Intermediate Physics Laboratory I & II: Syllabus

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I. GOALS OF THE COURSE

- To learn to make careful observations of physical systems, independent of preconceived theoretical models. Understanding the importance of the phrase: "The facts are friendly".
- To gain experience in (and learn the importance of) using reproducible research methods; this course now requires that you have taken computational physics so that you have experience using Jupyter Notebooks for data analysis—this is the same tool used by the LIGO group to release the Nobel Prize winning research that resulted in the first detection of gravitational waves.
- Exposure to experiments and instrumentation in several different fields of physics, including at least some that you have not encountered in other courses.
- To learn and experience the typical working methods of a modern research laboratory. Most crucially, this means working successfully together in groups towards common goals.
- To learn how to create and keep a laboratory notebook.
- To learn to create Jupyter Notebooks that explain your research and illustrate methodically and clearly how you analyzed the data you gathered.
- To learn how to typeset with LaTeX, and to be able to write a scientific paper in RevTeX format.
- To use proper methods of error analysis when dealing with experimental data.
- To make effective oral presentations, and effective written presentations.
- To add to your toolbag some of the "standard tricks" every working experimentalist knows.

Structure of the course

You will collaborate in small groups (two or three people, with two being the norm); for the most part you will be graded on the results produced by your group, just as we are in the "real world" of research. The groupings of collaborators may be changed during the semester if needed. Students in Phy242 will typically be working individually, as 242 satisfies a capstone requirement, and will require a final presentation to the whole department as well as a final written report in RevTeX format with an accompanying Jupyter Notebook.

As a group member you will participate in four to five research projects—this is an intensive, fun, moderately-paced course with a tight schedule. Each research project has four phases:

1. **Initial research and planning for the experiment.** This will typically require some research at the library, on the net, or through your own notes from past courses, as well as an examination of the apparatus as hand. This is the portion where you use you theoretical understanding to model what you expect to occur and how you will carry out the experiment.
2. **Lab work** For each project, there will be one partial lab session (the day of the initial presentation) and two to four full lab sessions . You are expected to have preliminary results by the end of the second full lab session.
3. **Final presentation**. At the conclusion of each experiment, the group will give a 10-minute oral-presentation of its results. This presentation is modeled on an invited talk at a physics conference.
4. **Final report**. One week after the final presentation, the group must present me with a copy of the final report:
   - For all laboratories, you must make available your Jupyter Notebook which explains your work, imports your data, and produces all the analysis, and discusses your conclusions.
   - For **one** of the **four** lab reports, you must also turn in marked-up drafts of the final report, and two days later the final version must be handed in. These reports should closely follow the guidelines for a manuscript to be submitted to a well-known physics journal such as The American Journal of Physics or Physical Review Letters. A template which you can use is downloadable from the course website.

How can you possibly do a good job on all of these presentations and reports? By operating the same way as real research groups – by dividing the work among the group members, while maintaining joint responsibility of all group members for all work produced.

It cannot be too highly stressed, however, that the entire group must participate in the creation of, and approve the final form of, each presentation and report. Whoever is giving a presentation for the group, must first give one or more "dry runs" to the other group members so they can suggest changes, and the other members must not be shy about requesting major or minor revisions as required to reflect well upon the group! Similarly, the first author of a report must give his first draft to the other members to "mark up", and the first author should expect to see a lot of red ink from all the other authors. This is the way research groups operate.

The project folder

For each project, a separate loose-leaf folder will be kept by the group – I will supply these folders. Everything to do with the project will go in the folder; I will want to look at the folder at intervals, and collect it at the end of the project. The project folder should contain at least the following:

(a) Handouts on the project I give you.

(b) Photocopies of relevant articles that I have told you to read, or that the group has found.

(c) When the group meets outside of class (as it must, if only by phone or email), any decisions made about how to handle the project should be noted on a dated pages that go in the folder.

(d) The original lab notes, taken during the lab sessions (not copies). Each page must be dated and numbered so that there is no ambiguity about the order in which the notes were taken. At the end of each lab session you should briefly go over the notes you have taken with one of us, and have us initial these pages. I will provide written feedback on your laboratory notebook so that you may improve your ability to keep a detailed and well written record of your work.

(e) Detailed notes showing the analysis of the data and its reduction to presentable form. I do not want you to do this analysis and then copy it over for the folder; rather, the folder should contain the original pages on which the analysis is done (including printouts of computer programs used, etc). These pages need not be "presentation quality", but they must be sufficiently clear for the group to be able to reproduce or check any stage of the analysis.

(f) The viewgraphs for the final presentation (print them if done on computer)

(g) The first, rough draft of the report as marked up by the other group members.

(h) The final report as submitted.

Note that these are all materials that the group would normally produce in the course of doing the project. I am simply asking you to collect them all in one location.

Assessment

Your grade in this course will be based on assessments in several areas:

- Jupyter Notebook and Lab Reports 400 pts
- Final Oral Presentations 200 pts
- Project Folder/Lab Notebook 100 pts
- Misc. Exercises 100 pts
- Final Exam 200 pts

Textbook:

There is no required text for the course. I will supply needed handouts and you will locate needed references in the library. USM also has electronic subscriptions to many physics journals. If you have a properly enabled USM ID card, you can get the full text of many journal articles online for free. See the Web of Science link on the course home page.

Office Hours

In general, feel free to stop in for help if needed! It would be most helpful if you could make one of the office hours listed below. If not, just ask, and we'll set up some time to meet.

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Office Hours:
by Appointment

II. INFORMATION FOR PRESENTATIONS

At the large conferences held several times per year by the American Physical Society, any researcher is allowed to present his results in a 10-minute“contributed” talk. These talks are usually given with the aid of transparencies or computer based presentations. The audience does not interrupt the speaker, but there is a two minute question-and-answer period at the end. This is the model we will use for the presentations in iLab. Ten minutes is a very short time, and the trick is to successfully communicate the necessary points to your audience before the time is up. Here are a few guidelines for your presentations, taken directly from the APS website, which I have selectively omitted irrelevant portions:

APS Guidelines for contributed talks

APS meetings are one of many programs offered by the Society to advance and diffuse the knowledge of physics. The opportunity to present an abstract at an APS meeting is a privilege which entails a responsibility on the part of the author to present his/her research in a polished, clear and succinct manner. This applies to both oral presentations (i.e. delivery and supporting A-V) and poster presentations. The Guidelines for First-time Speakers and Session Chairs is published to assist authors presenting for the first time and session chairs in making the best presentations possible, and to enhance the quality of APS meetings.

Speaker Guidelines

Step back from the details of your research and think about what your audience might like to learn from your work. Keep it simple - remember, less is more.

Organization and Presentation tips:

Your talk should include:

1. Statement of hypothesis and purpose of the research
2. Describe your methods of investigation
3. Include data collected and what was learned
4. Give conclusions based on the collected data
5. Emphasis on significance and highlights of the research.
6. Prepare notes that highlight the salient points of your talk.
7. Practice the delivery of your talk several times prior to your presentation along with your slide or transparency sequence being sure to fit your talk into the time allocated to you.
8. Use simple sentences; avoid jargon, highly specialized vocabulary and unfamiliar abbreviations.
9. Think about questions you might be asked about your work and be prepared with well-thought out answers, being mindful of the limited time for Q and A.

Audio-Visuals

1. Audio-visuals should amplify your oral presentation, not duplicate it.
2. Choose the medium that will optimally display your information - don’t use words if a picture will convey it more clearly (graphs, tables, charts, etc.)
3. Use:
   (a) line graphs to show trends;
   (b) bar graphs to compare magnitudes;
   (c) pie graphs to demonstrate relative portions of a whole.

Delivery

1. Prepare notes that highlight the salient points of your talk.
2. Practice the delivery of your talk several times prior to your presentation along with your slide or transparency sequence being sure to fit your talk into the time allocated to you.
3. Use simple sentences; avoid jargon, highly specialized vocabulary and unfamiliar abbreviations.
4. Think about questions you might be asked about your work and be prepared with well-thought out answers, being mindful of the limited time for Q and A.

III. EVALUATION OF PRESENTATIONS

On the next page is a form I will use to evaluate final presentations – use this as a check-list as you prepare the talks.

Evaluation of Final Presentation

Date:____________________________
Group Members (presenter circled):

Experiment:___________________________________

Each of the following categories is evaluated on a scale of 1-5, with 3 indicating a fully satisfactory (but not outstanding) performance; 2 indicates some elements we are looking for are absent. Not all of these categories will be equally applicable to all experiments. This is an evaluation of the group effort, not just the presenter, and considers both the presentation and the discussion that follows.

___ Starts with title, list of collaborators, brief outline.

___ Viewgraphs are clear, informative, well labeled, professional-looking.

___ Oral presentation is clear and well-delivered, filling specified time period of 10 minutes. Talk shows good pacing with a clear narrative.

___ Physics content: Does the presentation discuss the essential physics to be explored, rather than just pulling formulas from books and papers? Are the physics assertions made correct? Does the discussion of the physics motivate the experiment that was done?

___ Description of the experiment: Is a clear description given of what was done? Are clear diagrams of the apparatus presented where appropriate? Are the experimental protocols followed described in sufficient, but not excessive, detail? Were the experimental procedures appropriate to the goals of the experiment?

___ Presentation of data: Are real data shown? Are data well-presented (such as well-labeled graphs, with error bars as appropriate)?

___ Error analysis: Are the largest sources of error identified and treated quantitatively? Are systematic and random errors discussed? Are convincing arguments (such as order-of-magnitude estimates) presented for ignoring smaller sources of error?

___ Presentation of results and conclusions: Are the main results and conclusions highlighted at the end of the talk? When appropriate, have your results been compared to "known" values? Are possible improvements to the experiment briefly discussed?

___ Input from all group members demonstrated by: (a) Freedom from obvious typos and mistakes, which shows that all members carefully reviewed the presentation; (b) Discussion after the presentation – all group members should actively participate.

Keep in mind that the purposes of your presentations are:

(a) To tell us what you did and why. Do not assume that your audience already knows the physics that you have had to learn to do the experiment. Do not assume your audience knows anything at all about the experimental setup. Show at least some real data to make your audience believe you really did an experiment.

(b) To convince your always-skeptical audience that you understand the main sources of uncertainty in your results.

(c) To present your results in an honest, straightforward way. Do not oversell by pretending to measure results that you really didn't; do not undersell by failing to extract all the possible value from your data and observations.

IV. INFORMATION FOR LAB REPORTS

Like the oral presentations, the lab reports for iLab are based on a research model. The lab report will be in precisely the form required for a manuscript submitted to a well-known research journal, The American Journal of Physics (AJP). The only difference will be the length: your reports will be no more than 6 typed pages, including figures and references. Please look at some issues of AJP (in the library or online) to get a better feel for the style and content expected in a research paper – it is rather different from lab reports you may have done in the past. The purposes of the report are the same as for the final presentation, which I repeat here:

(a) To describe what you did and why. Do not assume that your reader already knows the new physics that you have had to learn to do the experiment. Do not assume your reader knows anything at all about the experimental setup. Show at least some real data to make your reader believe you really did an experiment.

(b) To convince your always-skeptical reader that you understand the main sources of uncertainty in your results.

(c) To present your results in an honest, straightforward way. Do not oversell by pretending to measure results that you really didn't; do not undersell by failing to extract all the possible value from your data and observations. Of course, any omissions or errors that came to light during the final presentation must be dealt with correctly in the final report.

It is extremely important in scientific report to have correct and appropriate references; a report of this length would typically have five to ten references. The purpose of the references is to back up assertions made in the text, and to give proper credit to work done by others. Therefore:

(a) Whenever you repeat a formula or other statement from an article or book, make a reference to the article or book. References may also be made to other printed matter such as instruction manuals.

(b) If you get some important information from an expert, make a reference to that person as follows: [1] Joe Shmoe, private communication.

(c) Do not make reference to your own lab notes. Your readers assume that statements about your own experiment are backed up by well-organized original data and notes that you could produce upon demand. The only way to learn the appropriate use of references is to look through some actual journal articles.

Procedures. The designated "report writer" for the group will produce the first draft of the report, and will appear in the byline as the first author. The first draft will be given to the other group member(s), who will edit it. I want to see these edited drafts on the date under "Draft Report" in the schedule handed out. The first round of editing, if done seriously, will always result in many changes, large and small - otherwise the other group members are not contributing enough to the report.

On the next page is a form I will use to evaluate final reports – use this as a check-list as you prepare them. You may see sample papers online by using the Web of Science link on the course homepage and looking up any articles in the American Journal of Physics.

Evaluation of Final Report

Date:________________________
Group Members (Primary Authors circled):

Experiment:____________________________

Each of the following categories is evaluated on a scale of 1-5, with 3 indicating a fully satisfactory (but not outstanding) performance; 2 indicates some elements I am looking for are absent. Not all of these categories will be equally applicable to all experiments. **This is an evaluation of the group effort, not just the first author.**

___ Conforms to length limit (4-6 pages, including figures, captions and references).

___ Conforms to style guidelines. Has, in this order: Title, Authors, Institution, Abstract, Text, and List of References. Meets typographical requirements of the guidelines, in particular for references in the text, and for the list of references at the end.

___ Abstract: Clearly and briefly states what was done, and what the results were. Can stand on its own as a useful summary of the report.

___ Introduction, physics background: Is the physics background information justifying the experiment presented in a brief, but useful manner? Are the physics assertions made correct? Does the discussion of the physics motivate the experiment that was done?

___ Description of the experiment: Is a clear description given of what was done? Are clear diagrams of the apparatus presented where appropriate? Are the experimental protocols followed described in sufficient, but not excessive, detail? Were the experimental procedures appropriate to the goals of the experiment?

___ Presentation of data: Are real data shown? Are data well-presented (such as well-labeled graphs, with error bars as appropriate)?

___ Error analysis: Are the largest sources of error identified and treated quantitatively? Are convincing arguments (such as order-of-magnitude estimates) presented for ignoring smaller sources of error? Every measured quantity must have an associated uncertainty!

___ Presentation of results and conclusions: Are the main results and conclusions highlighted at the end of the report? Are possible improvements to the experiment briefly discussed?

___ References: Are references made where appropriate? Do the references contain the information needed for readers to retrieve them? Each report must have at least 5 references.

___ Figures: Are the figures clear, informative, and well labeled? Do they include all needed information, while omitting extraneous and irrelevant information? Do the figure captions provided useful information? Could a reader get a rough idea of what was done by just looking at the figures and reading the captions?

___ Input from all group members demonstrated by: (a) Freedom from obvious typos and mistakes, which shows that all members carefully reviewed the report; (b) Edited drafts.

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