in a scientific journal, go the library and find a recent issue of “American Journal of Physics”. Pick an article that you find interesting, read it carefully and pay attention to style of writing and format of presentation. Do not try to duplicate the print layout of the published article (like two columns, inserted figures etc). This is a writing exercise, not a printing exercise.

Your report should have a title. Use the name of the assignment or pick your own title. The report should be preceded by an “Abstract”. The abstract states in a few concise sentences (less than about 200 words) what you have done and what you concluded from your work.

The body of the report typically contains several sections:

### I. Introduction

An introduction gives the reader a preview and a “road map” of your report. It should inform the reader about the background of your work, the scope of your investigations, and point to the sections where specific details are to be found. The introduction should briefly present the basic theory of your experiment and give the equations that you used. Equations must



be incorporated into the text, i.e., they must be part of a grammatically correct sentence. It is not permissible to simply write “dangling” equations.

## II. Experimental Methods

This section contains the details of your experiment, the experimental equipment and apparatus, and the methods that you used to analyze the data.

A figure of the experimental setup is much better than long verbal descriptions. It is not necessary to restate in the body of the text what is obvious from the figure, but each figure should have a caption. The caption appears below the figure and contains only brief information required to understand the figure. Figures are numbered and referred to in the text as Fig. X. Do not copy and paste figures from the lab manual.

Describe how you used the apparatus, how you obtained the raw data and how you deduced the final results from the raw data. Be explicit and give the equations that you used. Equations are to be numbered in sequence and are referred to in the text as Eq. x.

Describe how you arrived at estimates for experimental errors. This section does not contain actual data.

## III. Results and Analysis

In this section you will present the raw data that you accumulated in the lab and give the results of your analysis. If you use tables to display the data, the tables must have a heading which identifies the quantities in that table (including units).

It is often better to present your results in the form of graphs rather than tables. You will plot, for instance, the reflected light intensity as a function of the incident angle. This is usually much more informative than tables of numbers. Use Python or equivalent for graphing data and import the graphs into WORD/L<sup>A</sup>T<sub>E</sub>X.

All data graphs count as figures and are numbered in sequence (Fig. 1, 2 ...). Provide captions which clearly say what is shown. Label the axes in all graphs. For data points use circles, squares or other symbols to distinguish different sets of points. Error bars on data points are usually required.

## IV. Conclusions

This last section of the text contains the conclusions of your work. The introduction stated your goals; here you draw the bottom line and judge if you achieved those goals. If you did not quite succeed in all respects, discuss the problem and suggest improvements for future work.

## V. References:

If you refer to published source material (textbooks, journal articles) in the text of your report, number the references in sequence as they appear in the text (e.g. in square brackets). A list of published work (titled References) should appear at the end of your report. You can use WORD’s footnote/endnote feature for this. L<sup>A</sup>T<sub>E</sub>X has a special package (BibTeX) for this.

Grading of writing option course: The grade given for the Writing Option course is based only on the three submitted formal reports and is independent of that for the lab/lecture course.

## Experiment List

The introductory experiments are Numerical Methods and Test Measurements; they are required for all students. Handouts for all experiments are in CourseWeb.

### Introductory - required

1. Numerical Methods
2. Test Measurements

### Resonance Experiments (do at least 1)

3. RLC Circuit
4. Acoustical Cavity Modes
5. Acoustical Gas Thermometer \*
6. Electron Spin Resonance (ESR)

### Quantum Mechanics Origins (do at least 1)

7. Single Photon Interference \*
8. Electron Diffraction
9. Photoelectric Effect
10. Black-Body Radiation \*

### Others

11. Microwave Optics
12. Noise Fundamentals
13. Nuclear Magnetic Resonance (NMR) \*
14. Chaotic Circuit \*
15. Muon Lifetime \*
16. Radiation Detection \*
17. Scanning Tunneling Microscope (STM) \*
18. Mössbauer Spectroscopy
19. Ultrasound

\* working in pairs most appropriate