LABORATORY MANUAL

PHYSICS 4L
SPRING 2014

Most of these labs include extensive material developed by Catherine H. Crouch specifically for Physics 4L. CHC acknowledges helpful ideas from labs developed by Kenneth Heller and Patricia Heller of the University of Minnesota, especially for the optics and capacitor labs. CHC also acknowledges Eric Anderson and Lili Cui of the University of Maryland Baltimore County for providing the original version of "Neural Circuit Models".

Laboratory Schedule

Acknowledgements
Reference 1: Laboratory Overview
Reference 2: Experimental Uncertainty and Error Analysis
Reference 3: Introduction to Kaleidagraph

Week 1 (Jan. 20)	no laboratory
Week 2 (Jan. 27)	Lab 1: Reflection and refraction
Week 3 (Feb. 3)	Lab 2: Microscope optics
Week 4 (Feb. 10)	Lab 3: Vision correction; interference problem solving
Week 5 (Feb. 17)	Lab 4: Interference, diffraction, and limits of resolution
Week 6 (Feb. 24)	Lab 5: Electric field and potential workshop
Week 7 (March 3)	Lab 6: Equipotential mapping
Week 8 (March 17)	Lab 7: Electrocardiography and potential difference
Week 9 (March 24)	Lab 8: Voltage, current, and resistance
Week 10 (March 31)	Lab 9: Discharging capacitors
Week 11 (April 7)	Lab 10: Neural circuit models
Week 12 (April 14)	Lab 11: Magnetic forces on moving charges
Week 13 (April 21)	Lab 12: Problem solving with magnetic fields and flux
Week 14 (April 28)	Lab 13: Electromagnetic induction

Welcome to the Physics 4L laboratory!

PURPOSE AND INSTRUCTIONAL APPROACH

The purpose of the laboratory component of Physics 4L is to give you hands-on experience with electromagnetic and optical phenomena. Physics is about the real world, so this hands-on experience is very important! Your goal should be to increase your understanding of the physics you are studying in class, and to explore both the power and the limitations of the theories introduced as models for real physical phenomena. Consequently, you should do your best to understand everything that is going on in the lab both conceptually and quantitatively.

Another important purpose is to give you practice analyzing quantitative data— specifically, comparing data to models, and thereby determining how well the models fit the data. If a model does not fit the data, you should strive to understand where the discrepancy might have come from, which often pushes you to the deepest understanding of both the model and your experiment.

It is OK if you do not understand everything when you walk into the laboratory, if you make some mistakes on the preparatory assignments, and if you do not do everything right the first time in the experiments, as long as you make your best effort to prepare and to engage with the material. Making mistakes is, in fact, one of the more efficient ways to learn. If your understanding from the classroom doesn't seem to match what you observe, ask questions!

Professor Crouch has developed some new laboratories for Physics 4L that focus on the biological applications of this material. In many of these laboratories, you, the students, must take a greater role in identifying what to measure in order to answer scientific questions.

Because of the time and effort required to develop new laboratories, only some of the labs are new. As a result, you will participate in two different styles of labs this semester. In one style the laboratory goal is typically expressed as a problem to be solved or a question to be answered. Rather than following a detailed procedure, you and your partner will come up with a plan of measurements that will help you answer the question as posed. In the other style, you will be provided with a procedure to follow; throughout the procedure you will find questions designed to help you reflect on what you are doing and why. In both cases you are encouraged to talk to the other group at your table and to ask questions of your lab instructor if you need guidance. Your suggestions and feedback on the laboratories are most welcome!

Remember that your goal is to put to work the ideas you are learning in this course,* not *to mindlessly follow procedures. Relax, explore, make mistakes, and ask lots of questions!

LABORATORY SAFETY

Laboratory safety is critically important. Occasionally we will do experiments where inappropriate use of the equipment could injure someone. If you have any doubts about the safe way to carry out procedures, do not do anything until you have discussed this with your lab instructor. If you are concerned that your lab partner is doing something unsafe, ask them to stop until you can check in with the instructor. Typically your instructor will go over safety procedures at the beginning of lab.

HOW PHYSICS 4L LAB WORKS

Notebook:
You must have a bound, graph-ruled laboratory notebook that is used only for Physics 4L lab during this semester (typically you will turn it in at the end of lab and get it back on Friday). You are welcome to use one from a previous course if it has plenty of blank pages.

Lab preparation:
Each week before lab, you should read the introductory material posted on the course web site in the top area (linked to the "Lab" page).

In your lab notebook, answer any assigned prediction and warmup questions, **and** write one paragraph summarizing the goal of the laboratory and the physical principles illustrated by the laboratory. Your instructor will grade these for completeness at the start of lab.

Attendance
Attendance at your assigned lab section is required every week.

If you have a significant conflict with your assigned lab one week, and you wish to attend a different section, **you must obtain permission by email no later than the week before** from your lab instructor. Your instructor may require you to find a student to trade with.

If you become suddenly and seriously ill, or a family emergency develops, please communicate with Prof. Crouch about your situation as promptly as possible.

Lab manual:
Copies of instructions for how to operate equipment, any procedures to follow, and the introductory material for each lab will be kept in binders in the laboratory. You will not have your own personal copy of the lab manual.

Lab partners:
You will usually work in pairs in the lab; occasionally, the nature of the lab or the equipment available will mean that you work in groups around the lab tables. Take turns with all of the tasks of the lab: making measurements, keeping records, and writing the discussion of your work. All lab group members should leave the lab understanding all aspects of the lab, and your group will receive a common grade for one member's lab notebook (see below).

LAB GRADES
Your lab grade makes up 15% of your final course grade. Your lab grade is based on the record of your laboratory work in your notebook. Notebooks will be graded out of 10 points; a score of 10 will be reserved for unusually complete or thoughtful work.

In addition, you must complete the prelab assignments to earn full credit for the notebook. You will receive full credit if your prelab shows serious effort, even if there are mistakes and small omissions. (Be sure to correct any errors in the preparatory assignment as you do the laboratory!) No prelab will result in a 30% penalty on that week's lab score.

THE LAB NOTEBOOK

Keeping good records is a critical part of doing scientific work of any kind. As mentioned above, you must bring your lab notebook every week.

Each member of the lab group should keep a complete lab notebook. In most cases the data tables and graphs or the answers to follow-up questions (not preparatory questions) should be prepared on the lab computers, agreed upon by the entire group, and then printed and taped into each member's notebook.

At the end of each lab, one member of each lab group will turn in his or her lab notebook, and all members of the lab group will receive a common grade for that notebook. Lab members should alternate turning in the notebook.

Each notebook entry should be include the following:

- Begin with the **title** of the lab.
- Complete the preparatory (prediction and warmup) assignments. Include sketches or diagrams as needed to make your reasoning clear.
- Before you come to lab, write a single paragraph describing the purpose of the lab and the physical principles which it illustrates.
- For laboratories in which you choose what measurements to make, your notebook should include a complete, clear explanation of what you did, including a **diagram** of the apparatus with each component labeled. No fancy artwork is needed — block diagrams are typically sufficient. (If the apparatus is clearly and fully illustrated in the lab manual, and if you do not need to record a diagram in order for it to be clear what you did, you may cite the manual rather than reproducing the diagram.)
- If the procedure for making measurements is clearly outlined in the lab manual, then it is not necessary to describe the procedure; simply record that measurements were performed as described in the manual.
- Record **data** in tables, either by hand or by printing out data entered directly in a spreadsheet. Include the units and uncertainty in the measurements. Record how you arrived at the estimated uncertainty.
- Include printouts of **graphs** of data (or occasionally, qualitative sketches) when useful.
- Thoroughly document all **analysis** of your data, recording all calculations performed and explaining what each variable represents. Include equations used to calculate uncertainties when appropriate.
- Give a brief summary of your **final results including uncertainties**, and a brief discussion of the meaning of your findings. (Many of the laboratories give questions to be answered at the end of the lab that help you reflect on the results; you can either answer questions individually or write a paragraph that combines the answers to several questions; mark clearly in your lab book which text addresses which questions.)