Modern Physics Laboratory

Dr. Kate Jones (Nielsen 407B) and Dr. Christine Cheney (Nielsen 404B)
Physics 461: Fall 2019

General Information:
Class hours: 9:00 – 12:00 Monday/Wednesday

Prerequisites: It is essential that all students have a background in modern physics, therefore Phys 250, Phys 411, or equivalent are required. Electronics laboratory, 361 is also required, but can be waived where students have demonstrated experience with modern electronics.

Books: There is no textbook for this course, but **each student needs to purchase a laboratory notebook**. The quality of notes in the lab notebook will be included in the performance of experiment part of the grade.

Course Objectives: This lab course is suitable for upper level undergraduates and beginning graduate students. It provides hands-on experience with experiments in modern physics that are challenging at varying levels of expertise. Much of the equipment is interfaced to personal computers which are available for data acquisition and analysis. It is expected that students complete seven experiments in a semester. Students are encouraged to inquire into the possibility of performing an experiment of their own design, make refinements to the experiments, or expand the range of measurements suggested in the handouts.

1. Goals:
Physicists need to understand how measurements are made, what the limitations of these measurements are, and how to interpret and communicate the results.

Judgement: Students need to identify the goals of the experiment, and figure out how to achieve the goals in the time available. It is important for students to balance the time spent learning the apparatus and its limitations with time spent taking data.

Experience with scientific apparatus: This ranges from being able to read instrument scales, to using computerized data acquisition systems, to knowing safety hazards, and to effectively using specific pieces of equipment. One goal is that students learn how to design experiments of their own.

Data analysis: It is important that students graph their data early in the measurements so that mistakes can be identified. Students should make order of magnitude calculations of various effects, and assess if they may contribute to the results. It is good practice to assess the limitations to the accuracy of the results. Sometimes, reducing the error will entail taking data for a longer period of time or making additional measurements. Students will learn how to interpret data and the necessity for error analysis in this process.

Communication skills: Each student will give an oral report on their work and write formal written reports. Guidelines are given below. Although students make measurements in pairs, the oral and written reports will be done individually.

Physical concepts: Many physics concepts learned in a lecture setting will be used and explored through the experiments.

EXPERIMENTS

The experiments that are available to be performed this semester are as follows:

Experiments

1. Zeeman Effect
2. Compton Scattering
3. X-Ray Bragg Diffraction
4. Temperature Dependent Lifetimes of Fluorescence from a Phosphor
5. Nuclear magnetic resonance
6. Hall Effect
7. Cesium Heatpipe Experiment
    a. Resonance Ionization Spectroscopy of Cesium
    b. Absorption Spectroscopy of Cesium
    c. Stimulated Electronic Raman Scattering of Cesium
    d. Fabry-Perot Interferometry with a Nitrogen Pumped Tunable Dye Laser

The Cesium Heatpipe Experiment is often replaced by the Speed of Light Experiment.

Other experiments that may be available are as follows:

Other Experiments that may be available

1. Cavendish Experiment--Determination of Gravitational Constant
2. Muon lifetime
3. The Speed of Light--Rotating Mirror Version

General Instructions

Grading

Students are expected to attend class at least 6 hours per week during the scheduled laboratory hours. These are arranged during the first week of the semester. Attendence is extremely important. Any absence needs to be explained, otherwise this could be grounds for failing. Students should arrive promptly for scheduled sessions. The laboratory time can be used for background reading, as well as taking data and graphing results. While collecting data, it is reasonable that students work on **writing previous reports, although generally these should be worked on outside of lab time**. Laboratory reports are due one week after the data have been taken. Any student who is delinquent by two reports cannot move on to their next experiment. The grading takes into account laboratory performance, written reports, and a major power point presentation on one of the experiments performed.

Lab Conduct

Safety first: We have tried to minimize electrical and radiation hazards, but there are always possibilities for injury. Follow all safety procedures for handling lasers, the x-ray machine, radioactive materials, and high voltage sources. **Be careful with the equipment**. Don't make connections unless you understand what you're doing. **Don't play with the equipment with "Idle Hands."** Read the equipment manuals.

Be courteous: Return tools, equipment, etc. to their proper place. Don't remove equipment from someone else's experiment for use on your own (without asking first).

ACADEMIC HONESTY

All work submitted by a student is expected to represent their own work. Students are expected to submit their own homework. Students are expected to perform all work in conformance with the University policies regarding Academic Honesty.

Any student who feels s/he may need an accommodation based on the impact of a disability should contact me privately to discuss your specific needs. Please contact the Office of Disability Services at 865-974-6087 in Dunford Hall to coordinate reasonable accommodations for students with documented disabilities.

The final grade will be assigned from the weighted average based on the following *provisional* grading scale.

A	90 and above
A-	87 and above
B+	83 and above
B	80 and above
B-	77 and above
C+	73 and above
C	70 and above
C-	67 and above
D+	63 and above
D	60 and above
D-	57 and above
F	below 57

Modern Physics Laboratory Reporting Requirements

1. One experiment will be selected in consultation with the instructor to be reported on in depth. This will be both written and a MS Powerpoint presentation to the class.

2. Reports for the remaining experiments will be **brief reports** which consist of the following:
    a. A title page listing the course name and number, name of the experiment, the date performed, and the experiment collaborators.
    b. A short introduction **including a few sentences on the physical process being investigated** and what you want to find. It should be clear that you understand the experimental process and the underlying physics.
    c. An **original** diagram of the experiment with all the associated instrumentation and wiring. This should be clear, whether drawn by hand (with a ruler etc.) or on a computer.
    d. Raw data should be available to instructors upon request (you do not need to append pages of tabulated data).
    e. Graphs of representative data and analysis of data.
    f. A summary of the analysis, final results, and error analysis.

3. **Detailed report** will consist of the following:
    a. A title page listing the course name and number, name of the experiment, the date performed, and the experiment collaborators.
    b. An introduction section in which the overall experiment and its objectives are described.

c. A description and derivation of the pertinent theory that supports the experiment to demonstrate your understanding of the principles being studied.
d. A description of the experimental apparatus and instrumentation, complete with a schematic diagram and description of the purposes of each piece of equipment.
e. Presentation of results section. This should include the raw data and graphs of the raw data.
f. Analysis of Results—Description of the analysis of results including calculations and graphical analyses.
g. Discussion of results with error analysis—identify the sources of errors and their significance in the analysis of results. Calculate/estimate the expected errors in the final quantity, where appropriate.

4. Presentations
    a. Presentations will be during the final exam period. All students will attend the presentation session.
    b. The presentations will be given in pairs. Each student will contribute equally, typically the time is split evenly between students.
    c. Each presentation will be 10 minutes, with approximately 2-5 minutes for questions.
    d. Students should expect basic physics questions relating to any of the experiments performed during the semester during the presentation session. A sample list shall be given during the semester.
    e. A handout on presentation skills will be provided near the end of the semester.

5. Final grades will be calculated as follows:
    a. Performance of experiment—proper use of equipment, use of time, use of good experimental techniques, good experimental note taking, care of equipment--7 points per experiment for 7 experiments, a total of 49 points. (This part is completely subjective by the instructor.) ***Data and analysis should be submitted for all 7 experiments.***
    b. Results and analysis of experiments—the 5 experiments with brief reports--5 points per experiment for the 5 experiments for a total of 25 points.
    c. Detailed report 14 points.
    d. Presentation 12 points.
    e. In all cases, good results are paramount. All the experiments are capable of producing good results, but depend on the care and diligence that the experimenter gives to the experiment.

Additional Notes on Written Reports

You should write your report for a physicist who understands the physics behind your work, but needs to be told exactly what went on and how it turned out.

A short introduction should explain what you tried to do and why. Little credit will be given for long histories of the experiment or theoretical derivations that can be found in the references or handouts. Give a brief explanation of the formulae you used and how you used them. Describe any unique characteristics of the experiment and present derivations of non-standard formulas.

The experimental section should give enough information to enable someone to reproduce your results. **This should NOT take the form of a list of** instructions, but should be in the **past** tense, describing what was done. You should: Show the equipment used and their interconnections, Explain the data acquisition procedures, Describe the statistical uncertainties and an explanation of how they were assigned, Discuss possible sources of systematic error and how you handled them.

The analysis section should show how the data and their uncertainties (random and systematic) produce the final results and their uncertainties. Present graphs or tables of derived quantities with their associated uncertainties. Show how the errors were assigned.

The results section should give a concise listing of the major findings of the experiment. Comparisons between your results and theoretical expectations or other experimental values should be made. You may also want to comment on how the experiment could be improved.